Cost of non-completion of the TEN-T

Final Report

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ASTRA	Assessment of Transport Strategies, System Dynamics Model,
BCR	Benefit-cost ratio
BVWP	Bundesverkehrswegeplanung (German Federal Cross-modal Infrastructure Planning, in English FTIP)
CBA	Cost-benefit analyis
CEF	Connecting Europe Facility
CF	Cohesion Fund
CGE	Computable General Equilibrium Model
CNC	Core Network Corridor of the TEN-T
EC	European Commission
EFSI	European Fund for Strategic Investments
EIB	European Investment Bank
ERDF	European Regional Development Fund
ERTMS	European Rail Traffic Management System
EU	European Union
EU LFS	European Union Labour Force Survey
FTIP	Federal Transport Infrastruture Plan (German BVWP)
GDP	Gross domestic product

GHG	Greenhouse Gas Emissions
GVA	Gross value added
HSR	High-speed rail
INEA	Innovation and Networks Executive Agency
ITF	International Transport Forum
NPV	Net present value
NUTS	Nomenclature of Territorial Units for Statistics
OD O/D	Origin-Destination
REF	Reference Scenario with full implementation of TEN-T core network
SCGE	Spatial Computed General Equilibrium Models
SDM	System Dynamics Modelling
SEA	Strategic Environmental Assessment
SMCP	Social Marginal Cost Pricing
TEN	Trans-European Networks (communication, energy, transport)
TEN-T	Trans-European Transport Networks
WIOD	World Input-Output Database
YoE	Years of employment, employment years

1 Non-technical summary

The cost of not implementing the TEN-T core network

For one and a half year now, the European Union has a new transport infrastructure policy which is marked by a strengthened network approach. The multi-modal core network, as the central part of this policy, is planned to be completed by 2030 and to gradually develop into the infrastructural basis for a sustainable and efficient European mobility system. Building this network involves preparing and implementing thousands of projects, in fields such as the establishment of missing cross-border links, the removal of bottlenecks, the improvement of connections between transport modes and the equipment for intelligent and innovative transport solutions.

All this requires significant investments, and it creates jobs notably in the construction and other industrial sectors. It enhances accessibility of all European regions and thereby stimulates economic activity, and it improves infrastructure quality which contributes to reducing travelling times and transport cost. This leads to secondary effects in various sectors of the economy which remain effective beyond 2030.

The results of the study show in an impressive way what "price" Europe would have to pay when Member States and other stakeholders failed to implement the core network as the central element of the new TEN-T policy: The economy would give away an 1,8 % growth potential and 10 million man-years of jobs would not materialize. This seems unjustifiable – even more so at a time when Europe makes great efforts to overcome the consequences of the economic crisis. The results show that investing in transport infrastructure promises more to the European economy and its citizens than what it costs.

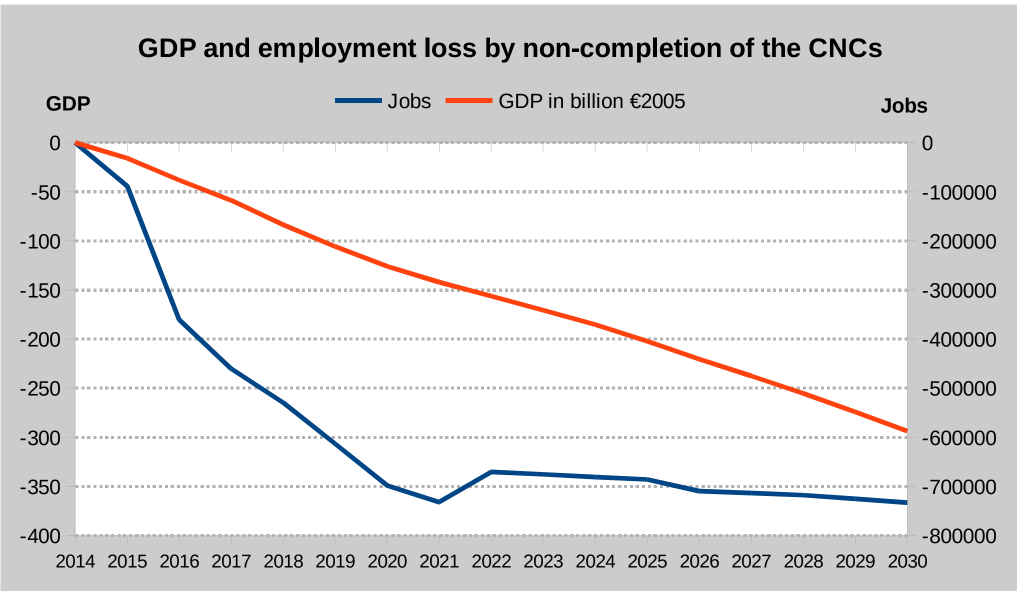
The study has been conducted concomitant with the comprehensive analysis of the nine TEN-T core network corridors which included a market analysis and led to the identification of projects and their cost. Given that the projects, to be implemented along the corridors until 2030, have different degrees of maturity, detailed cost data were only available for part of the projects (representing 457 billion Euro in total). Overall the Commission, together with the Member States, has estimated a total cost of 700 to 750 billion Euro for the full completion of the core network.

The impact of non-completion of TEN-T by 2030

This study analysed the impact of non-completion of the core TEN-T by 2030 assuming that their implementation remained at the status of 2015. This means investment would not be made, transport time and cost savings of the TEN-T would not be achieved. Such a scenario was tested with a mathematical model integrating the European transport and economic systems of EU Member States (ASTRA model) and compared with the Reference Scenario to estimate wider economic effects of non-completion of the core TEN-T.

We found that the economic impacts of non-completion of the core TEN-T would be very substantial. The GDP of the EU would remain 1.8% lower in 2030. In constant Euro of 2005 this reduction of GDP would amount to EUR 294 billion in the year 2030. As the lower GDP can be observed since 2015 and for any year from 2015 until 2030 these reductions can be accumulated to estimate the total loss of GDP over that period: this would amount to a reduction of GDP of EUR 2,570 billion. Putting this in relation to the required investment of EUR 457 billion this means: for any Euro invested into the core TEN-T close to 6 Euro additional GDP will have been generated until 2030.

The second wider economic impact relates to employment. About 730,000 jobs would be not created in 2030 without the core TEN-T. Accumulating these losses of jobs from 2015 until 2030 about 10 million jobs would not be created in the EU that would have been created by the core TEN-T otherwise. This means per any billion Euro invested into the core TEN-T close to 20,000 jobs would be generated. We also found that the implementation of the core TEN-T would have benefited over-proportionally the more vulnerable low skilled groups of employees.



Source: Fraunhofer ISI

Figure 1: Loss of GDP and jobs between 2015 and 2030 by non-completion of CNC

We also analysed the non-completion of two key elements of the core TEN-T: the cross-border projects that enable to establish reliable and high capacity links between Member States along the corridors and the innovative technologies that enable to make better use of the infrastructures (e.g. by intelligent traffic management) and to ensure interoperability between Member States which is an important pre-requisite for fluent and reliable inter-country traffic.

We found that not completing the cross-border projects along the nine CNC would reduce investment by EUR 43 billion. The EU GDP in 2030 would be reduced by EUR 86 billion. The accumulated loss of GDP between 2015 and 2030 would reach EUR 725 billion. 190,000 jobs less would be created in 2030 and the total reduction of jobs by not completing the cross-border projects would be close to 1.9 million over the period 2015 to 2030.

The impact of non-completion of innovative technologies along the nine CNC is of similar magnitude. Investments would be reduced by EUR 41 billion with an impact on GDP that is reduced by EUR 89 billion in 2030. The number of jobs not generated would be above 200,000 in 2030. The accumulated values reach EUR 723 billion of loss of GDP and 1.9 million jobs not created between 2015 and 2030.

In fact, the multipliers of cross-border projects and of innovative technologies were substantially higher than for the average of the whole core TEN-T. For GDP any Euro invested into the cross-border projects generated close to 17 Euro additional GDP. For innovative technologies this number even is found to be close to 18 additional Euro of GDP for any invested Euro. Also the numbers of jobs not created per any billion Euro not invested is comparably high with 44,500 and 46,500 for cross-border projects and innovative technologies, respectively. These results suggest that both the cross-border projects and innovative technologies constitute key elements of the core TEN-T.

Our findings highlight that implementing the core TEN-T network by 2030 would provide a substantial stimulus to the European economy, fostering both GDP and employment. They also suggest that the generated employment would benefit over-proportionally vulnerable groups, i.e. lower skilled workers. The highest economic multipliers were found for implementing the major cross-border projects along the nine CNC and for deploying innovative technologies. Implementing the core TEN-T network including the cross-border projects and the innovative technologies can thus be recommended as a suitable policy to combat the weak economic situation in Europe.

2 Executive Summary

Objective of the study

This study makes a quantitative assessment of the cost of not completing implementation of the Trans-European Transport Networks (TEN-T) by 2030. The study focuses on the core network of TEN-T as defined by the new TEN-T guidelines of 2013 (EU Regulation 1315/2013) and the new funding rules as provided by the Connecting Europe Facility (CEF) (EU Regulation 1316/2013).

While the European Reference Scenario assumes that implementation of the core TEN-T network will be completed by 2030 this study compiled and assessed three scenarios in which the core TEN-T network would not be completed by 2030. In fact it assumed that work on TEN-T would cease by 2015. These scenarios were compared with the *Reference Scenario*. The scenario assessment focused on the wider economic effects, in particular the effects on gross domestic product (GDP) and employment. Additionally, a detailed qualitative and quantitative analysis of the jobs potentially created by TEN-T was performed and the results were compared with findings in the literature.

Background of TEN-T policy

The Trans-European Networks (TEN) is a premier development issue of European economic and social policy that dates back to the Treaty of Rome (1957). TEN include communications, energy and transport infrastructure networks. The adoption of a Common Transport Policy (CTP) was already foreseen at this founding stage of the EU.

However, the implementation of such European infrastructure networks was so slow that the Treaty of Maastricht (1992) included an obligation for the European Commission and the European Parliament to prepare guidelines for the development of TEN and to update them periodically. For the TEN-T the first guidelines were published in 1996, followed by revisions in 2004 and 2011/13.

The latest revision of the TEN-T guidelines was proposed by the European Commission in 2011 and put into regulation at the end of 2013. TEN-T projects should fit into the strategic European transport network, as the core network developed by an analytical top-down approach, but also into the Strategic Transport Plans to be set up by each Member State. Together the core network and the comprehensive network form the TEN-T. The TEN-T core network is structured into nine core network corridors (CNC) that connect at least three European Member States each and serve the European internal market as well as international markets. An example of a CNC is the North-South oriented Scandinavian-Mediterranean corridor that runs from Southern Finland via Sweden, Denmark, Germany, Austria to Italy and ends in Malta. The nine CNCs make up 75% of the total TEN-T core network. The TEN-T core network is planned to be fully implemented by 2030.

In parallel to the TEN-T guidelines the Connecting Europe Facility (CEF) was established to structure and organize funding of the TEN. The CEF was initially assigned a budget of

EUR 26.25 billion for transport for the period 2014 to 2020, which meant a tripling of TEN-T funds compared to the previous 7-years programming period. The costs of planned investments for the period up to 2020 were estimated at EUR 500 billion, of which half would be required to implement the core network. TEN-T co-funding rates were increased to reach up to 40% for cross-border projects and 30% for critical bottlenecks. Also the implementation of innovative technologies that is required by the TEN-T guidelines (e.g. intelligent traffic management systems and alternative fuelling infrastructures) is supported by TEN-T funds.

Definition of Scenarios

The scenarios analysed by this study are constructed in a logical sequence. Initially two test cases were carried out to develop the methodology and improve it before assessing the main scenario of non-completion of the core TEN-T. Subsequently, two sensitivity scenarios were elaborated. All the scenario results were compared to a *Reference Scenario* that assumes full implementation of the core TEN-T by 2030. The three scenarios are:

- Non-completion of the nine core network corridors (*No CNC* scenario): main scenario requiring an investment of EUR 457 billion in EU28 between 2015 and 2030.
- Non-completion of the cross-border projects along the nine CNC (*No CNC Cross-Border* scenario): first sensitivity analysis with an investment of EUR 43 billion between 2015 and 2030.
- Non-completion of the implementation of innovative technologies as defined by article 33 of the valid TEN-T guidelines along the nine CNC (*No CNC Innovation* scenario): second sensitivity analysis with an investment of close to EUR 41 billion between 2015 and 2030.

To estimate the results for the full TEN-T core network, the findings of the main scenario *No CNC* were extrapolated, taking into account the length of the additional networks for full completion.

Approach of the study to estimate the wider economic impacts

During 2014, the European Commission contracted nine consortia to elaborate the status of development of each CNC. A major output of these nine studies were nine work plans describing the individual projects to be implemented for the respective CNC including their timing and investment profiles. These work plans constituted a major pillar and input for our study. The second pillar was the integrated transport-economy-environment model ASTRA (Assessment of Transport Strategies). The nine work plans were provided to prepare the input to the economic models and the transport models of ASTRA. Major inputs were investments and changes of travel time and costs. As input to the economic models, the investment profile of each scenario was identified by aggregating the investment trajectory of each project of a CNC. Investments were also categorized into different types e.g. tunnel, terminal, ERTMS, etc. Each category triggers investment demand to be satisfied by different sectors e.g. construction, electronics, etc. As data on the funding structure was generally lacking, it was assumed that investments would be funded by government budgets. To derive the input needed for the transport models, estimates were made of the time and cost changes generated by the projects in international, national and regional transport flows. These transport effects were then fed into ASTRA. The non-completion scenarios were quantified by reducing investments by the identified amounts in the model and by increasing travel times. The ASTRA model then provides estimates of the changes of GDP and employment of the scenarios.

Elaboration of two test cases on core network corridors (CNCs)

The study commenced by assessing the impacts of two test cases assuming non-completion of the Scandinavian-Mediterranean corridor (*No CNC ScanMed*) or the Rhine-Alpine corridor (*No CNC RhAlp*), respectively. According to the CNC work plans, investments in projects for the Rhine-Alpine corridor account for EUR 29.2 billion for EU28 (including investments in Switzerland increases this value to EUR 42.8 billion), while the total investment for projects along the Scandinavian-Mediterranean corridor is significantly higher at EUR 105 billion. The simulations with the ASTRA-EC model reveal that about 758 thousand job-years less are expected to be created in the EU between 2015 and 2030 in the case of *No CNC RhAlp*. About 1.59 million job-years less is the result of the impact assessment for *No CNC ScanMed*. In relation to the investments which will not be made in both scenarios, the impact of *No CNC RhAlp* is stronger by about 25,900 job-years not created per billion Euro invested. Investments in projects for CNC ScanMed are expected to have fewer impacts on job-years not created because of differences in traffic loads and achieved time savings between the two CNC. ASTRA-EC calculates about 14,700 job-years not created per billion Euro not invested for *No CNC ScanMed*. Economic sectors are not affected equally by the non-completion scenarios. The net employment effects considering direct (via investments), indirect (via supply chain) and induced (via overall economic growth) impacts are assumed to be highest for the construction sector and a number of service sectors. When compared with the *Reference Scenario*, *No CNC ScanMed* causes a loss of about EUR 98 billion GDP in the year 2030 and *No CNC RhAlp* a loss of about EUR 48.5 billion. If annual GDP losses are accumulated, this would mean EUR 807 billion (*No CNC ScanMed*) and EUR 384 billion (*No CNC RhAlp*) less between 2015 and 2030.

Findings from the non-completion scenario of the nine CNCs and extension to the full core TEN-T network

Based on the analysis of the two test cases on CNCs above, the impact assessment approach was then refined to analyse the impacts of not completing any of the nine CNC (*No CNC* scenario). Instead of allocating all investments to the construction sector, they were now split across different sectors according to the type of investment (e.g. construction, machinery, metal products, etc.). Subtracting all the investments realized until 2014 or planned after 2030, and all double-counted projects that appeared in more than one

CNC resulted in total investments of about EUR 457 billion for EU28. More than 50% of these investments are planned for CNC projects in Italy, Germany and France. Nevertheless, relating planned investments to GDP for each Member State shows that especially smaller Member States like Latvia, Slovenia and Bulgaria in the attempt to catch-up with their infrastructure endowment have to cover relatively high investments in CNC projects.

The combination of reduced investments and not realized improvements to travel time and cost has negative impacts on the EU economy but also affects transport demand and the modal split. GDP in the EU is expected to be lower than in the *Reference Scenario* by about EUR 294 billion in 2030, that is equivalent to a reduction of GDP by -1.8% in 2030. In terms of average annual growth, this is equivalent to -0.1 percentage points less annual GDP growth in the EU. The accumulated loss of GDP between 2015 and 2030 is expected to be about EUR 2,570 billion. There are substantial negative impacts of *No CNC* on the EU labour market according to the ASTRA scenario simulation: about 8.9 million job-years not created in the EU between 2015 and 2030. Comparing the labour market impact with the planned investments for all nine CNC, the employment multiplier would be about 19,600 job-years per billion Euro, which falls in-between the multipliers of test cases *No CNC ScanMed* and *No CNC RhAlp*. A major difference stems from the different geographical coverage. As was the case in the No CNC, there is a significant share of investments planned for EU Member States with lower GDP per capita and comparatively low labour productivity. The effect of not investing in CNC projects is even stronger in countries with lower per capita GDP than in countries with high labour productivity as the same output change is then affecting a larger number of employees, so geographic location amplifies the effect on the labour market. Similar to the first two scenarios, the impact on jobs not created is strongest in the construction, other market services and trade sectors. A decomposition analysis was carried out to differentiate the impacts of the investments and the impacts of transport changes. This revealed that the impact of travel time and cost changes induced by CNC contributes about 50% to the employment impacts in the year 2030. The other half comes from reduced investments.

Projects listed in the work plans of the nine CNC account for about 75% of the TEN-T core network in terms of length. Based on the scenario analysis findings, the impacts of not completing the full TEN-T core network could be extrapolated. To do so, a similar investment structure as for the nine CNC was assumed for the remaining 25% of the network. Using GDP and employment multipliers in the range of the *No CNC* scenario and of only 50% of that an extrapolation of the range of impacts of the full TEN-T that is precautionary and not overoptimistic could be made. The resulting estimations were between 10.4 million and 11.9 million job-years less in the EU for the full core TEN-T network and between EUR 2,940 and 3,380 billion accumulated GDP losses for the period 2015 until 2030.

Besides the social and economic impacts, external costs are also influenced by No CNC. Based on the cost factors taken from the recent Handbook on external costs of transport published by the European Commission, external costs are expected to be about EUR 370 million higher in 2030 in the *No CNC* scenario compared with the *Reference Scenar-*

io. The major driver of higher external costs is the higher modal share of road transport and the lower share of rail due to a large number of not realized rail projects in the *No CNC* scenario.

Findings of the two sensitivity scenarios

Two further scenarios were carried out on the main building blocks of TEN-T policy: not completing major cross-border projects (*No CNC Cross-Border*) and not implementing innovative technologies (*No CNC Innovation*). Major cross-border projects in the CNC list of projects play a significant role in the design of the TEN-T network as they are supposed to remove significant bottlenecks and therefore improve travel times substantially. As a result, it can be expected that the wider economic impacts are higher in relation to the money invested than for single CNC or all nine CNC. The analysis with ASTRA-EC confirms this expectation. While major cross-border CNC projects account for EUR 43 billion investments in the EU between 2015 and 2030, GDP is expected to be EUR 86 billion lower in 2030 in the case of *No CNC Cross-Border* compared to the *Reference Scenario*. This is at a similar level as the impact of *No CNC ScanMed* which featured about EUR 108 billion avoided investments. Regarding the labour market, the impact was even stronger than for *No CNC ScanMed*. *No CNC Cross-Border* means about 2.1 million job-years not created in the EU between 2015 and 2030. In relation to the money invested, this is equal to a multiplier of 44,500 job-years (not) created per billion Euro (not) invested.

The last of the three scenarios assumes non-completion of the deployment of innovative technologies within the CNC work plans as defined by Article 33 of the TEN-T guidelines. The majority of the 450 innovative projects identified in the CNC work plans concern the deployment of different levels of ERTMS. After ERTMS, deployment of the SESAR system constitutes the second largest innovative technology. In total, investments in the EU of about EUR 40.8 billion between 2015 and 2030 fall under the category of innovative technologies of CNC projects. Based on the outcomes of other impact assessment studies, the potential impact of innovative technologies on travel time and cost changes was identified and used as input for the ASTRA-EC calculation. *No CNC Innovation* is expected to lead to a loss in GDP of about EUR 89 billion compared with the *Reference Scenario* in the year 2030. The accumulated loss of GDP is substantial at EUR 723 billion between 2015 and 2030. About 2.1 million job-years are not created in *No CNC Innovation* between 2015 and 2030. In relation to the money invested, this equals 46,400 job-years (not) created per billion Euro (not) invested.

Experts peer review

Our findings and the draft final report have been discussed with twelve external peer reviewers from academia, banks and government at a peer review meeting on March 26th 2015 (you can find the minutes of the peer review meeting in annex II). Prior to the meeting the peer reviewers were sent the draft final report. Basically the group of experts endorsed the methodology of the study. Comments for modifications and improvements were divers: while some experts argued in favour of pure project based assessments, others proposed the use of alternative economic models and again others expected that the total benefits of the TEN-T were not fully captured by our approach.

Summary of wider economic impacts – macro-economic indicators

Table 1 summarizes the results found by our study for the macro-economic indicators for the three scenarios and the full core TEN-T network. Investments are presented for the entire period from 2015 until 2030, as well as for the accumulated indicators of loss of GDP and job-years not created. Additionally, the reduction in GDP and employment for the year 2030 is presented compared to the *Reference Scenario*. The calculated investments are in a range between EUR 40.8 billion and EUR 623 billion. The accumulated loss of GDP ranges between EUR 723 billion and EUR 3,380 billion over 15 years for the innovative technologies and for the full core TEN-T network, respectively. The job-years not created are expected to be between 1,900,000 and 11,900,000 for the innovative technologies and the full core TEN-T network, respectively.

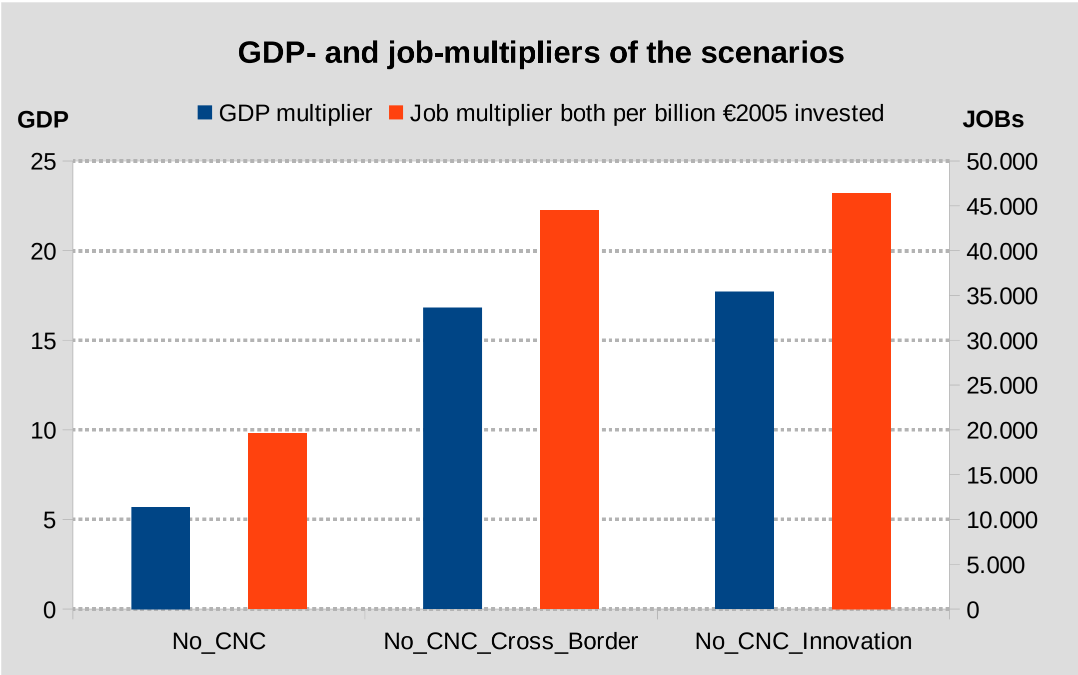
Table 1: Macro-economic impacts for the scenarios and the core TEN-T network

Scenario	Investment not made in EU28	GDP loss 2030	GDP loss accumulated 2015-2030	Jobs 2030 not created	Job-years not created Accumulated 2015-2030
	Billion €	Billion €	Billion €	Persons	Persons
No_CNC	-457	-294	-2,570	-733,000	-8,900,000
No_CNC_Cross_Border	-43.2	-86	-725	-189,000	-1,920,000
No_CNC_Innovation	-40.8	-89	-723	-206,000	-1,900,000
Non completion core TEN-T	-623		-2,940 – -3,380		-10,400,000 – -11,900,000

Source: own calculation

Summary of GDP and employment multipliers

Figure 1 shows the differences in the economic multipliers between the three scenarios in terms of job-years (not) created (right-hand axis) and accumulated (loss of) GDP (left-hand axis) per billion Euro (not) invested over the period 2015 to 2030. It should be noted that multipliers result from two negative values e.g. GDP loss due to investments not made and thus mathematically result into a positive value. The multipliers in the year 2030 for jobs created per billion Euro invested are estimated to range between 19,500 and 46,500 and between close to 6 and close to 18 for GDP. Especially the two sensitivity scenarios on cross-border projects and innovative technologies are characterized by comparably high impacts on the European economic system.



Source: Fraunhofer ISI

Figure 2: Full-time equivalent jobs (FTE) and GDP multipliers per billion Euro invested per scenario

Occupations and skills of employment generated

Considering the employment impacts at sectoral level calculated by ASTRA, the structure of the occupations in each sector and the skill level of employees in the different sectors enables to draw conclusions regarding the quality and type of jobs potentially created by TEN-T investments. Up to 2020 in particular, there are occupation increases in manual labour and related trades. This impact decreases slightly but is still at a high level in 2030. This is largely due to increased construction work. The analysis of impacts on skill levels reveals that, in relative terms, the more vulnerable low-skilled workers stand to benefit from the TEN-T policy.

Innovation support of TEN-T policy

Looking at mobility innovations in general, the EU has the highest share in global patents of all competing economies, which confirms both the leading position it has achieved in this field and the importance of the field for the EU economy. This study analysed and compared the innovation systems of all modes. We found that rail had the highest patenting dynamics in the period 2008 to 2010 and that fostering rail innovations via TEN-T has the potential to generate lead market effects for the EU and thus higher exports to countries outside the EU. To a lesser extent, TEN-T policy could also stimulate lead market effects for shipping, while we do not expect such effects for road or air. Equipping and interfacing infrastructures with IT systems to enhance their capacity and capabilities is another promising global market in which European activities could be stimulated by TEN-T policy.

Conclusions

The most important conclusions of the study can be summarised by the following statements:

- Non-completion of the core TEN-T network by 2030 will generate a substantial loss of GDP and employment between now and 2030.
- In 2030, EU27 GDP would be EUR 294 billion lower without the nine CNC compared to the *Reference Scenario*.
- The number of jobs not created in EU27 by failing to complete the CNC implementation would reach about 733,000 compared with the *Reference Scenario* in 2030.
- Accumulating the losses in GDP and jobs over the period 2015 until 2030 results in a total loss of EUR 2,570 billion and 8.9 million job-years of employment not generated.
- For the full core TEN-T network, the numbers range between EUR 2,940 and 3,380 billion loss of accumulated GDP, and between 10.4 million and 11.9 million job-years not created.
- Thus we can safely argue that the core TEN-T implementation would create 10 million job-years.
- Annual investment in the core TEN-T network will be between 0.1% and 1.7% of GDP of the different Member States. Higher shares are observed in new Member States.
- Our analysis considers benefits until 2030. This already goes beyond the usual profit targets of businesses. Obviously, TEN-T infrastructure is a beneficial investment in the long term. This requires the involvement of investors with long-term planning horizons, if governments are not willing or not able to bear the full investment costs themselves.
- Our estimates stop at the year 2030. There will be additional further benefits of the TEN-T for the EU economy after 2030.
- Our findings reveal that transport-related impacts are underestimated in the so-called cost of non-Europe studies.
- All skill categories would benefit from additional employment due to TEN-T. Lower skilled employment would benefit over-proportionally from implementing TEN-T.
- The employment multiplier that was found to be 19,600 job-years per billion Euro for the nine CNC lies within the observed range of transport infrastructure studies.
- The cross-border projects and innovative technologies generate the highest multipliers. This reveals that they are integral building blocks for the whole TEN-T concept and generate a high European added value.

Recommendations

Our findings suggest that implementing the core TEN-T network by 2030 would provide a substantial stimulus to the European economy, fostering both GDP and employment. They also suggest that the generated employment would benefit over-proportionally vulnerable groups, i.e. lower skilled workers. The highest economic multipliers were found for implementing the major cross-border projects along the nine CNC and deploying innovative technologies. Implementing the core TEN-T network including the cross-border projects and the innovative technologies can thus be

3 Introduction

This study makes a quantitative assessment of the cost of not completing implementation of the Trans-European Transport Networks (TEN-T) that the EU would have to bear by 2030. The study focuses on the core network of TEN-T as defined by the new TEN-T guidelines of 2013 (EU Regulation 1315/2013) and the new funding rules as provided by the Connecting Europe Facility (CEF) (EU Regulation 1316/2013).

The European Commission has contracted Fraunhofer Institute for Systems and Innovation Research (ISI), Karlsruhe, together with PTV AG, Karlsruhe, and Infras AG, Zurich to carry out this study. This project team was supported by M-Five GmbH, also based in Karlsruhe, to complete the final report and to summarize the findings and recommendations.

Background and outline of TEN-T policy

The Trans-European Networks (TEN) are a premier development issue of European economic and social policy that dates back to the Treaty of Rome (1957). TEN include communications, energy and transport infrastructure networks. The adoption of a Common Transport Policy (CTP) was already foreseen at this founding stage of the EU.

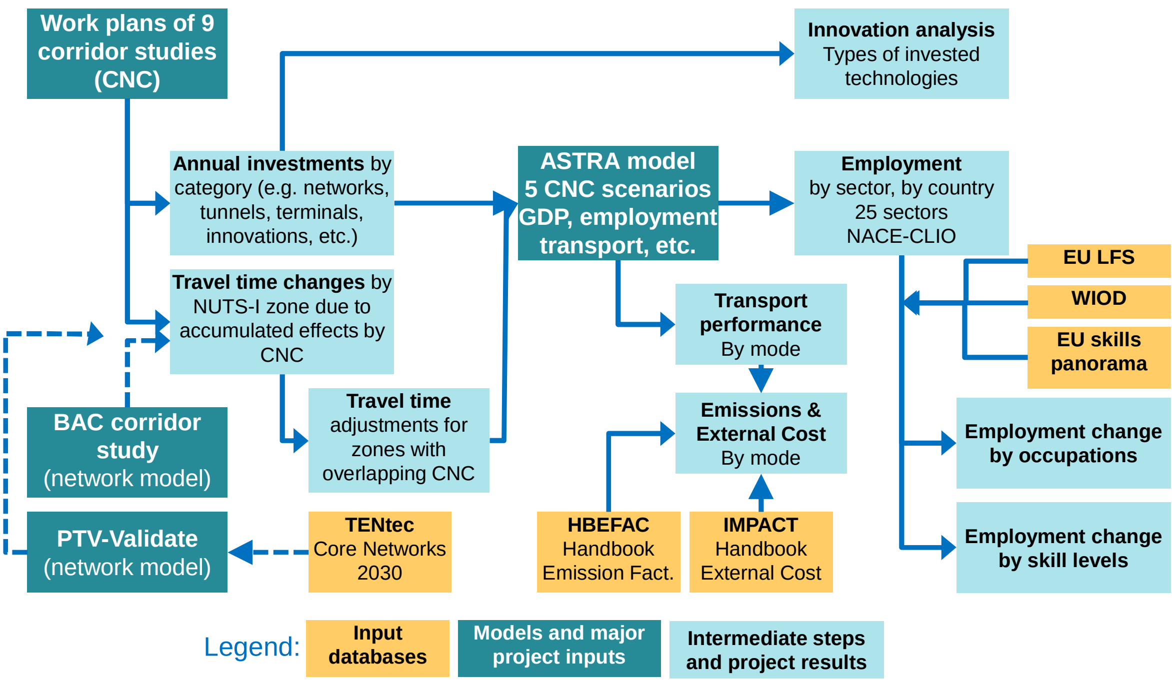
However, the implementation of such European infrastructure networks was so slow that the Treaty of Maastricht (1992) included an obligation for the European Commission and the European Parliament to prepare guidelines for the development of TEN and to update them periodically. For the TEN-T the first guidelines were published in 1996, followed by revisions in 2004 and 2011/13.

The latest revision of the TEN-T guidelines was put into effect at the end of 2013. TEN-T projects should fit since then into the strategic European transport network, as the core network developed by an analytical top-down approach, but also into the Strategic Transport Plans to be set up by each Member State defining the so-called comprehensive network. Together the core network and the comprehensive network form the TEN-T. The TEN-T core network is structured into nine core network corridors (CNC) that connect at least three European Member States each and serve the European internal market as well as they connect to international markets. The nine CNCs make up 75% of the total TEN-T core network. The TEN-T core network that is planned to be fully implemented by 2030 is in the focus of this study.

In parallel to the TEN-T guidelines the Connecting Europe Facility (CEF) was established to structure and organize funding of the TEN. The CEF was initially assigned a budget of EUR 26.25 billion to co-fund transport projects for the period 2014 to 2020, which meant a tripling of TEN-T funds compared to the previous 7-years programming period. TEN-T co-funding rates were set at up to 40% for cross-border projects and 30% for critical bottlenecks. Also the implementation of innovative technologies (e.g. intelligent traffic management systems and alternative fuelling infrastructures) can be supported by TEN-T funds.

Approach of this study

Basically this study is conceived as a combined qualitative and quantitative study. The qualitative part builds on a literature review, desk research including simple spread-sheet analyses and the knowledge of the involved experts and peer reviewers. The quantitative part builds on the elaborated integrated assessment model ASTRA (=Assessment of Transport Strategies) and the work plans and project lists of the nine core network corridor studies that were undertaken during the year 2014. Further databases were consulted where appropriate for our analyses e.g. EU Labour Force Survey (LFS) or the World-Input-Output Database (WIOD) (see Figure 3).



Source: Fraunhofer ISI

Figure 3: Inputs, main tools, project steps and results of the study

The project activities were accompanied and supported by a Steering Group at the European Commission involving the Directorates General (DG) EMPL, GROW, MOVE and the European Innovation and Networks Executive Agency (INEA). The draft project results went through both a peer review by invited external experts who received the draft report and were invited to a peer review meeting and a review by the Steering Group. The study was carried out from November 2014 until April 2015 with the completion of the final report lasting until mid of June.

Understanding of the scenarios and the economic analyses

European impact assessments are grounded in a common scenario framework that is agreed between different DGs of the European Commission and with the Member States. Core of this common framework is a European Reference Scenario that defines GDP, population and other important developments in the Member States for future time horizons until 2030 and even up to 2050. The current and agreed European Reference Scenario assumes that implementation of the core TEN-T network will be completed by 2030. In contrast this study compiled and assessed three scenarios in which the core TEN-T network would not be completed by 2030 and compared these with the European Reference Scenario. Basically we assumed that completion of the core TEN-T network is stopped in 2015. The assessment of these scenarios focused on the wider economic effects, in particular the effects on gross domestic product (GDP) and employment. Building on the latter, a detailed qualitative and quantitative analysis of the jobs potentially created by TEN-T was performed and the results were compared with findings in the literature. Furthermore, the external cost and the impact on innovation by the TEN-T policy in the different transport modes is analysed.

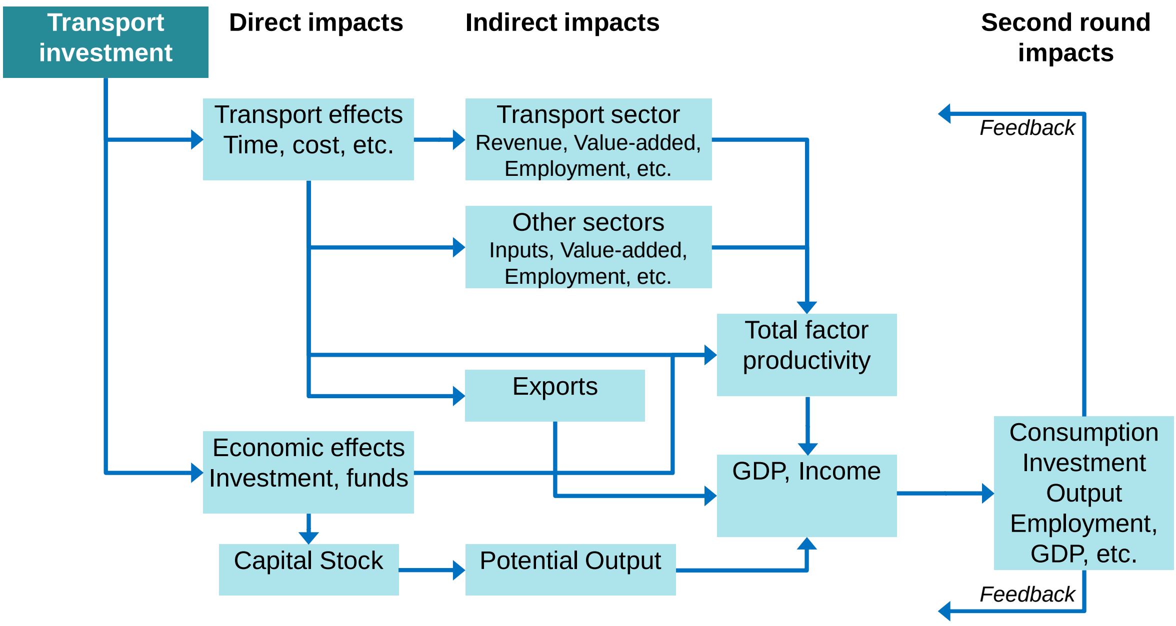
Structure of this report

The report starts with a review of the literature on economic impacts and jobs generated by infrastructure investment. Further it elaborates on particular aspects shaping the debate about the economic value of transport infrastructure investment. After that the modelling approach using the ASTRA-EC model and the input data for the assessment are explained. The presentation of results starts with the analysis of the impacts of two out of the nine core network corridors. These corridors were used as test cases to develop the methodology for the analysis of the three main scenarios of the study. The main study result is presented in the following section on not completing the nine core network corridors (CNC) and the full core TEN-T network. This is complemented and followed by a closer look at the quality of jobs lost. After that the two sensitivity scenarios look at the impact of the large cross-border projects and the innovative technologies. Finally an overview on the five scenarios (two test cases, main scenario, two sensitivity scenarios) is provided and the economic impact of implementing the full TEN-T core network by 2030 is compared qualitatively with impacts possibly generated by investments into other sectors. The findings of the study are then summarized and presented in a section on conclusions. The report closes with an annex on different economic assessment methods and the cited references.

4 Review of economic impacts of transport infrastructure

The economic impacts of the TEN-T core network broadly speaking consist of direct impacts and indirect impacts. The direct impacts include transport impacts (e.g. changes of travel time, modal-split, etc.) and economic impacts due to the fact that the implementation of the TEN-T requires resources and funds for such investments. Indirect impacts comprise a large number of effects (e.g. change of productivity in the transport sector, investments in supplier industries, change of productivity in other sectors, ex- and imports of EU countries, etc.). In our understanding indirect effects are synonymous to wider economic effects. The economic literature provides further terminology e.g. induced effects, catalytic effects, second round effects, though a unified understanding of the different effects does not exist.

Figure 4 presents the chain of effects kicked-off by transport investments. Speaking of a chain is actually a simplification as the initial indirect impacts in the economy modify GDP, which in turn in the next round of calculations (imagine this as the next quarter or the next year) causes second round impacts e.g. further changes of investment or employment. Thus, actually we are talking about a loop of effects (as it will be later shown in Figure 11) or feedbacks and the concept of a chain of effects constitutes a simplification.



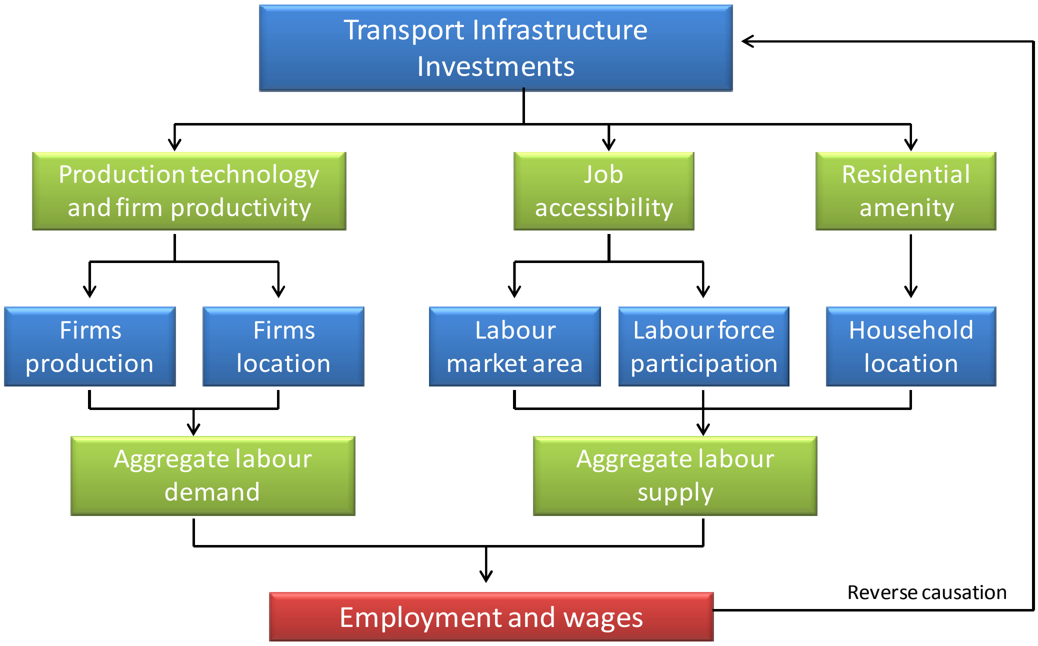
Source: Fraunhofer ISI

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

To capture the full effects of not implementing the TEN-T a methodology must be appropriate to model also indirect impacts and second round impacts comprehensively.

4.1 Assessing the impacts on jobs

Employment has been traditionally identified as a key matter for governments and policy-makers, especially since the beginning of the current economic crisis. Among other social and economic benefits, different studies (ITF, 2013; Haider et al., 2013) have emphasized the vital role of transport infrastructure on job generation and the labour market in general. The contribution of transport investment lies not only in the new employment opportunities for the workforce, but also the provision of enhanced accessibility for industry development, decrease of transportation costs, improved factor productivity, more reliable mobility, etc. In this respect, the theoretical impact of transport infrastructure investment on employment is represented in Figure 5.



Source: own representation after Profillidis et al. (2013)

Figure 5: Causal relationship between transport infrastructure investments and labour market

As pointed out by Wallis (2009), the development of the trans-European transport network constitutes a key instrument of the EU policy to improve competitiveness, income and employment, in line with the Lisbon Strategy. By providing better access to economic centres, an efficient trans-European network is intended to foster economic growth and employment throughout the EU, especially in peripheral and disadvantaged regions. Therefore, the cost of not completing the TEN-T, also in terms of employment, needs to be carefully analyzed.

This section is organized as follows. Firstly, we briefly summarize previous research studies addressing the impact of transport infrastructure on employment, and describe the methodology we followed for the analysis. Secondly, we display and comment the main results obtained by the literature review.

4.1.1 Methodological considerations

Many previous reports and research studies have examined and discussed about the impact of transport infrastructure on employment, generally within a broader analysis to estimate its wider economic impacts – GDP, productivity growth, etc. – in a certain territory. Due to the special interest exhibited by local decision-makers and the greater confidence provided by current techniques, previous research has focused on the short-term impacts of transport infrastructure and, more specifically, transport infrastructure investments (Metsäranta et al., 2013).

It is commonly referred in the literature (OECD, 2002; NRA, 2013) that the magnitude of goods and services demanded by transport investment projects in the short-term generates significant increases in the level of local employment, both direct jobs[1] in the construction industry and in other economic sectors supplying equipments and construction materials. Projects with high traditional construction and engineering content, such as highway projects, have been identified as having the largest multiplier effect on local job generation. In this respect, it has been also noted (Bivens, 2014) that, although construction and manufacturing activities require higher investments per person employed – given their high capital input intensity –, they generally support more indirect jobs in ancillary sectors than those jobs created more cheaply in other areas. Estimates regarding the impact of transport infrastructure investment on job creation are numerous in the literature and are summarized below.

Long-run impacts on employment, following the primary transport effects, have also been widely commented in the literature (Jiwattanakulpaisarn, 2007; Department for Transport, 2007). Structural changes due to accessibility improvements (mainly cost and travel time reductions) may impact in the labor market by different ways. Firstly, they can support clusters and agglomerations, making the labour market areas larger because job centres can be reached from longer distances within reasonable time. Secondly, they turn the labour market more productive and efficient, since employment mobility can improve job matching and hence the balance of labour demand and supply. Nevertheless, it is also assumed that the impact of infrastructure on jobs is not universally positive (OECD, 2008). The improved transport infrastructure, by increasing the competition through more mobile

[1] The literature most often applies the term jobs without any distinction if it would be a temporary job (e.g. existing only during construction of the infrastructure) or a permanent job. The proper terminology would be to speak about years-of-employment (YoE), which then includes both temporary and permanent employment. Temporary employment would then be counted in the YoE with the number of years a job is existing and permanent jobs with the number of years they exist until the end of the period of analysis (i.e. the forecasting horizon, which in this study is 2030). Thus concerning our own results we speak about years of employment and employment years, respectively.

labour from outside the region, may take up any increase in jobs from the higher level of activity, resulting in the so-called “two-way problem”.

As a result, it is possible that the new infrastructure promotes the economic growth of the local economy, but at the same time may be bad for the employment prospects of local residents within the region. However, some authors (Kernohan et al., 2011) have suggested that job relocation effects are not likely to be very significant at a regional level for all but the most extensive transport schemes, such as high-speed rail or strategic highway projects. In the same line, Metsäranta et al. (2013) have pointed out that the value of long-term effects is quite low compared with the short-run multiplier impacts, at least regarding regional development.

However, little efforts have been developed to quantify these effects, since some authors (Bivens, 2014) argue that it is not possible to reliably forecast the long-term impact of transport investments on jobs. The only contribution we can find in this field is the impact of infrastructure investments on the composition of labour demand, especially focusing on education and level of wage associated with the jobs created.

As pointed out above, numerous reports and research studies have previously estimated the impact of transport infrastructure investment on jobs, mainly in the short-term. The techniques used for this purpose are varied, but among the most common ones we can find:

- Input-Output (IO) models: this technique typically stresses the flow-on effects of a boost in employment resulting from the construction and/or operation of a given transport infrastructure. Preferable for analyses at the regional level, IO models provide a sense of the potential range of employment generation but have a limited ability to predict new employment generation from an economy-wide perspective (Schwartz et al., 2009). Furthermore, IO models typically distinguish three kind of job generation:
    - Direct employment: jobs generated in the construction and engineering industry due to capital expenditures on transport investment projects.
    - Indirect employment: jobs generated in supplying industries in response to demand for additional inputs, required by construction industries.
    - Induced employment: jobs generated due to an increase in the demand for all goods and services, when construction and other supplying sector employees spend their (new) income. Then, it is needed to estimate a consumption multiplier, that is, the percentage of new income that is spent rather than saved by employees.
- Computable General Equilibrium (CGE) models: this kind of models produces estimates of employment gains by using extensive quantitative information. Preferable for analyses at the national level, they mainly measure demand side changes in the labour market.

- Land Use and Transportation Interaction (LUTI) models: this technique is generally used to predict redistribution of employment location between areas, based on changes in labour productivity.

However, it is necessary to point out that, according to Wallis (2009), these methodologies have been subject to criticism and must be treated with extreme caution. This author warns that these techniques are useful to establish a range of possible values, but it would be unlikely that they can accurately predict national employment impacts of a given transport investment.

4.1.2 Empirical values of job-years creation by transport investment

Numerous reports have previously quantified the short-run impact of transport infrastructure investment on the level of employment. Among the first ones we can find the study by Cleary et al. (1973) of the M4 in South Wales, based on surveys. They concluded that the construction of the motorway generated some 10,300 job-years over 20 years, and subsequently attracted between 9,000 and 12,000 job-years in firms not previously located in the region. Since then, research studies analyzing the influence of transport investment on employment have increasingly proliferated in the last years. A summary of previous results is displayed in Table 2, by showing the average number of total job-years generated by each kind of infrastructure. We can also notice that road projects are among the transport investments with the highest impact on job generation.

Table 2: Total employment effects (for each € 1 billion of investment in infrastructure)

Project type	Studies reviewed	Total employment generated (Direct + Indirect + Induced)	
		Average values	Total Range
Energy	16	26,136	8,829 – 51,185
Transportation	25	24,223	12,709 – 37,259
Highways	5	34,288	22,535 – 37,259
Roads and bridges	8	33,770	18,926 – 35,307
Rail	4	18,871	12,709 – 22,286
Mass Transit	5	29,295	23,329 – 32,430
Buildings	10	26,204	17,736 – 32,119
Water	6	25,297	18,352 – 30,435
Telecommunication	3	28,608	19,729 – 31,646
Health	1	20,356	20,356

Source: NRA (2013)

The literature in this field is especially broad in the United States, responding to the aim of the federal government to quantify the wider impacts of the transportation spending programs subsequently approved. According to the calculations by the US Department of Transportation (2008), US$ 1 billion in road construction resulted in 6,055 direct job-years on site and another 7,790 in indirect jobs from material supply. Additionally, it has been calculated that the American Recovery and Reinvestment Act (ARRA) would create or sustain 6,8 million job-years, resulting in 8,600 direct jobs per billion euro invested (Romer et al., 2009), although other authors have been recently reduced this estimation (Cogan et al., 2010; Conley et al., 2013). Also in America, analyses of infrastructure investment in Canada and the United States have typically estimated total employment effects between 10,000 and 15,000 job-years for all infrastructure types for an investment of $1 billion (Haider et al., 2013). Finally, higher impacts have been identified for less developed areas, since the incremental stimulus proposed in 2009 for the LAC region was calculated to generate about 80,000 jobs per US$1billion.

In this respect, it should be noted that results may differ between geographical areas. According to Profillidis et al. (2013), per billion US$ (or € respectively) of spending on public transportation capital investments, nearly 23,800 job-years are supported in the United States, while in the EU15 the figure is smaller (13,150 job-years). Regarding transportation operations investments, over 41,000 jobs and 22,000 jobs are supported in the United States and the EU, respectively, for each billion US$/€ of annual spending on public transportation operations.

Within the European Union, Rienstra et al. (1998) concluded that no meaningful impacts on employment resulted in the Netherlands from new road accessibility improvements. More recently, Fabra et al. (2012) estimated an impact of around 16,000 job-years for a 4-year investment in the Spanish Rail Mediterranean corridor. Furthermore, Metsäranta et al. (2009) compared the impact of similar investments on job generation in different regions of Sweden.

At this point, we should point out that the magnitude and incidence of transport investment on employment will probably vary with different drivers. For example, the direct employment generation may be highly sensitive to assumptions about project location, project type and size, the technology to be employed in each project, etc. (Schwartz et al., 2009) On the other hand, indirect job estimates are generally sensitive to leakage created from the division between locally produced versus imported inputs.

Job creation by economic sector

Apart from estimating the level of employment generated by a certain amount of transport investment projects, different reports have addressed additional aspects of job creation. For instance, Bivens et al. (2009) calculated how direct and total jobs supported by transport investment varied depending on the financing approach used. Nevertheless, it is more common that previous research deeply analyzing the impact of transport investment on employment estimate the distribution of jobs created across sectors in the economy.

As pointed out above, researchers and consultancy groups from the US have recently shown a special interest to assess the impact of transport investment in the level of employment. Their approaches generally comprise a detailed analysis evaluating the distribution of new employment across the economic sectors: construction, manufacturing, trade, finance, health care, etc. In this respect, the Department of the Treasury (2012) estimated that the direct effects of the 2013 Federal Budget proposal for infrastructure investment would concentrate on construction (62%) and manufacturing (12%), followed by sectors such as retail and wholesale trade. Similar results are obtained by the CIC (2012) for an economic benefit assessment in California. Heintz et al. (2009) provided a more illustrative approach by calculating the direct, indirect and induced jobs generated by a nationwide infrastructure investment program in the country. According to these authors, the services and construction activities would be the most benefited, with 48.4% and 40.7% respectively of the new jobs, while sectors such as manufacturing (9.3%) or agriculture would show more limited changes. Finally, DeVol et al. (2010) concluded that specific infrastructure investments would have a greater impact (direct + indirect new jobs) on construction (34%) and trade (12%) activities, with a smaller share for manufacturing (9%), health care, accommodation and professional services.

Outside the United States, probably the most detailed results in terms of total jobs created in each economic subsector are displayed by Fabra et al. (2012) for the case of the Spanish Rail Mediterranean corridor, with a higher impact on services and construction activities. For the UK, CECA (2013) estimated the employment impacts for each 1,000 job increase in infrastructure construction, whose results are displayed in Table 2. Furthermore, focusing on the Canadian province of Ontario, Haider et al. (2013) pointed out that, although direct impacts of non-residential construction would generate jobs in construction related trades, new job employment would significantly appear in sectors such as retail, legal and accounting services, engineering and accommodation activities.

Table 3: Employment impacts of a 1,000 job increase in the construction sector arising from infrastructure investment (Thousands of jobs)

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

Source: CECA (2013)

It is also essential to take into account the different impact of transport infrastructure on employment over time. For the particular case of public transportation infrastructure, the report by Weisbrod et al. (2009) illustrates the different kinds of employment generated by capital investment and operation. In this respect, new jobs during the investment period especially focus on construction (31%), manufacturing (13%) and wholesale&retail trade (10%) among others. By contrast, government (46%), wholesale&retail trade (10%) and health services (7%) are the sectors more benefiting during the period of operation.

Unlike the traditional approach of estimating new jobs sorted by economic sectors, Haider et al. (2013) complemented their analysis by focusing on occupations rather than industries. Based on the case study of Ontario (Canada), they calculated that a $12 billion investment in the non-residential engineering and construction building industry would generate around 22,000 new clerical positions in addition to the 21,000 middle and other management occupation jobs (see Table 3). Among the biggest occupations we also find sales and service jobs, followed by trade and skilled transport operators. Additionally, a report for the American Public Transportation Association (EDRG, 2009) estimated the proportion of jobs generated by expenditures in public transportation (both capital investment and operation) sorted by the skill level required. Then, the authors classify the amount of jobs generated in four categories: blue collar semi-skilled, blue collar skilled, white collar semi-skilled and white collar skilled jobs. They concluded that both capital and operations spending generates a very broad range of jobs spanning all basic job categories, with significant shares of the blue-collar semi-skilled category.

Table 4: Top 10 occupations generating employment from investments in infrastructure in Ontario

Occupation	Total jobs generated in Ontario	Jobs per billion € invested
Clerical occupations	22,014	1,284
Middle and other Management occupations	21,072	1,229
Intermediate Sales and Service occupations	20,196	1,178
Elemental Sales and Service occupations	18,762	1,094
Trades and skilled Transport and Equipment operators	15,948	930
Skilled Administrative and Business occupations	12,564	733
Professional occupations in Natural and Applied Sciences	11,063	645
Skilled Sales and Service Occupations	10,922	637
Processing and Manufacturing machine operators and assemblers	10,598	618
Intermediate occupations in Transport, Equipment operation, Installation and Maintenance	7,255	423
Total by the investment		8,771

Source: Haider et al. (2013)

Converted with an exchange rate of 0.7 €/CD$

Finally, we should point out that, to our knowledge, very few researches have estimated the impacts on employment due to reductions in generalized costs. One of the scarce reports found in the literature was developed by WERU (1996) regarding the A-55 motorway in North Wales. According to the authors, transport improvements had a negative impact on employment within the communication and transport sector, while results were especially positive for branches such as retail and distribution, public services, metal industry and engineering.

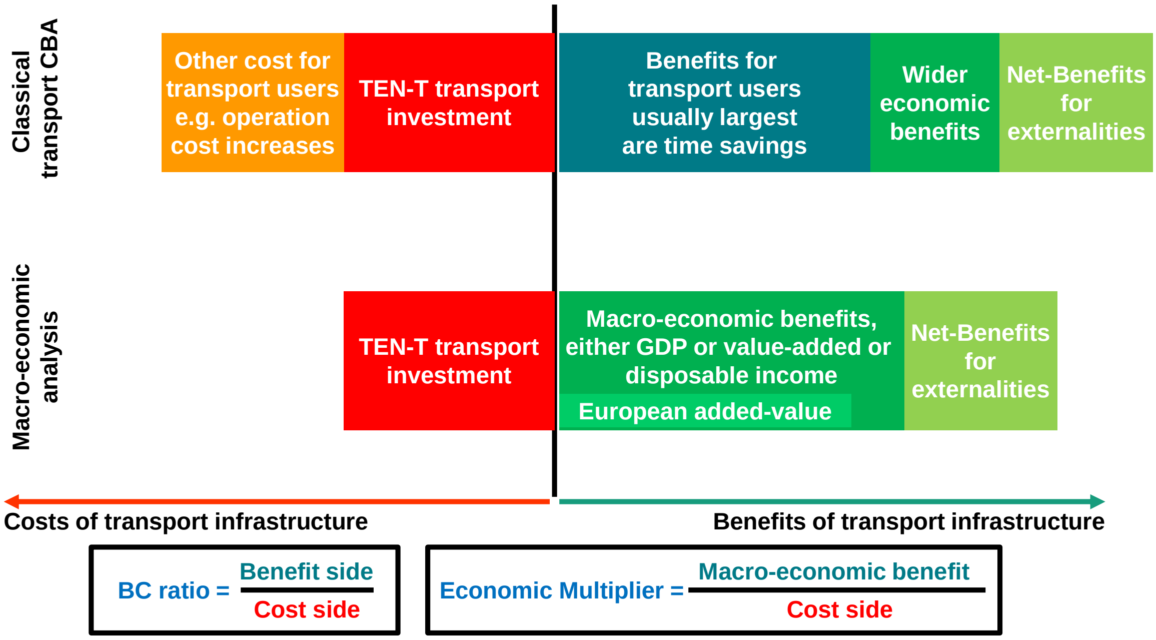
4.2 European added value and cross-border spillovers

Schade et al. (2014b) concluded that wider socio-economic benefits and European added value, which is part thereof, are typical benefits of large transport projects for which classical transport CBAs would be insufficient to assess the projects comprehensively. Each of the nine CNCs as a whole can be seen as a very large project. Hence, their recommendation to the European Parliament not to neglect the indirect effects and the European added value applies to the CNCs. This study obviously contributes to their recommendation to further develop the existing scientific knowledge as well as practical approaches to improve the understanding and accuracy of measuring European added value and wider economic benefits.

The famous Mohring paper (1993) suggested that in case of marginal cost prices were charged for transport infrastructure and that homogenous preferences would exist for transport services or for benefits accruing all the benefits of transport infrastructures could be comprehensively measured on the infrastructure itself. Thus they would not needed to be measured somewhere else in the economy. In other words, what we call wider economic benefits would not exist according to this author. Though Mohring points out that for a classical cost benefit analysis in an open-economy there could exist further economic gains to the country where the infrastructure investment takes place, when it benefits from other countries usage of the infrastructure, the paper is often used as justification to apply classical transport cost benefit analysis and considering **only** the costs and benefits measured on the networks. However, since 2000 recent literature has supported the existence of wider economic benefits and pointed out that their impacts are larger than estimated by the classical appraisal, including for TEN-T and other long-distance infrastructures in Europe. Apart from the open-economy issues mentioned by Mohring, the main reason is that transport networks have very special economic characteristics as pointed out by the International Transport Forum (ITF): "*They are associated with multiple market failures, including public good characteristics and externalities (both positive and negative).*" (ITF 2013, p. 30).

Figure 6 presents a scheme to understand the benefit and cost components of the different assessment approaches. A **classical transport CBA** is based on changes of user benefits, changes of user costs (if any), investment costs and the net changes of externalities (here assumed as a net benefit for externalities). Wider economic benefits would only be accepted if certain assumptions hold (e.g. open economy CBA). Such a CBA is founded in micro-economics.

The **macro-economic analysis** applied in this study is building on **economic multipliers** that consider very similar benefit and cost components at the classical transport CBA. On the cost side it would include the same investments as in the classical transport CBA. Also net-benefits for externalities would be equal. However, the benefit indicator would come from the macro-economic model and typically would be change of GDP, value-added or income (in case of a negative result e.g. a loss of GDP, it would be a cost not a benefit). Part of the macro-economic benefits would result from the European added-value of an infrastructure, which in particular results from cross-border projects generating spill-overs between EU countries and adapting the trade patterns as well as the productivity of the economies. The latter incorporates two components: productivity change due to national transport improvements and due to improvements of international transport, of which the latter would be another source of European added-value.



Source: own elaboration, Schade/Krail 2015

Figure 6: Benefits of a classical transport CBA and wider economic benefits

The scientific literature on European added-value is developing. Already early papers argued that European added value is particularly relevant for cross-border projects (Exel et al. 2002). Other early papers also proposed methods to measure indirect effects and to consider the dynamics between transport, the production system and international trade. In particular, integrated assessment models comprising transport, trade and macro-economy would enable measuring such indirect (macro-economic) effects (Schade/Rothengatter 2004). The need for such models has been recently emphasized again by Iacono et al. (2013) when analysing the economic impact of transport investment in the US. The authors concluded that the combination of transport models with large scale economic models would be required to assess the economic impacts. The interactions that should be modelled by such an integrated assessment model have also been described by Lakshmanan (2008, p. 63) for an OECD roundtable on the *Wider economic benefits of transport* hold 2007 in Boston. The author underlines that changes of the transport system affect accessibility, labour supply, trade, and lead to second round effects expanding production and stimulating structural change finally altering total factor productivity and GDP growth. The modelling approach of our study, using ASTRA-EC, is broadly consistent with these propositions.

Another line of recent papers suggest further methods to measure European added value. Their proposal is to build on the assessment of spillovers of single sections of a large project and then suggesting increased European co-funding for those sections that would generate high spillovers across borders. In general, the findings again point to cross-border sections to be those of high European added value. However, the authors put the disclaimer that this could not be generalised as other factors may have additionally played a role to generate the spillovers (Gutiérrez et al. 2011). Recent findings with this approach confirm that it is important to model trade in order to assess economic impacts of transport infrastructure and that the value of spillover effects seems to be in the order of half of the investments made in case of motorways in Spain. Again border regions are identified to be those with more significant spillover effects (Condeço-Melhorado et al. 2013, Salas-Olmedo/Gutierrez 2014). Thus from the literature we can conclude that new cross-border infrastructure and new infrastructure in regions adjacent to borders bear the potential to generate European added value.

A striking example of such a cross-border effect generating European added-value is observed during the preparation of the German Federal Transport Infrastructure Plan (FTIP) in 2014/2015. Denmark is foreseeing to fund all infrastructure of the planned Fehmarn-Belt Crossing on their territory as well as across the sea. Germany will only fund their access links on German territory i.e. the links crossing the Fehmarn Island in Germany and linking them to the mainland networks. This project reveals the highest cost-benefit ratio of all German infrastructure project analysed. The reasons are the spill-over benefits to Germany generated by the Danish investment for the largest part of the Fehmarn-Belt Crossing.

4.3 Agglomeration effects and network effects

There are further effects of transport infrastructure debated in the literature, such as network effects and agglomeration effects. The latter are clearly linked with transport infrastructure, since better accessibility improves productivity of regions and thus may generate economies of scale (e.g. a larger catchment area to sell products or to attract qualified employees). By contrast, there might be some confusion with network effects. In classical terminology, positive network effects arise if the use of a product by one new user does not only provide individual benefits to the specific user, but also to other already existing users of the product. Famous examples are telephones or fax machines. According to this interpretation of network effects, congestion constitutes a negative network effect since each further user may create disbenefits to other users in case he contributes to create congestion. A further interpretation of network effects relates to the options created by a network structure. More linkages within a network create more route options as well as more resilience or reliability in case of disruptions of some links within the network. This may be termed network value, though there seem to be some interference with the term accessibility. Therefore, given the current stage of theory development, in our study we focus on European added value and productivity effects (see section 4.2), but not on network effects as they are defined in the economics literature.

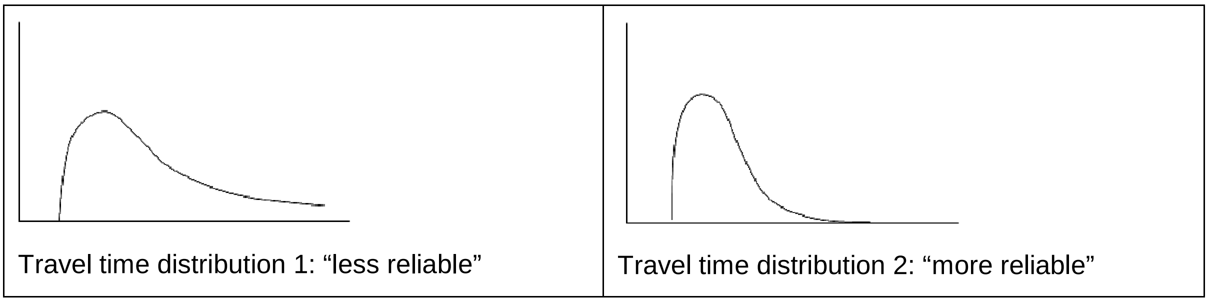
The measurement of agglomeration effects, started by Fujita et al. (1999), is usually linked in a close way with computable general equilibrium models (CGE). Venables (2004) also compared benefits assessment by applying a classical transport CBA to urban transport investment versus measuring agglomeration benefits. Through an econometric approach, he concluded that agglomeration benefits could be several times larger than the classical CBA measurement. The following estimates of agglomeration benefits pointed out that they should add some 10 to 20% of additional benefits to a classical CBA (Graham, 2008). However, more recent analyses of agglomeration effects concluded that they would be much smaller, both for urban areas (Melo et al., 2013) and at the level of High-speed rail corridors (Graham/Melo 2010) and other European corridors (Witte et al., 2015).

Other approaches applied a multi-model approach in particular attempting to model the labour market reactions in greater detail as they assumed that market imperfections would be largest on these markets such that wider economic effects should be observable by this approach. In a Dutch case study on Maglev rail projects it was found that such indirect effects could add up to further 38% additional benefits in relation to the direct benefits measured by classical transport CBA (Elhorst/Oosterhaven 2008).

4.4 Economic impacts of transport reliability

For some years, the term “reliability” in transport systems has been discussed regularly and accordingly claims towards political stakeholders have been made to take action for more reliable transport systems. In this respect, it is an essential topic to be considered during the planning and evaluation process for the core TEN-T corridors.

It can be said that theoretical knowledge about reliability is even internationally not very extensive. Even the definition of the term reliability cannot be provided intuitively. In general, a trip from A to B is rated as unreliable if a traveller stucks in a traffic jam or his train is delayed. In terms of a commuter, who is delayed every morning because of “the same” traffic jam, this congestion is very reliable. Reliability in this context can be defined as the deviation from an expected mean of the travel or transport time, or the deviation from an expected arrival time, whereby both delays and early arrivals have to be considered. Deviations from the expected travel time can be mathematically described by a distribution of travel times or arrival times. In case of ‘certain traffic congestions’ a higher (expected) mean of the travel time can be stated, even though the dispersion around this mean can be very low.



Source: after Walther et al. (2014)

Figure 7: Travel time distributions

For specific transport carriers as well as for the disaggregation between passenger and freight transport, the different characteristics of reliability have to be considered. Unreliability in traffic systems affects at a first level the means of transportation, e.g. cars, trains etc. At a second level, passengers and freight carried by these means of transport are also affected. In the context of the methodology for the new German Federal Transport Infrastructure Plan (FTIP), only the effects on the second level are to be assessed, meaning that the focus is set on the effects on passenger and freight by the unreliability of one or more means of transport. For example, a train operating a certain route with major time variations is not considered to have a relevant impact on the indicator ‘unreliability’, if trains serving this relation only feature low occupancy rates. Additionally, it is important to mention that, in the course of the evaluation process for e.g. European corridors, only improvements of reliability due to infrastructure measures are allowed to be considered. This is especially problematic in the railway sector, since unreliability often occurs due to problems with the rolling stock, through deficiencies in the existing technical infrastructure or through delays on “upstream” sectors.

In general, three approaches for measuring and assessing reliability or unreliability, respectively, for a certain route can be used (Significance et al. 2012, page 14 and following):

- Standard deviation of travel time distribution
- (Anticipated) buffer times to avoid delays
- Deviations from contracted arrival times in schedule bound systems (schedule delay) in frequency (percentage of arrivals) and extent (delays measured by e.g. minutes).

Apart from the explicit definition of reliability, the indicator is always related to one O-D relation, meaning possible routes from A to B. However, the routes used on a given relation are determined by solving the shortest path problem based on travel times, costs, etc. The existing literature repeatedly suggests using the deviation from the mean travel time as a measure for the unreliability, and to estimate it track specific as a function of the volume-to-capacity ratio. In this way a simultaneous shortest path algorithm, which integrates the reliability concept, could be tried. Nevertheless, this procedure implies an essential constraint: the standard deviations from the average travel time of sequential route sections must not be correlated with each other. This assumption becomes more unlikely as the route sections gets shorter.

For the road sector the concept of using the standard deviation as an indicator for reliability could be developed. The resulting model will be explained below. For the rail sector, the concepts of standard deviation and deviation from contracted arrival times are both possible solutions in principle. The time scheduled approach, however, is not easy to implement, since up to date there exists no schedule of TEN-T core corridor rail network 2030. For that reason, this approach for modelling reliability can only be realized by an assumed endogenous train line system.

For rail freight transport and intermodal freight transport, respectively, the transport and logistics industry uses buffer times. Buffer times transform delay risks - meaning possibly arising time losses - into certain time losses compared to an undisrupted journey. These are the costs of the risk reduction. The buffer times are calculated in such a way that, together with the mean travel time, they cover the travel and transport time distribution up to only a very small quantile.

For the transport carrier inland waterway, reliability is of lower importance as long delivery periods normally enable complying with contracted arrival times. The main influence on reliability arises from the water level fluctuations and the resulting maximum loading of ships, which determine reliability of this transport mode. Variability of loaded drafts due to fluctuating water levels is reflected by transport prices. These prices include insurance rates for shifting the transport orders to alternative carriers in the case of insufficient water level. Hence, transport prices for inland waterway transport include the costs for unreliability, and a separate indicator is not needed to be developed.

Next, the approach for the transport carrier road is illustrated, since meaningful results already exist in this area. The research design for FTIP has been determined as follows:

- Functional determination of the standard deviation for the travel times as a parameter of reliability.
- Consideration of only the congestion related variability of the travel time. This corresponds to the logic that, within the framework of the FTIP, only infrastructure related changes of transport reliability can be assessed. Moreover in highly frequented areas the same speeds for trucks and passenger cars can be used.

- The functional connection between volume-capacity ratio and standard deviation is approximated with regard to the particular route sections on the base of simulations. During this process, a correlation analysis is needed to prove the independence of the disruptions on adjacent route sections.

Founded on simulations for real bottleneck situations on federal motorways, the model mentioned below, which introduces a quantifier with a length relation, was developed. Regarding the quantifier, a non-correlation of the route sections can be assumed (compare with Geistefeld & Hohmann 2014, page 23 and following).

The model has to be applied for each individual section as subject to the (maximum) volume-to-capacity ratio of the section, if necessary through the summary of consecutive sections for the same bottleneck (1):

$$s_R(x) = \begin{cases} a \cdot (x - 0{,}75)^b \cdot \sqrt{\dfrac{L}{L_{Reference}}} & \text{for } x \geq 0{,}75 \\ 0 & \text{else} \end{cases} \quad (1)$$

being

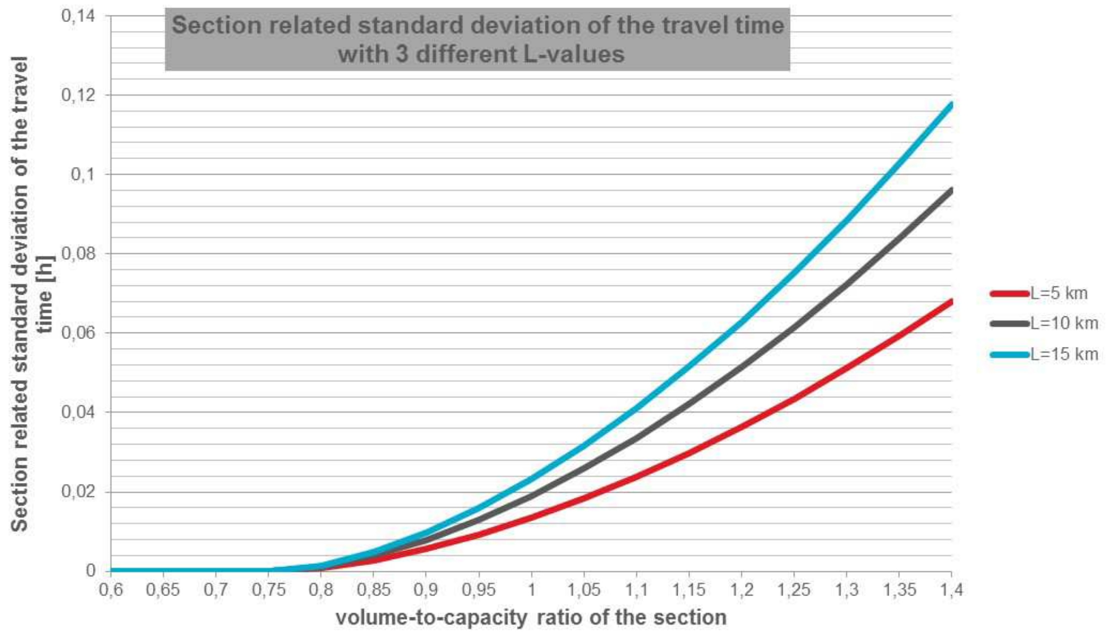
S_R	= section related standard deviation of the travel time [h]
X	= volume-to-capacity ratio of the section
a,b	= parameters resulting from regression
L	= section length [km]
$L_{Reference}$	= reference length [km]

With the standard deviations of n individual sections within a route, the resulting standard deviation for the travel time of the total route can be calculated by using equation (2):

$$s_{R,total} = \sqrt{\sum_{i=1}^{n} s_{R,i}^{\,2}} \quad (2)$$

being

$S_{R,total}$	= standard deviation of the travel time on the total route [h]
$S_{R,i}$	= standard deviation of the travel time on the trip i [h]
n	= number of sections within the route.



Source: after Walther et al. (2014)

Figure 8: Standard deviation for the road mode

An empirical validation of the coherences derived from regression analysis is not directly possible. This is due to the fact that, in the course of the simulation for the estimation of the functions, the influences on infrastructure could be isolated, while in reality aspects such as weather, accidents etc. can have an additional impact on unreliability and therefore the empirical standard deviation.

The calculation of the standard deviation is based on the results of the assignment procedure, so no further data requirements arise. As reliability is bound to a complete relation from A to B, all paths used by cars in the transport model must be stored, at least temporarily. The handling of these data constitutes a challenge for transport models. Moreover, cost rates for monetizing the reliability indicator for integration in cost-benefit-analysis do not exist at the European level. For the German FTIP a SP-survey was conducted to get cost rates for e.g. one hour of standard deviation.

We have explained that quantification of reliability for inland waterway is part of the transport cost of this mode. For scheduled modes (air and rail passenger) the quantification requires a schedule for 2030, which would be an obstacle to quantification as long as it is not provided or could be assumed. For road transport the explained approach to quantify reliability requires the availability of a European network including the relevant attributes for 2030 as well as a European transport model. However, both issues are not available up to date. Therefore economic impacts of lower reliability along the TEN-T core network was not quantified for this study, though we would argue that such impacts exist and would constitute a negative impact if the TEN-T would not be completed.

Also in the case of reliability there could be made the distinction between measuring it based on a network modelling approach, a direct effect as explained above, and aspiring to measure it as an indirect effect not on the networks but as reactions of economic sectors. The German forwarding company Löblein, who is engaged in intermodal transport chains, reports that due to punctuality problems and thus unreliability of rail transport they have to own additional 100 containers of their total 600 containers. In other words, this unreliability adds some 20 % to the cost of containers (Verkehrsrundschau 47/2014). However, in this example punctuality and reliability seem to be the two sides of the same coin. One could try to argue that reliability is the consequence of punctuality. In the distinction between direct and indirect effects it would then make sense to treat punctuality as a direct effect in the transport sector and reliability as the indirect effect in the sectors demanding transport services. With this concept we might add reliability benefits in the ASTRA model to the effects on economic sectors, in which we could identify and measure such effects (e.g. in terms of additional stocks in warehouses or additional containers). This requires some further development of theory and estimates of cost parameters such that it could also not be applied in this study.

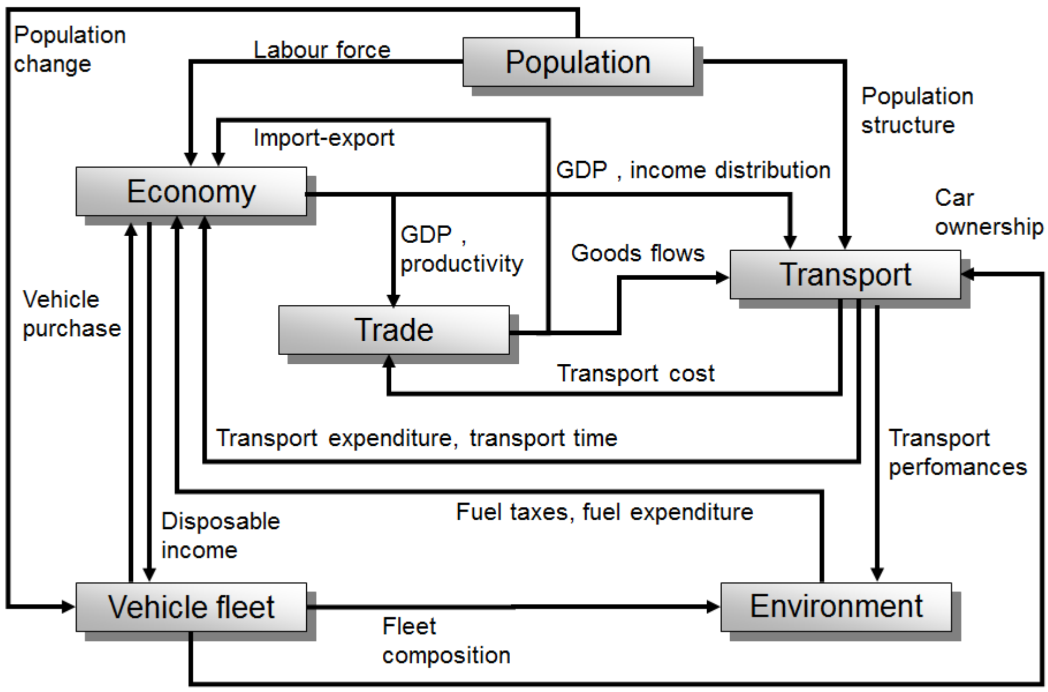
5 Methodology

The quantitative assessment of costs of non-completion of the core TEN-T network until 2030 mainly builds on the preparation and application of the ASTRA-EC model. In a first stage, the methodology of the ASTRA-EC model was adapted in order to estimate costs and employment impacts of two test cases on non-completion of two CNC corridors: Scandinavian-Mediterranean and Rhine-Alpine corridors. In a further analytical step, the methodology was improved to assess the impacts of the non-completion of the full core TEN-T network until 2030. Finally, ASTRA-EC was applied for analyzing the wider economic impacts of two TEN-T policy building blocks: first for the non-delivery of major cross-border projects and second for the non-delivery of horizontal priorities respectively innovative technologies. The following chapter provides a detailed description of the refined approach. After that the findings of the quantitative analysis on the two test cases will be presented and discussed as part of this methodological section.

5.1 Explanation of the ASTRA-EC model

The methodology to assess the impacts of a non-completion of core TEN-T network until 2030 is mainly determined by ASTRA-EC, developed during the ASSIST project and provided as a tool to the European Commission DG MOVE for the assessment of social, economic and environmental impacts of sustainable transport policies. ASTRA-EC is the most recent version of the ASTRA model, continuously developed since 1997 (see www.astra-model.eu). The latter model was applied in 2002-2004 to assess TEN-T infrastructure and transport policy of the EU15 (e.g. by the TIPMAC project, and also by a PhD thesis (Schade 2005)).

The System Dynamics model ASTRA-EC is an integrated assessment model (IAM) allowing the analysis of impacts of various transport policies and strategies. Like for all IAMs it links different systems such that changes in one system can induce changes in another system and vice versa. ASTRA-EC simulates the systems of transport, demography, economy and environment. In doing so, it enables the analysis of direct, indirect and induced effects of transport policies on all systems covered. The non-completion of TEN-T policy belongs to the category of policies that could influence not only the transport system. It induces direct effects on the transport system via new, improved or optimized transport infrastructure or via innovative technologies (e.g. ERTMS or SESAR) as well as direct impacts on the economy via investments and on the society via employment impacts. The different systems are dynamically interlinked in ASTRA-EC (see Figure 9) such that for example changes in the transport system lead to indirect or second-round impacts in the economy. Recent scientific advice to the European Parliament calls these effect wider economic impacts and suggests that these will be important for an appropriate assessment of cost and benefits of the TEN-T network (Schade et al. 2013).



Source: TRT - Fraunhofer-ISI

Figure 9: Overview of the linkages between the modules in ASTRA-EC

As illustrated in Figure 9, ASTRA-EC consists of different modules, each related to one specific aspect, such as the economy, the transport demand, the vehicle fleet. The main modules cover the following aspects:

- Population and social structure (age cohorts and income groups),
- Economy (including GDP, sectoral output, input-output tables, government households, employment, consumption and investment),
- Foreign trade (inside EU and to partners from outside EU),
- Transport (including demand estimation, modal split, transport cost and infrastructure networks)
- Vehicle fleet (passenger and freight road vehicles),
- Environment (including pollutant emissions, CO_2 emissions, fuel consumption).

Geographically, ASTRA-EC covers all EU27 member states plus Norway and Switzerland but so far not Croatia. Impacts on growth and labour market of the TEN-T core network for Croatia will not be assessed by ASTRA-EC as this would require time-consuming modelling work which is not feasible in the project framework given. As for the transport system a more detailed spatial differentiation is applied in ASTRA-EC. National transport flows are simulated on NUTS1 level, regional transport on NUTS2 level.

ASTRA-EC calculates all monetary indicators in real terms in constant Euro 2005[2]. Exogenous inputs are deflated with an EU27 GDP deflator taken from Eurostat. Therefore, all monetary model inputs as well as monetary outcome indicators are expressed in constant Euro 2005 as well in this report.

Like for all System Dynamics Models and as opposed to static transport models, ASTRA-EC simulates the development of indicators simulated within the covered systems for a whole pathway from 1995 to 2050 on an annual basis. The simulation starts in the past such that the endogenous development of major indicators in all systems can be calibrated to fit to statistical time series data from homogenous data sources (mainly from Eurostat). The *Reference Scenario* (REF) of ASTRA-EC was made in line for major demographic, economic, transport and environmental indicators for each EU27 member state with the 2013 PRIMES-TREMOVE Reference Scenario (European Commission 2013) for the upcoming simulation period until 2050 (see Krail et al. 2014). The REF covers all policy measures approved until the end of 2013. Specifically, the REF already considers the new TEN-T policy by 2030 as it was defined by EU Regulations 1315/2013 and 1316/2013.

The following section describes the methodology in the ASTRA-EC model and the refined approach for assessing impacts of a non-completion of the core TEN-T network until 2030. It highlights the model reactions at the specific areas tangled by TEN-T policy such that other parts of the model (e.g. the environmental or vehicle fleet module) are not part of the description. More detailed information about the whole ASTRA-EC model is provided by the ASTRA homepage (www.astra-model.eu), or by the comprehensive descriptions from Schade (2005), Krail (2009) and Fermi et al. (2014).

5.2 Methodology to elaborate the impulses of the TEN-T policy

ASTRA-EC calculates passenger and freight transport by applying an adapted classical four stage transport modelling approach. Due to its major purpose of assessing impacts of transport policies on transport demand itself, but also on the economy, the society and the environment (and vice-versa) and the fact that it calculates changes for the whole pathway from 1995 to 2050 on an annual basis, the spatial differentiation of ASTRA-EC is not as detailed as in a pure network-based transport model.

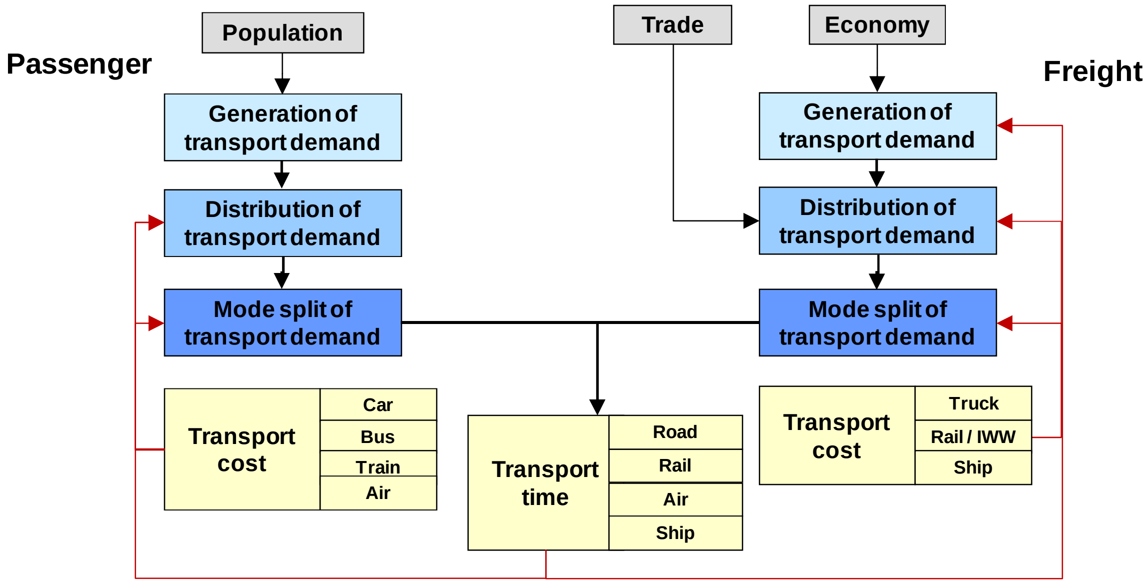
The transport modelling approach is similar for both, passenger and freight transport. The model generates annual passenger trips driven by socio-economic indicators like the number of persons per age and income on NUTS2 level. The next stage consists of the distribution of trips to potential destinations. This stage is carried out in three sequential stages. First, the trips differentiated by trip purpose and the originating NUTS2 zone are

[2] The conversion factor from current Euro to constant Euro 2005 is given by 0.9016.

split into trips within the respective NUTS2 zone (intra-NUTS2) and those with destination in any other NUTS2 zone (extra-NUTS2). The initial share is derived from the ETIS plus matrix. The share develops over time considering changes of average generalized costs (over all modes). Second, the remaining number of extra-NUTS2 trips are allocated into domestic and international trips. This is done by applying an initial share (as well from ETIS plus) which changes over time with an exogenous trend per country and trip purpose. This is the starting point for the final distribution of national and international passenger trips into origin and destination zone. In order to limit the number of calculations requested, ASTRA-EC aggregates the number of trips for national (domestic) trips on NUTS1 level and for international trips even on country level. The same spatial differentiation is then applied for the third stage, the modal split. Hence, cross-border demand matrices can only be provided on a country level for origin to destination (O/D) while national passenger transport flows are simulated on a NUTS1 level.

ASTRA-EC makes use of the same spatial differentiation and aggregation for O/D matrices of freight transport. The only difference can be found in the first transport modelling stage. The starting point for the generation of freight volumes per origin zone is for all domestic freight flows the country-specific production values per sector. This monetary value is then multiplied with a volume-to-value ratio which is calibrated based on ETIS plus. The resulting original zones for freight volumes are hence only on country level. In order to allocate the national freight flows to an originating zone on NUTS2 level, ASTRA-EC applies a share derived from the ETIS plus matrix. This share changes endogenously over time based on the share of active population for each NUTS2 zone calculated in the economic module of ASTRA-EC. International freight transport is converted from monetary export flows per country pair and economic sector into volumes per country pair and goods category. As the export flows already indicate the direction of freight flows, no distribution is necessary in this case. As regards national freight transport, the model aggregates the volumes on NUTS1 level before distributing the volumes to the national destination on NUTS1 level.

As concerns the effects of a non-completion of two single CNC corridors, the whole CNC, major cross-border projects within the CNC and innovative technologies within the CNC lacking transport infrastructure development as well as innovative technologies optimising transport systems in Europe induce a growth of travel time and costs as compared to the REF with completion until 2030. Travel times for passenger and freight transport are thus the most important impulses to be considered as direct effects on the transport system. Figure 10 depicts the implementation of direct travel time and cost impacts on the first three stages of transport modelling in ASTRA-EC, both for passenger and freight. Times and costs are supposed to change destination as well as the modal choice for the covered transport modes in ASTRA-EC. Furthermore, ASTRA-EC considers changing economic and foreign trade growth as well as changes in the distribution of income of private households to have second-round effects on transport demand.



Source: Fraunhofer-ISI

Figure 10: Impulses of TEN-T policy on the Transport Module

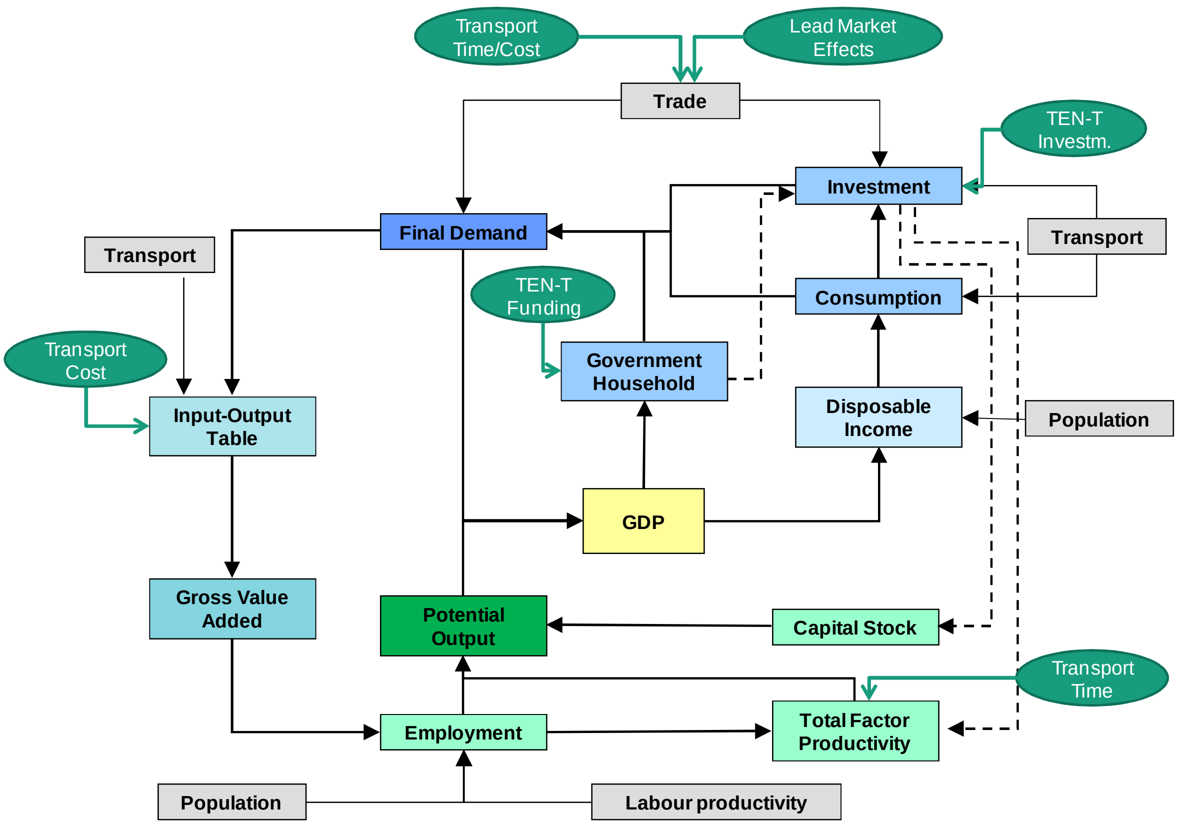
Due to the different spatial levels of transport demand modelling for regional (NUTS2), national (NUTS1) and international transport (NUTS0) in ASTRA-EC, travel times are not implemented in terms of single times for each O/D relation. ASTRA-EC considers average speed in terms of time per km for each NUTS1 zone. This information is then used to calculate the average travel time per O/D relation via summing up the time requested for passing through all NUTS1 zones between the origin and the destination zone. Based on information of transit flows through each NUTS1 zone between origin and destination derived from the ETIS plus matrix, the probability that travel demand per mode passes a certain NUTS1 zone is calculated. This information is used to sum up the requested time for each national and international O/D relation. For instance, the travel time for a trip from the NUTS1 zone DE1 (Baden-Wurttemberg in Germany) to ITC (North West in Italy) will be accounted mainly by the time requested for crossing the NUTS1 zones DE1, CH0 (Switzerland) and ITC. Besides the travel time requested for the main routes between origin and destination zone, also travel times for alternative routes (e.g. via Austria or France) are considered. This is accounted via the probabilities described above. The consequence for assessing travel time impacts for a non-completion of TEN-T policy is that travel time reduction achieved by TEN-T infrastructure and innovative technologies need to be implemented for each NUTS1 zone individually. In the case of the two test cases – the impacts of non-completion of the Scandinavian-Mediterranean and Rhine-Alpine corridors – and the impact of a non-completion of the other seven CNC the growth of travel time for each NUTS1 zone per mode was added as a factor increasing the travel time used in the REF considering all nine CNC until 2030. Due to the uncertainty about the future year in which the completion of a project or a whole corridor can be expected and thus the full travel time reduction can be achieved, it has been assumed that the full travel time impact will be achieved in a linear growth from 2015 until 2030.

The most comprehensive approach for estimating travel time impacts of a non-completion of CNC would be to simulate it with a detailed and state-of-the-art European transport-network model like VISUM which was foreseen in this project. This approach could only be partly followed for the analysis of the first two TEN-T corridors. Lacking data and information about the TEN-tec data in 2030 did not allow a reliable analysis with VISUM. As for the analysis of the impact of the non-completion of the whole CNC data gaps could not be filled. Based on an analysis of the TEN-tec data provided by the EC, information about railway tracks or motorway lanes was indicated for only 7% of all CNC sections. Data for design speed was stated for only 3% of the sections and the projections for travel flows even for only 2% of the sections. A manual integration of missing data was due to the level of the data gaps not feasible. Therefore, the analysis of travel time impacts needed to follow an alternative approach mainly without support of a network-based transport model. Results of a network-based model analysis were only available for the Baltic-Adriatic corridor. Despite the lack of quantitative travel time savings for the remaining 8 TEN-T corridors, the model-based results from the Baltic-Adriatic corridor provided a range of potential travel time impacts for at least a number of road and rail project types. The second major source for the estimation of travel time changes was the complete list of investments CNC projects and provided by the EC in December 2014. For this purpose, Fraunhofer-ISI and PTV started with an assignment of the 2,679 single projects stated in the CNC investment list to NUTS1 zones. Possible travel time and cost impacts of projects with an assumed finalization after the year 2030 were not considered. Information like the length of a section, the number of additional tracks and lanes, the foreseen use (high-speed or fulfilling the maximum speed requirements of the TEN-T regulation) as compared with the current status were used to estimate the impact on the distances and travel times. More details about the underlying assumption for the estimation of travel time and cost impacts are provided in the following section.

The second input determining the distribution and modal split are costs per O/D relation. They are composed out of ticket prices for public transport modes (train, bus, air) and perceived costs for car mode. On top, road charges are added. Tolls are accounted on NUTS2 level, but are aggregated in the calculation of O/D link-based costs on national level. As for the implementation of the impacts of TEN-T policy on costs, a possible reduction of travel distances induced by the scenario-specific part of CNC was assumed as the factor changing travel costs per mode on each O/D relation. Similar to the approach for travel time, the impacts on travel distance per O/D relation are then cumulated for each transit NUTS1 zone in-between origin and destination zone for each mode individually.

ASTRA-EC follows an integrated modelling approach such that it further considers economic changes directly induced by the non-completion of a transport infrastructure. Figure 11 shows the structure of the ASTRA-EC economic module and the impulses of the non-completion of CNC into the economic module. This is in the first line the avoided investments in CNC including innovative technologies which need to be subtracted from the whole TEN-T policy investments considered in the REF scenario. In the case of the non-completion of the CNC, the avoided investments of all sections or projects were accounted to the mode and the member states (plus Switzerland and Norway) financing the infrastructure. The baseline for the integration of avoided investments was the approach developed for the analysis of the two TEN-T corridors Scandinavian-Mediterranean and Rhine-Alpine. For the analysis of the non-completion of the CNC until 2030, the approach was further developed. The reason for this revision is that not all types of TEN-T infrastructure investments induce economic impacts or impacts on the labour market in the same way. Previously, all avoided CNC investments were assigned to the NACE sector "Construction". All different types of construction from small crafts enterprises up to highly specified tunnel construction companies are included. Obviously, the same amount of money invested in smaller craftsman companies does not influence the creation of jobs in the same way as for tunnel construction companies due to differing labour productivities. The second important impact concerns the structure of intermediate products and services. Again, the type of investment impacts the intermediate sectors in a different way. In order to consider these differences between the single projects indicated in the list of investments, the single investments were at first allocated to six categories: *tunnel*, *bridge*, *track* (or *lane*), *station* (railway), *terminal* (airports, seaports, inland ports and multimodal platforms), *innovation* (e.g. ERTMS) and *study*. In the case of projects consisting of more than one type of investment, the part of the project with the expected highest share on the total investment sum was chosen. This categorization of investments was the baseline for assigning the investments to more than just the sector *Construction*. As an example, investments of the type *terminal* are supposed to be split into the sectors *Industrial_Machines*, *Metal_Products*, *Computers*, *Electronics* and *Construction*. Nevertheless, the largest share of the investment sum is allocated to the Construction sector besides for type *innovation* and for type *study*.

In order to provide as well a pathway of annual investments per country and sector for each year between 2015 and 2030, a number of gaps in the investment lists needed to be filled. The underlying assumptions for bridging these gaps are described in the following section.



Source: *Fraunhofer-ISI*

Figure 11: Impulses of TEN-T policy on the Economic Module

According to the ASTRA-EC approach, avoided CNC infrastructure investments reduce the sectoral investment per country exogenously. They are subtracted from the endogenously estimated investments. This reduction influences final demand, sectoral output and GDP negatively. On top of the direct investment impact, changing transport demand leads to changes in the economic system. This varies from changing consumption patterns of private households (e.g. using less often public transport) up to second-round impacts on corporate investments in rolling stock due to less freight demand. Final demand is steering the major input for the estimation of impacts on jobs in ASTRA-EC: sectoral output in terms of production values and gross value added per sector. ASTRA-EC simulates employment via gross value added per sector and exogenous labour productivity per sector. The growth of labour productivity is made in line with the 2013 *Energy, Transport and GHG Emissions Trends to 2050* Reference Scenario (which is using the PRIMES-TREMOVE model). Therefore, economic impulses of a non-completion of TEN-T play a significant role in the assessment of job and wider economic impacts.

Besides these impacts, ASTRA-EC takes into account direct impacts of travel time and cost changes on foreign trade (Schade/Krail 2004). Changes in passenger and freight travel time and costs are supposed to impact foreign trade. The extent of the impact of travel time and costs is compared with other drivers of foreign trade like differences in GDP and labour productivity and is observed to be noticeable but limited compared with GDP and productivity influences. Furthermore, changes in freight travel times induce changes in potential output of an economy via total factor productivity. Again, the effect of freight travel times varies between 5 and 10% (country-specific value) of the total effects, which is limited compared with the other relevant impacts i.e. changes of labour productivity and sectoral investment.

Another part in the economic module in which impulses on transport costs are considered as influencing factors is the sectoral interweavement in terms of national input-output tables. The tables change dynamically with changing transport costs which is considered in ASTRA-EC.

All impacts from a non-completion of CNC on the economic system implemented in ASTRA- EC described above induce negative impulses on the economy. The only positive effect from the non-completion of whole CNC or single corridors is given by reduced public investments in infrastructure. Government expenditures decrease which induces less financial burden on public households of EU member states. Even if ASTRA-EC does not simulate the financial market itself, it assumes that increasing public debt in a member state leads to increasing interest rates which reduces private investments in the member state.

5.3 ASTRA model inputs and major assumptions

Collecting the economic and transport impulses of a non-completion of the Core TEN-T Network Corridors (CNC) as well as of the four further scenarios until 2030 required setting a number of assumptions. These assumptions were necessary in order to overcome or at least deal with gaps on the level of transport and economic impacts of a corridor.

In total, the amount of the requested monetary investments, the planned start and end of the project, the type of investment, the country investing the money and the mode or modes for which the investment was planned were allocated to the list of 2,679 projects provided by the European Commission. The basic assumptions for the investment inputs for ASTRA-EC from this database were the following:

- All projects that have been started in 2014 are supposed to be stopped in 2015 such that a delta of investments due to the non-completion starts with the year 2015. Of course this is a simplification made for analytical reasons due to the lack of detailed information about ongoing projects and their expectable completion dates.
- All projects that end after 2030 are not considered;
- In the case of availability of a full set of information, the total amount of investment was equally distributed over the whole duration of the project;
- For about 55% of the projects no or only a rough estimation about the timing was indicated. In case that only the estimated end of the construction was indicated, the duration was estimated by 11 years in case of a total investment sum higher than 500 Million Euro. In case that the total investments were between 50 and 500 Million Euro the duration was estimated by 6 years, for projects with less than 50 Mil-

lion investment costs two years were assumed as duration. For some projects only a rough estimation on the starting year was indicated (e.g. start before 2020). For these cases, a start two years before the indicated date was expected.

- For about 16% of the projects, no investment costs were estimated in the original list of projects/sections. The potential investment costs for these projects were not added and remained zero.
- In case of cross-border projects, the investment was allocated according to the plan to the neighbouring countries (e.g. investments for the Brenner Base tunnel were split among AT and IT while the investments for the Fehmarn Belt fixed link were allocated to DK by 100%).
- As the investment database does not include investments in the deployment of SESAR, the investments for SESAR were extracted from a study conducted for the SESAR Joint Undertaking[3] and distributed to the major European airports according to the numbers of their annual air passenger departures.

The different amount of EC funding of single projects were not implemented individually. The number of projects which in theory could be funded and the resulting potential funding significantly surmount the available funding sources. Therefore, the CNC investments were completely allocated towards state budgets of the involved member states. This could be refined in case that a prioritization of projects is made and more detailed information becomes available.

The impulses induced by increasing travel times and costs due to non-completion of planned CNC infrastructure and deployment of innovative technologies were estimated based on a list of travel time savings provided by the European Commission for a number of relations on the CNC. These travel time savings were assigned towards the NUTS1 zones affected by the new corridor via a delta. Additionally, further information about time savings of single projects or sections were collected via a desk research (see as an example Table 5), via the findings from the network-based modelling results for the CNC Baltic-Adriatic and the elaboration of available information from the list of investments. Table 5 should be read such that travel time on the link Karlsruhe-Basel without the TEN-T projects completed would increase from 69 minutes to 100 minutes, which constitues an increase of 45% that enters into the ASTRA-EC model as a fraction of delta time i.e. 0.45.

[3] SESAR Joint Undertaking (2011): Assessing the macroeconomic impact of SESAR.

Table 5: Time savings for selected CNC projects/sections

Section/Project	Corridor	Status	Time savings	Delta Time
Karlsruhe-Basel	Rhine-Alpine	Not completed	from 100' to 69'	0.45
Locarno-Lugano	Rhine-Alpine	Not completed	from 55' to 22'	1.50
Brenner Base Tunnel	Scandinavian-Mediterranean	Not completed	from 2h to 55'	1.18
Fehmarn Fixed Link	Scandinavian-Mediterranean	Not completed	from 4h30' to 2h40'	0.69
Gotthard Base Tunnel	Rhine-Alpine	Not completed	from 3h40' to 2h40'	0.38
München-Berlin (VDE 8)	Scandinavian-Mediterranean	Not completed	from 6h00' to 3h55'	0.53

In the case that no information about time savings could be found during the desk research, further information about growth of speed or shortening of distances were used as inputs for the estimation of travel time saving potentials of single projects or sections on the nine CNC. Based on the travel time savings for road and rail transport calculated for the Baltic-Adriatic corridor and the information of the single projects, an approximation of plausible ranges of travel time savings induced by infrastructure changes could be made. Hence, the following range of travel time savings was assumed in the case of lacking detailed information about travel time savings like in the case of some projects presented in Table 5:

- Travel time changes induced by an improvement of road capacity were estimated by a general improvement of travel times of 0.5% up to 3% for passenger cars and busses on the links covered by the nine corridors. A travel time reduction of 1% up to 5% was approximated for trucks in the case of additional terminals and an improvement of logistics being part of the CNC.
- In the case of the rail network, a travel time improvement of 20% was assumed following the assessment of ERTMS impacts in the ASSIST project (Kritzinger et al. 2013). A reduction of travel time from 22 hours to 18 hours for the relation between Rotterdam and Geneva was indicated in this assessment.
- The optimization of access to airports as well as improvements of logistics in the terminals were estimated by a time saving of 1% up to 5% for the respective airports on the two corridors.
- The impact of the River Information System (RIS) for travel times of inland waterways was assumed to be 10%.
- Investments in seaports and maritime terminals were estimated to induce travel time (loading and unloading time) savings by 1% to 5%.
- In the case of lacking information about the impacts on speed, capacity improvement, optimization of logistics processes, etc. the monetary level of investment was taken as an indicator for setting the travel time savings within the expected range.

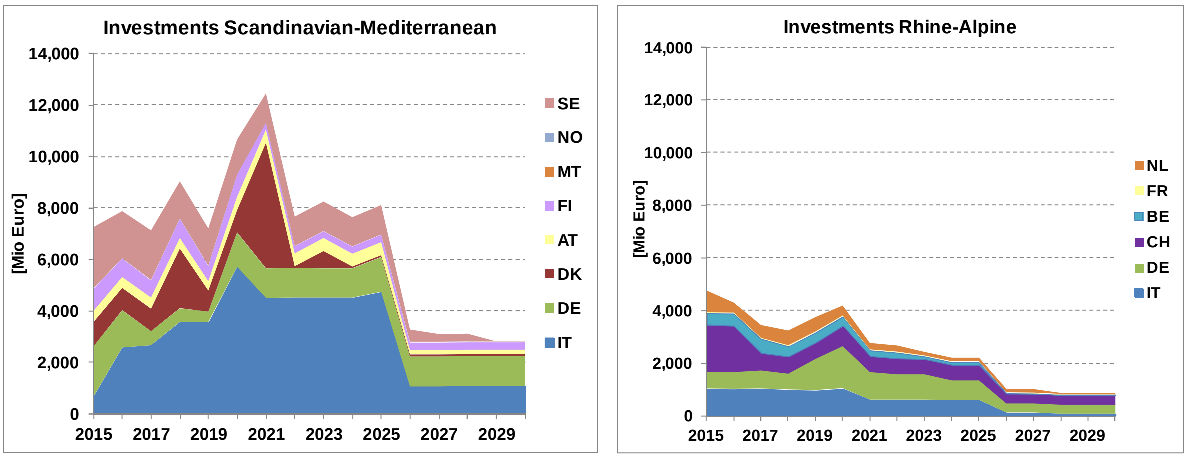
Finally, the travel time savings expected for each of the nine CNC and allocated to the 95 NUTS1 zones in EU27 were merged into travel time savings induced by the whole core TEN-T network. For this purpose, the expected transport demand for each corridor crossing a NUTS1 zone was taken as a weighting factor of the single travel time savings. An example for the necessity of this merging would be the crossing of the two North-South directed CNCs Rhine-Alpine and Scandinavian-Mediterranean with the East-West directed Mediterranean corridor in the Italian NUTS1 zone “ITC - North West”. In this case, three single travel time reductions were merged into a single number based on the expected travel demand per mode for each of the corridors.

5.4 Assessing the impact at corridor level – two test cases

5.4.1 Results of two corridors (Rhine-Alpine, Scan-Med)

The characteristics of the two TEN-T corridors analysed in the first step of the study via two separate test cases are important for evaluation of the impact assessment result. The Scandinavian-Mediterranean corridor (test case ScanMed) runs from Finland to Southern Italy stretching out to the ports of Malta and is as such far longer than the Rhine-Alpine corridor (test case RhAlp) which runs from the Netherlands to Northern Italy. The ScanMed is made up of projects in 7 EU member states plus Norway while RhAlp crosses 5 member states plus Switzerland. The projected investments in network infrastructure, in terminals as well as in the deployment with innovative technologies like ERTMS differ not only due to the length of the corridor but also due to the volume of the large projects on each corridor.

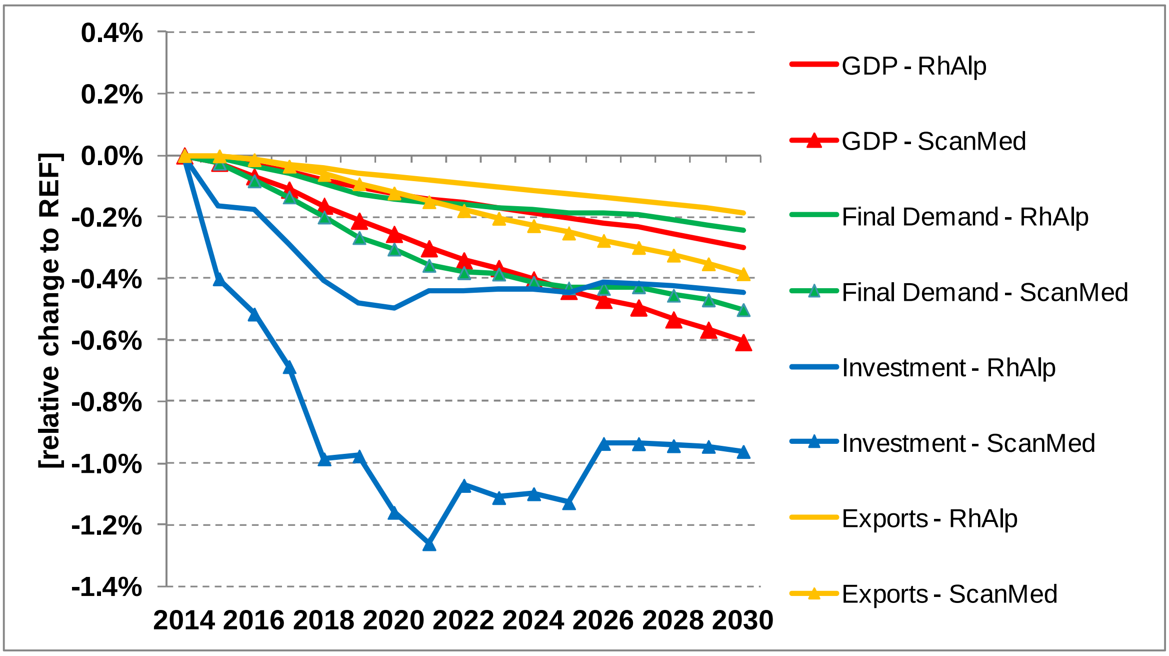
Figure 12 provides an overview on the pathway of investments for both corridors and for each member state based on the database developed in the first stage of this study. The investments in projects of the RhAlp account for € 40.5 billion between 2015 and 2030 (€ 29.2 billion for EU28) while the total amount of investment for projects in the *ScanMed* is with € 108 billion (for EU28) significantly higher (all monetary terms are expressed in constant $€_{2005}$). A high share of money invested in both corridors is planned for projects in Italy and Germany such that these two countries are significantly affected in both scenarios.



Source: own elaboration base on work plans

Figure 12: Investments per member state for both TEN-T corridors

The resulting wider economic impacts in case of a non-completion of each corridor separately on the whole EU27 are highlighted in Figure 13 in terms of relative change compared with the REF development. The set of investment, travel time and cost changes creates negative impulses on GDP of -0.3% for *RhAlp* and -0.6% for *ScanMed* until 2030. In absolute terms, the GDP decreases by € 48 billion in the case of non-completion of *RhAlp* until 2030 while it is by € 98 billion lower in case of the non-completion of *ScanMed* than in the REF scenario with full TEN-T network until 2030. Investments react via direct reduction and second-round effects via a decrease of -0.5% for *RhAlp* and -1% for *ScanMed* until 2030.



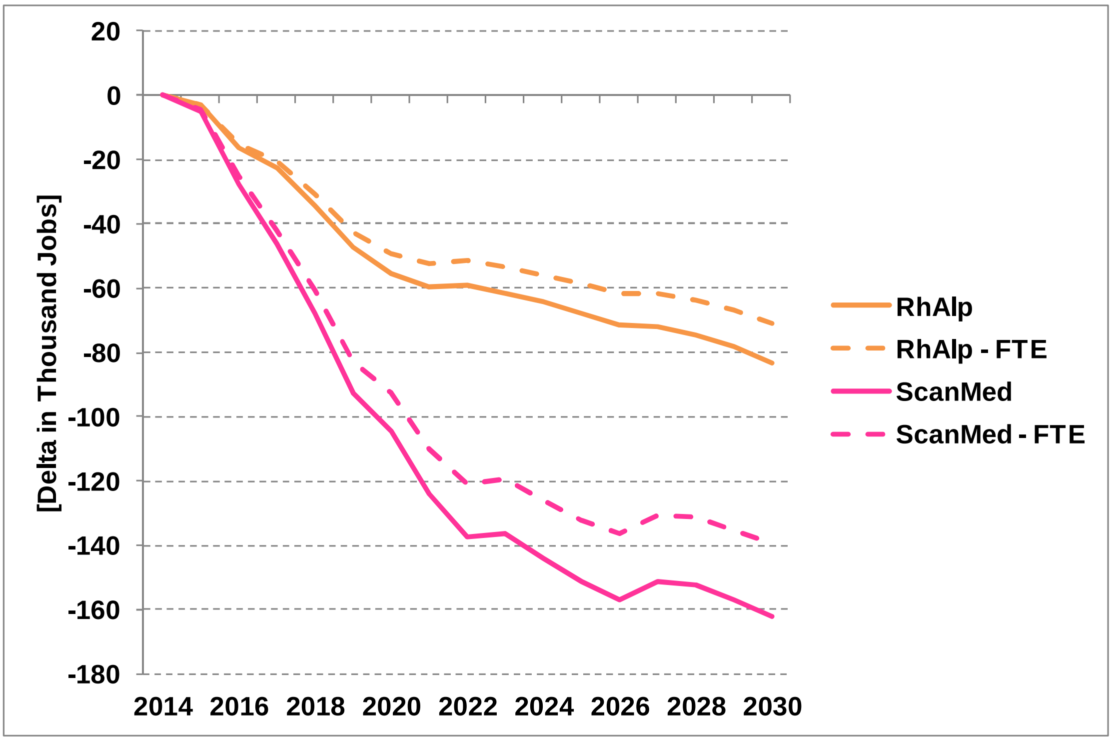
Source: own elaboration, ASTRA-EC model

Figure 13: Relative change of major economic indicators as compared with REF in EU27

The impact of travel time and cost increase induced by the non-completion does impact exports negatively but not as strong as GDP as a whole. ASTRA-EC assesses a downturn of exports within the EU of -0.2% for RhAlp and -0.4% for ScanMed. The influence of travel time and cost impacts on trade is not as strong weighted in ASTRA-EC as the impact of differences in labour productivity per sector and the GDP level of the trading partners. Hence, there is even a shift observable such that the loss of exports in countries tangled by the two corridors as compared with REF is partly substituted by slight increase of exports in countries of the EU not directly affected by the TEN-T projects of the corridors.

A non-completion of the two corridors is expected to have long-term negative impacts on EU27 labour market (see Figure 14). As compared with the REF scenario, ASTRA-EC assesses up to 83 thousand jobs less in the RhAlp scenario and even 162 thousand jobs less in the ScanMed scenario until 2030. Expressed in relative terms, this is equal to a decrease of -0.04% for RhAlp respectively -0.07% for ScanMed. Within the first five years after the start of the simulated failure of TEN-T policy for the two corridors, the loss of jobs is expected to be the steepest. This corresponds with the pathway of annual avoided investments in the single corridor projects until 2030.

ASTRA-EC considers in its calculation the split into full- and part-time employment. Especially sectors like Agriculture or Construction are supposed to have a higher share of part-time employed person than on average in the EU member states. Hence, the respective loss of jobs in full-time-equivalents (FTE) is noticeably smaller. A loss of 71 thousand FTE jobs is expected to be the result of the non-completion of the Rhine-Alpine corridor, while the failure of the Scandinavian-Mediterranean corridor leads to a decrease of 139 thousand FTE employed as compared with the REF scenario in 2030.

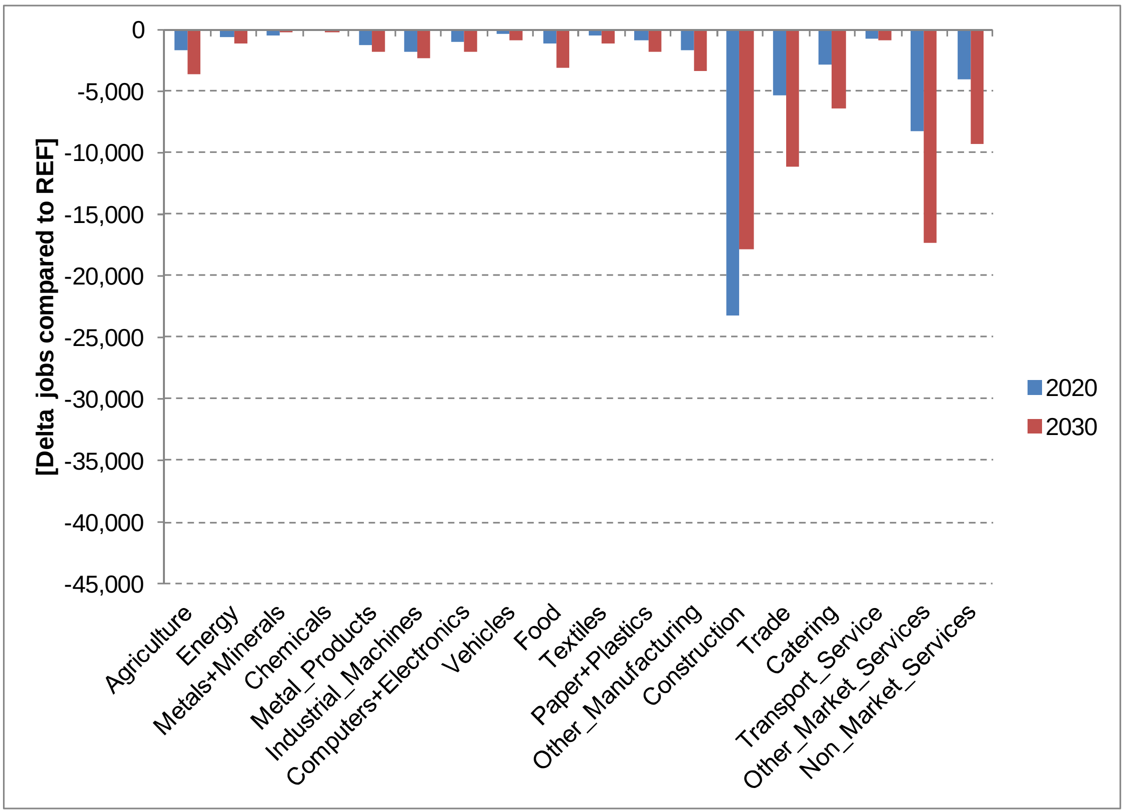


Source: own elaboration, ASTRA-EC model

Figure 14: Delta of jobs (total and full-time equivalent) in EU27 in RhAlp and ScanMed

Figure 15 and Figure 16 illustrate the impacts on the different economic sectors simulated in ASTRA-EC. For reasons of visibility, less significant affected sectors are clustered. So far, the lacking investments in TEN-T projects for the two corridors were supposed to be allocated by 100% to the economic sector Construction in ASTRA-EC. Therefore, the most significant impacts in terms of job losses occur in this sector. Nevertheless, also further sectors are directly affected by the non-completion of TEN-T infrastructure. A lower final demand in the sector Construction directly influences all sectors providing intermediate products and services to the Construction sector. ASTRA-EC takes this into account by simulating the amount of intermediate products from other sectors via national input-output tables. Therefore, direct effects of the lacking infrastructure cannot be directly identified by looking at the results of the construction sector.

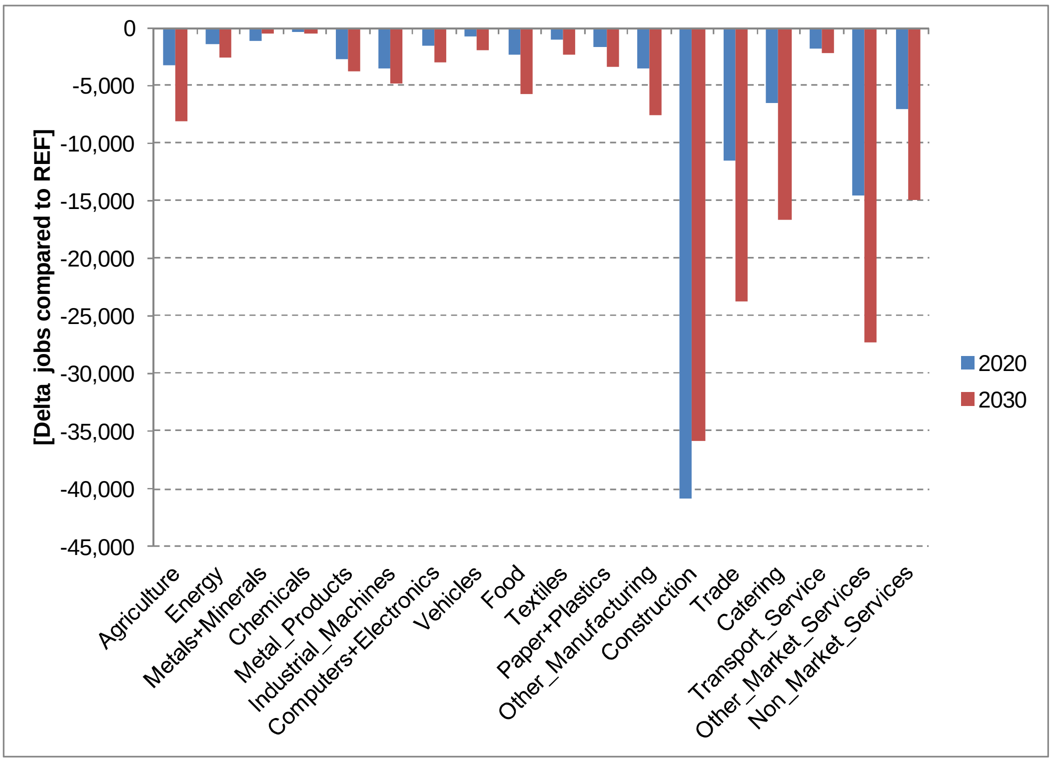
The structure of the job losses per sector shows for both scenarios, *RhAlp* and *ScanMed*, that besides the *Construction* sector also *Other* and *Non Market Services*, *Trade* and *Catering* (which includes tourism) are stronger affected by job losses as compared with the REF scenario.



Source: own elaboration, ASTRA-EC model

Figure 15: Delta of jobs per sector in EU27 in Rhine-Alpine corridor

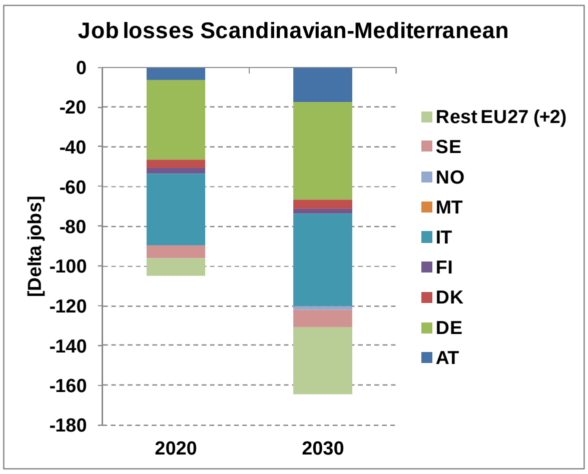
While for *RhAlp* about 18 thousand jobs are lost in the *Construction* sector, ASTRA-EC assesses about 36 thousand jobs to be lost in this sector in the *ScanMed* scenario. Addressing the lacking infrastructure not completely to the *Construction* sector would change the picture at least in the case of innovative technologies.

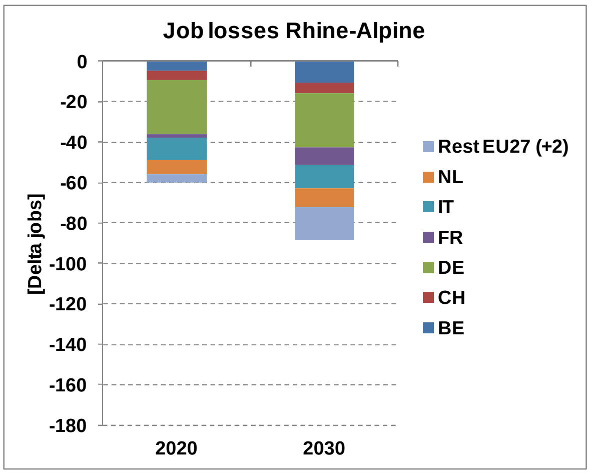


Source: own elaboration, ASTRA-EC model

Figure 16: Delta of jobs per sector in EU27 in Scandinavian-Mediterranean corridor

Due to the unequal distribution of investments for both corridors by EU member state, the impacts on employment differ significantly. Figure 17 provides an overview of the share on job losses for each member state directly affected by the respective corridor. Italy and Germany are supposed to be affected strongest by the non-completion of the two corridors. About 30% of the total jobs lost until 2030 are expected to hit the German labour market. The Italian labour market is strongest affected in the *ScanMed* scenario. ASTRA-EC calculates a share of about 28% on total jobs lost to occur in Italy.

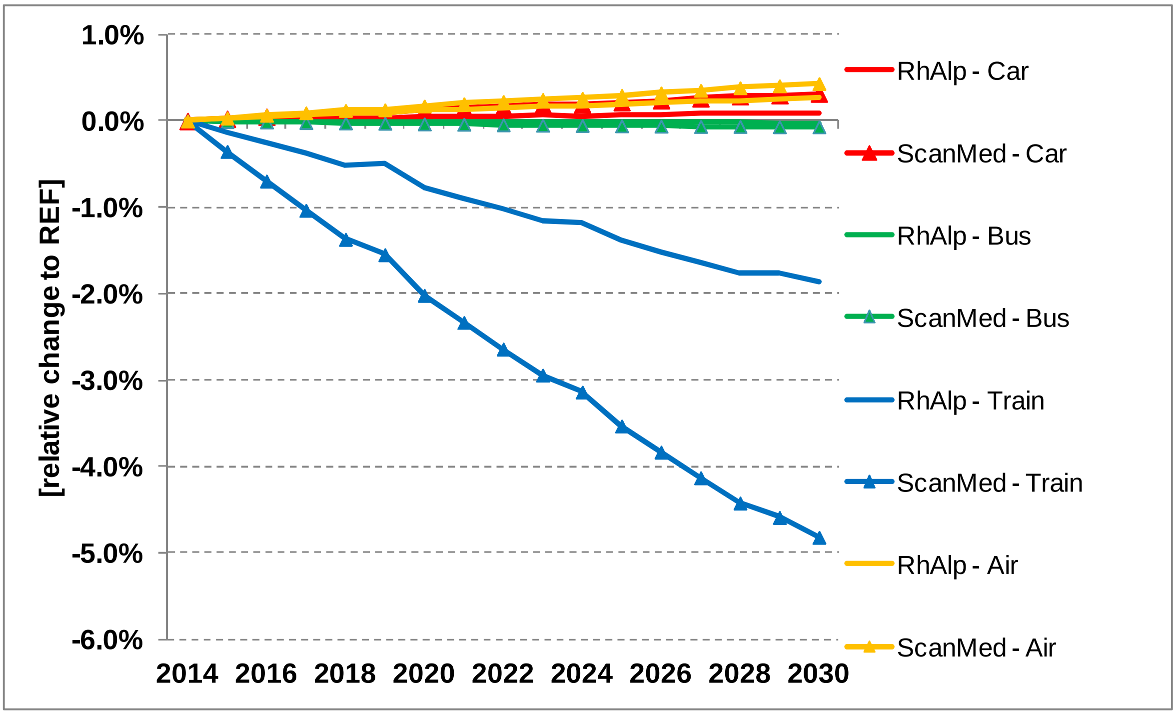




Source: own elaboration, ASTRA-EC model

Figure 17: Delta of jobs (total employment) per country for both corridors

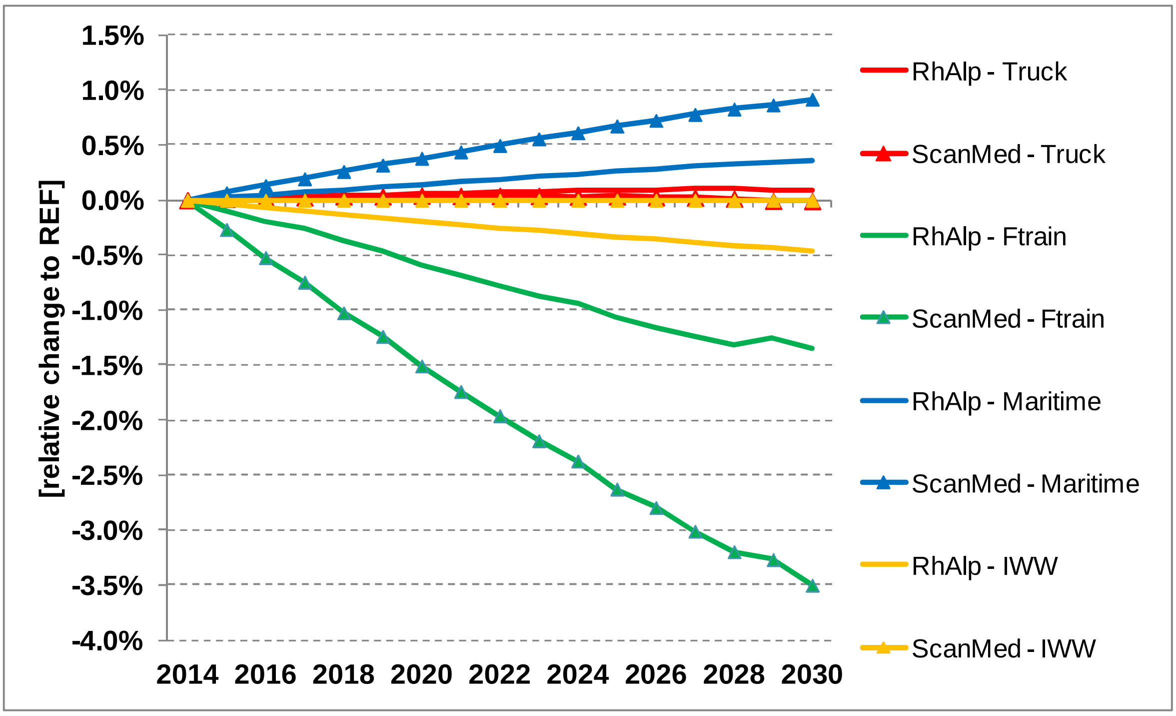
Simulating employment effects of transport policy with ASTRA-EC benefits from the consideration of all types of impacts: direct, indirect and second-round impacts. On the one hand, ASTRA-EC can help identifying the whole range of influences on labour markets. On the other hand, the share of the three types of impacts can only hardly be identified with ASTRA-EC. A straight-forward way of differentiating between direct and all other types of impacts would be to multiply the avoided investments in infrastructure and innovative technologies with country-specific labour productivities of the sector Construction. The result would be in the case of the two corridors that in the case of *RhAlp* about 49% of the job losses can be expected to be direct effects of non-completed infrastructure projects. For the *ScanMed* scenario, this approximation leads to a slightly higher share of 53% for direct impacts of the lacking investments.



Source: own elaboration, ASTRA-EC model

Figure 18: Relative change of passenger-km per mode in EU27 as compared with REF

Besides the impulses coming from avoided investments, travel time and cost impacts can be observed via changing transport performances for both, passenger and freight transport. Figure 18 and Figure 19 present the impacts of the non-completion on total passenger-km and ton-km travelled per year for EU27. Especially, the mode passenger and freight rail are affected negatively in the two scenarios due to the high proportion of investments into these modes in both TEN-T corridors. As regards the ScanMed corridor ASTRA-EC simulates a reduction of travel demand compared with REF of -4.9% for passenger rail while the impact on this mode is in the RhAlp case by -1.9% smaller but still negative. An effect for passenger and freight transport that is not desired as regards the targets of the EU to achieve a modal shift towards rail.



Source: own elaboration, ASTRA-EC model

Figure 19: Relative change of ton-km per mode in EU27 as compared with REF

5.4.2 Investment and travel time impacts of the other corridors

This section is providing an overview on the investment profile of the different CNCs and their individual impact on travel times in the affected regions. The values refer to the total investment made for each corridor as presented in Table 10 i.e. to the value of € 623 billion total investment into the CNC that includes investment prior to 2015.

Table 6 shows that the different CNC spend between 67% and 92% of their investment for networks, with an average of about 80% for this category of investment. The second most important category are the investments into tunnels with about 9% on average and a range from 0.3% and 16%. Terminals and innovations with on average about 4% also constitute important investment categories with the highest shares for terminals of about 9% in the Baltic-Adriatic corridor and for innovative technologies of about 6% in the Orient-East-Med corridor. Given that recent studies conclude that careful and reasonable planning of large transport projects is feasible and recommendable (Schade et al. 2014) the shares of budget planned for studies seems at the lower end, indicating that it should be carefully checked that larger investment projects are not facing the risk of insufficient planning.

Table 6: Split of investment of each CNC by type of investment

%	Baltic-Adriatic	Northsea-Baltic	Mediter-ranean	Orien-East-Med	Scandi-navian-Med	Rhine-Alpine	Atlantic	Northse-a-Med	Rhine-Danube
Networks	67.0%	87.9%	78.8%	79.9%	79.1%	92.5%	87.3%	76.0%	69.1%
Terminals	9.2%	1.8%	5.1%	4.4%	2.0%	0.7%	7.6%	7.1%	3.8%
Stations	4.6%	0.1%	1.2%	2.9%	0.2%	1.0%	0.1%	3.5%	13.7%
Bridges	0.9%	1.9%	0.1%	0.8%	0.8%	1.0%	0.0%	1.1%	1.7%
Tunnels	16.2%	2.5%	11.8%	5.8%	14.2%	1.3%	0.3%	10.5%	6.8%
Innovations	1.8%	5.6%	3.0%	6.1%	3.7%	3.3%	4.8%	1.6%	4.7%
Studies	0.2%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	0.1%	0.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Fraunhofer-ISI / EC elaboration building on the CNC workplans

Table 7 presents the distribution of investment categories between the 9 CNCs. Consuming 22% of the total investment budget the Scandinavian-Mediterranean corridor requires by far the highest investment. The share of close to 38% of all tunnel investments reflect that along this corridor some of the very large projects building tunnels are located, i.e. the Fehmarn-Belt Fixed Crossing and the Brenner Base Tunnel. Terminals are of particular importance for Baltic-Adriatic-, Atlantic- and Northsea-Mediterranean corridors that invest over-proportional in terminals compared with their share on total investment.

Table 7: Shares of investment of each corridor on the different types of investment

Share CNC on	Baltic-Adriatic	North-sea-Baltic	Medi-ter-ranean	Orien-East-Med	Scandi navian-Med	Rhine-Alpine	Atlantic	North-sea-Med	Rhine-Danube	Total
Networks	7.1%	9.4%	14.5%	6.9%	21.8%	11.8%	10.5%	10.3%	7.8%	100%
Terminals	18.0%	3.5%	17.3%	7.0%	10.0%	1.7%	16.8%	17.8%	7.9%	100%
Stations	15.5%	0.3%	6.9%	7.8%	1.6%	3.8%	0.3%	15.1%	48.7%	100%
Bridges	9.3%	19.1%	1.8%	6.2%	20.0%	11.5%	0.1%	14.2%	17.8%	100%
Tunnels	15.6%	2.5%	19.9%	4.6%	35.7%	1.5%	0.3%	13.0%	6.9%	100%
Innovations	4.2%	12.7%	12.0%	11.3%	22.0%	9.1%	12.4%	4.8%	11.5%	100%
Studies	13.1%	16.6%	0.6%	11.2%	4.1%	22.6%	1.7%	10.6%	19.6%	100%
Total	8.4%	8.5%	14.7%	6.9%	22.0%	10.2%	9.6%	10.8%	9.0%	100%

Source: Fraunhofer-ISI / EC elaboration building on the CNC workplans

Not implementing the CNC will lead to increases of travel times. These increases differ by mode as the investments are mode specific as well as they differ for passenger and freight transport of one mode, e.g. as terminals or stations mainly improve freight or passenger transport respectively. Table 8 presents the travel time increases for freight transport by mode in case of non-completion of the corridors. Presented are the ranges for all NUTS-I zones crossed by an individual CNC. This should be read as for instance, in the Northsea-Baltic corridor the affected NUTS-I zones would reveal freight travel time increases between 4% and 50% if the CNC would not be implemented. Comparing across modes shows that on average rail travel times are increasing most, whereas road travel time increases amount to one third of rail increases roughly. In a few cases, inland waterway transport is slowed down by a similar ratio as rail is, e.g. for the Baltic-Adriatic corridor. Maritime transport benefits by new and improved terminals at ports, better access to terminals and ports as well as improved ITS in ports and at the sea close to the ports.

Table 8: Range of increases of travel times in *NO CNC* scenario by corridor – freight transport

International Transport		**%-travel time increase in case of non-completion - range of all NUTS-I zones affected by a CNC**			
Freight travel time changes in 2030		**Rail**	**Truck**	**Maritime**	**IWW**
BAC	Baltic-Adriatic	1%-10.5%	1%-3%	3%-10%	3%-19%
NSB	Northsea-Baltic	4%-50%	2%-15%	1%-8%	3.5%-14%
MED	Mediterranean	3%-20%	1%-3%	1%-10%	2%-3%
OEM	Orient-East-Med	2%-20%	2%-20%	2%-10%	1%-19%
SCM	Scandinavian-Med	10% - 118%	5%-68%	5%	n.a.
RHA	Rhine-Alpine	20%-45%	5%	5%	10%
ATL	Atlantic	1%-20%	2%-7%	1%-5%	1%-2%
NSM	Northsea-Med	1%-25%	1%-6.5%	1%-8%	2%-14%
RHD	Rhine-Danube	5%-41%	1.5%-11%	2%-5%	5%-19%

Source: Fraunhofer-ISI / PTV elaboration building on the workplans, BAC from corridor study

Table 9 presents the travel time increases for passenger transport if the nine CNC would not be completed by 2030. Again rail transport is slowed down strongest. On average the impact on car transport seems slightly higher than for trucks, while for buses it is very similar to the effects on cars. Air transport is affected by worsened access conditions and time losses at terminals and by reduced runway capacity.

Table 9: Range of increases of travel times in *NO CNC* scenario by corridor – passenger transport

International Transport		%-travel time increase in case of non-completion - range of all NUTS-I zones affected by a CNC			
Passenger travel time changes in 2030		Rail	Car	Bus	Air
BAC	Baltic-Adriatic	1%-31%	1%-14%	1%-9%	1%-5%
NSB	Northsea-Baltic	3%-40%	2%-20%	1%-15%	2%-5%
MED	Mediterranean	1%-20%	1%-3%	1%-3%	1%-3%
OEM	Orient-East-Med	2%-20%	2%-20%	2%-20%	n.a.
SCM	Scandinavian-Med	10%-68%	3%-68%	3%-68%	5%-10%
RHA	Rhine-Alpine	20%-45%	3%	3%	5%
ATL	Atlantic	1%-12%	2%-6%	2%-6%	2%
NSM	Northsea-Med	1%-22%	1%-3.5%	1%-3.5%	1%-5%
RHD	Rhine-Danube	6%-33%	2%-11%	1%-11%	1%-5%

Source: Fraunhofer-ISI / PTV elaboration building on the workplans, BAC from corridor study

6 Assessing the impact at the level of all core network corridors (CNC)

6.1 Non-completion of the core network corridors of TEN-T

6.1.1 Investments to implement the nine CNC

This section focuses on the quantitative impact assessment results. From the economical point of view, the analysis of the single corridors Rhine-Alpine and Scandinavian-Mediterranean differs significantly in terms of the level of investments from the analysis of the impacts of a non-completion of the whole core TEN-T corridors (called *No CNC* scenario) until 2030. According to the most recent list of investments of the nine CNCs, the investments for 2,679 projects allocated to the core TEN-T network amount to € 623 billion[4] while the two mentioned corridors required only € 192 billion, i.e. less than one third. Nevertheless, the two corridors analysed as test cases can be considered to be important corridors, because of the level of travel demand along the corridors as well as the amount of investments in the case of the Scandinavian-Mediterranean corridor.

Table 10: Total and considered investments per CNC [Mio $Euro_{2005}$]

CNC	Total Investment	Investment 2015-2030
Atlantic	56,136	45,003
Baltic-Adriatic	52,784	37,366
Mediterranean	91,101	76,951
North Sea-Baltic	60,001	46,777
North Sea-Med	73,993	47,923
Orient/East Med	42,739	27,673
Rhine-Alpine**	61,203	42,869
Rhine-Danube	55,051	37,524
Scandinavian-Med	130,400	105,503
Total	***623,409***	***467,589***

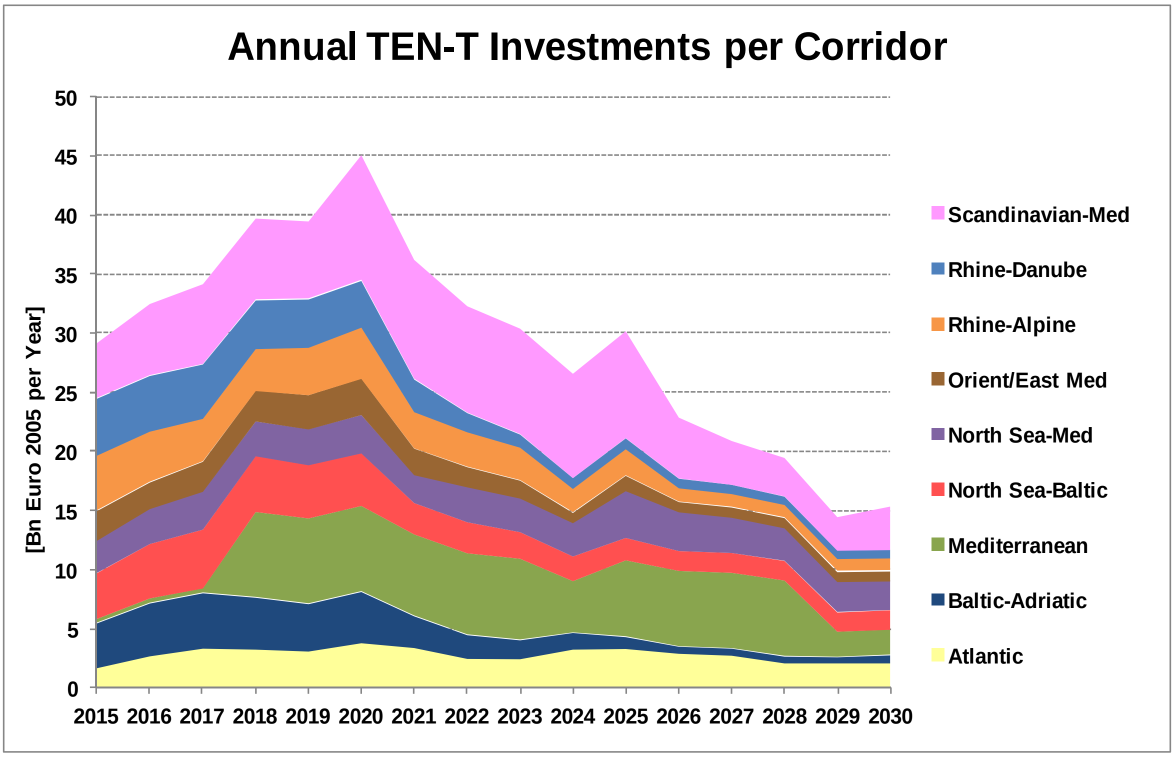
*** includes investments made by Switzerland* *Source: EC/Fraunhofer-ISI*

The analysis of the single projects in the list of investments revealed that investments of about € 33 billion have been accounted to two or more corridors. Hence, this sum was subtracted in order to eliminate the double-counting. Furthermore, the analysis with ASTRA-EC considers per definition only investments for projects between 2015 and 2030 such that the sum of avoided investments which are provided to ASTRA-EC as input are

4 All monetary values in ASTRA-EC are expressed in real terms as constant Euro 2005 using an EU27 deflator of 0.9016 for conversion from current to constant Euro 2005

by € 468 billion for EU28 plus Norway and Switzerland (€ 457 billion for EU28, € 454 billion for EU27) for this period significantly lower than the total sum of investment. Table 10 shows the total investments for each CNC and the remaining share of the investments within the period from 2015 and 2030 for EU28 plus Norway and Switzerland. As mentioned above, the Scandinavian-Mediterranean corridor is not only because of its length outstanding but mainly by its investments of € 106 billion for 2015 until 2030. The CNC Mediterranean follows with investments of € 77 billion for this period. All other corridors are expected to be in a range between € 28 billion (Orient/East Med) and € 48 billion (North Sea-Mediterranean).

Figure 20 presents the distribution of the CNC investments per corridor over time. The time pathway of investments between 2015 and 2030 shows that the largest share of investments is planned for the first period between 2015 and 2022. A high share of the projects that have been listed but without investment costs belong to the category of projects starting at a later stage. Hence, the real amount of investments could be higher for the last years. As regards the economic impact of avoided investments in the case of a non-completion of CNC until 2030, the timing of investments plays a significant role. The earlier the investments are made, the stronger the delayed second and third round effects can be as they are usually induced with a delay.



Source: EC/Fraunhofer-ISI

Figure 20: Development of annual TEN-T investments per CNC until 2030

ASTRA-EC calculates economic and employment impacts for each member state. Therefore, the distribution of investments between 2015 and 2030 per member state plays an important role (see Table 11). According to the list of investments provided by the EC in December 2014, about 20% of the total core investments (€ 95 billion) are made for core TEN-T corridors in Italy. Germany and France follow by 17% (€ 77 billion) respectively 16% (€ 73 billion) of the total CNC investments.

Besides the larger member states Italy, Germany and France, there are some other countries outstanding in the amount of investments planned for the CNC network between 2015 and 2030 – not in terms of the absolute level of investments planned, but in terms of the relation between average annual CNC investments and GDP (from the year 2013). This indicator highlights the importance of the level of the CNC investments for each member state (see Figure 21). Especially for the Eastern European EU member states the level of average annual investments reaches a significant share. In the case of Latvia the average annual CNC investments compared with GDP are by 1.7% the highest followed by Slovenia and Bulgaria. The share of average annual CNC investments on GDP is for all EU15 member states below 0.5%. Remarkable is the low level of CNC investments planned for UK even if only one corridor crosses UK[5].

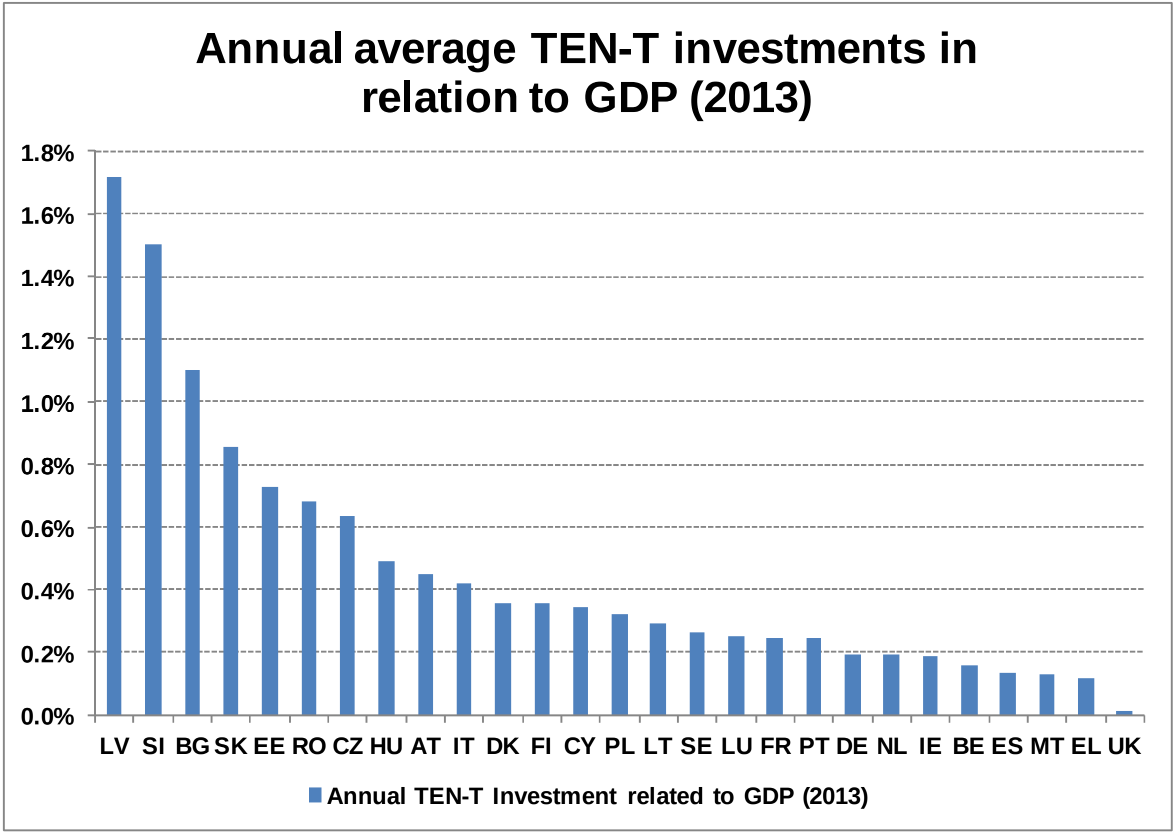
Table 11: Avoided investments per member state for *No CNC* [Mio Euro$_{2005}$]

MS	2015-2020	2021-2025	2026-2030	MS	2015-2020	2021-2025	2026-2030
AT	10,813	7,336	2,201	IE	945	1,865	1,639
BE	6,335	2,410	53	IT	34,580	42,037	18,036
BG	3,112	1,884	1,335	LT	1,413	49	0
CY	558	259	0	LU	1,441	202	0
CZ	9,184	4,338	156	LV	3,958	1,322	516
DE	35,431	24,079	17,546	MT	137	0	0
DK	5,897	4,330	2,656	NL	10,659	4,958	1,294
EE	755	597	597	PL	15,179	2,091	771
EL	1,336	861	931	PT	3,240	1,445	1,158
ES	8,739	6,323	4,524	RO	9,420	2,807	1,778
FI	5,055	3,171	1,770	SE	8,460	5,900	1,559
FR	19,402	25,718	28,328	SI	2,899	2,809	1,932
HU	4,435	1,977	516	SK	7,779	1,110	0
HR	1,157	1,539	620	UK	2,313	762	518

Source: EC/Fraunhofer-ISI

5 The reason for the comparably low level of CNC investments in UK is that the list of investments does not consider large investments in high-speed railway (HS2).

As explained in the methodological chapter the type of CNC investment influences the economic sectors in a different way. The highest share of CNC investments is planned for building new or upgrading railway tracks, motorways and inland waterways. About 76% of all planned CNC investments can be allocated to this type of infrastructure. 11% is planned for tunnel construction, 5% for new terminals (seaports and airports as well as multimodal platforms and hubs), 4% for innovative technologies, 2% for stations, 1% for bridge construction and 0.1% for studies.



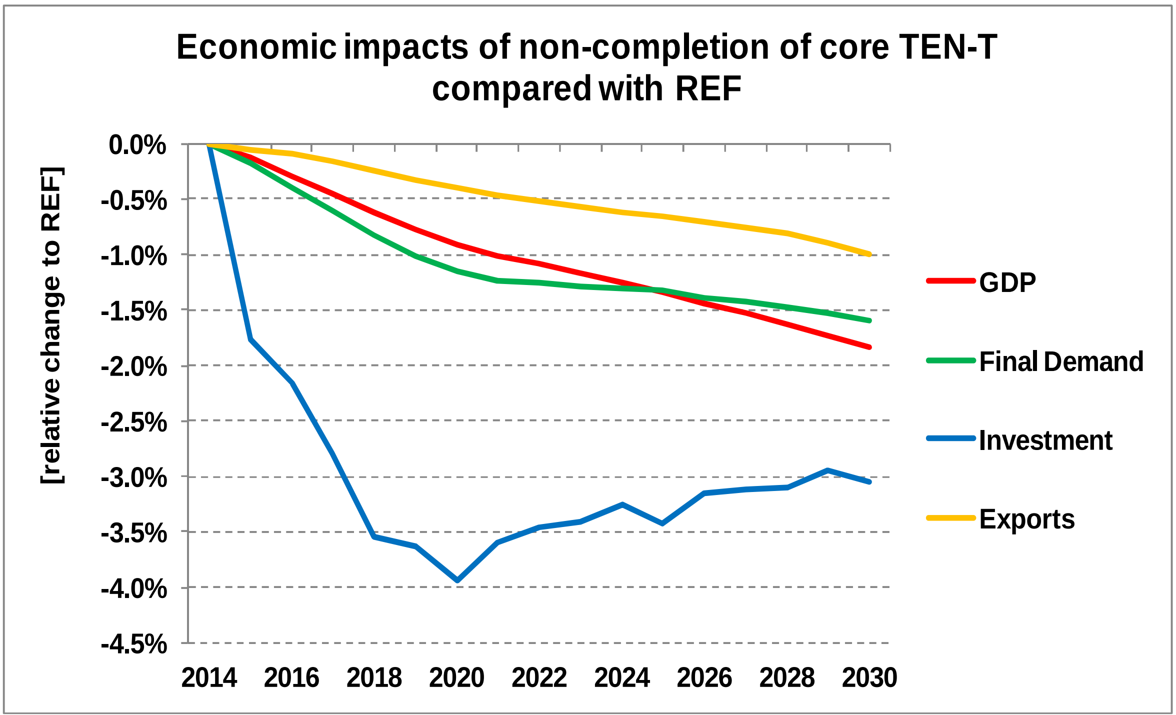
Source: Fraunhofer-ISI

Figure 21: Annual average CNC investments in relation to GDP (for the year 2013)

6.1.2 Wider economic impacts of non completion of the nine CNC

The resulting wider economic impacts for the *No CNC* scenario for EU27 between 2015 and 2030 are highlighted in Figure 22 in terms of relative change compared with the *Reference Scenario* (REF) development (see chapter 5.2). The set of avoided CNC infrastructure investments, not realized travel time and cost improvements creates negative impulses on GDP of -1.8% as compared with REF in the year 2030. In absolute terms GDP is expected to decrease by € 294 billion for *No CNC* compared with the REF scenario in 2030 (Figure 23). Accumulating the annual losses of GDP for EU27 between 2015 and 2030 as compared with the REF scenario would amount to about € 2,570 billion. In terms of average annual percentage growth of GDP for EU27 the non-completion of CNC would lead to a decrease of -0.1 percentage points for the period between 2015 to 2030.

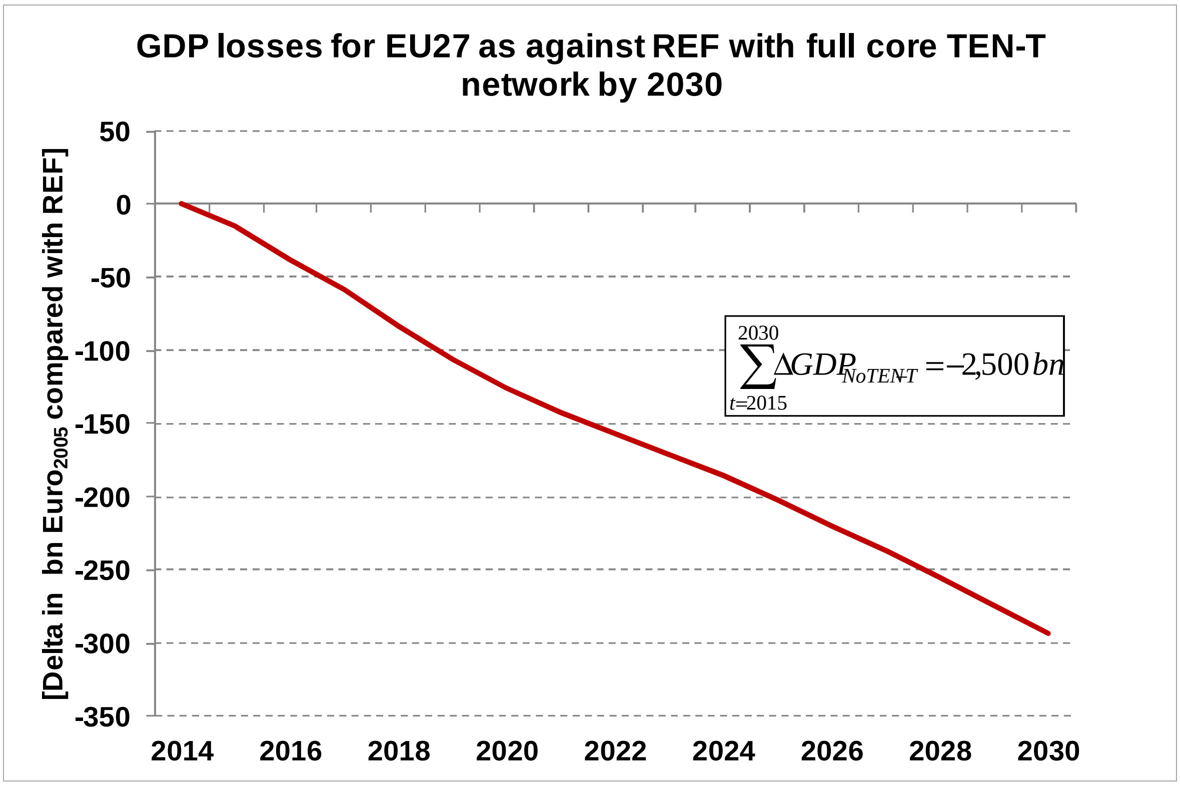
The pathway of investments changes by direct reduction of investments and second-round effects and leads to a decrease of -3.1% in the year 2030 as compared with the *Reference Scenario*. Due to the timing of avoided investments (see Figure 20), the highest impact on investments is assumed to take place around 2020.



Source: Fraunhofer-ISI

Figure 22: Relative change of major economic indicators as compared with REF in EU27

The impact of travel time and cost increase induced by the non-completion does impact exports negatively but not as strong as GDP as a whole. The simulation with ASTRA-EC shows a downturn of exports within the EU reaching -1% in the year 2030 for EU27. The influence of travel time and cost impacts on trade is not as strong weighted in ASTRA-EC as the impact of differences in labour productivity per sector and the GDP level of the trading partners. Partly, there is even a slight shift observable such that the loss of exports in countries more affected by the non-completion of CNC until 2030 as compared with REF is partly substituted by slight increase of exports in member states not as strongly affected by the non-completion.

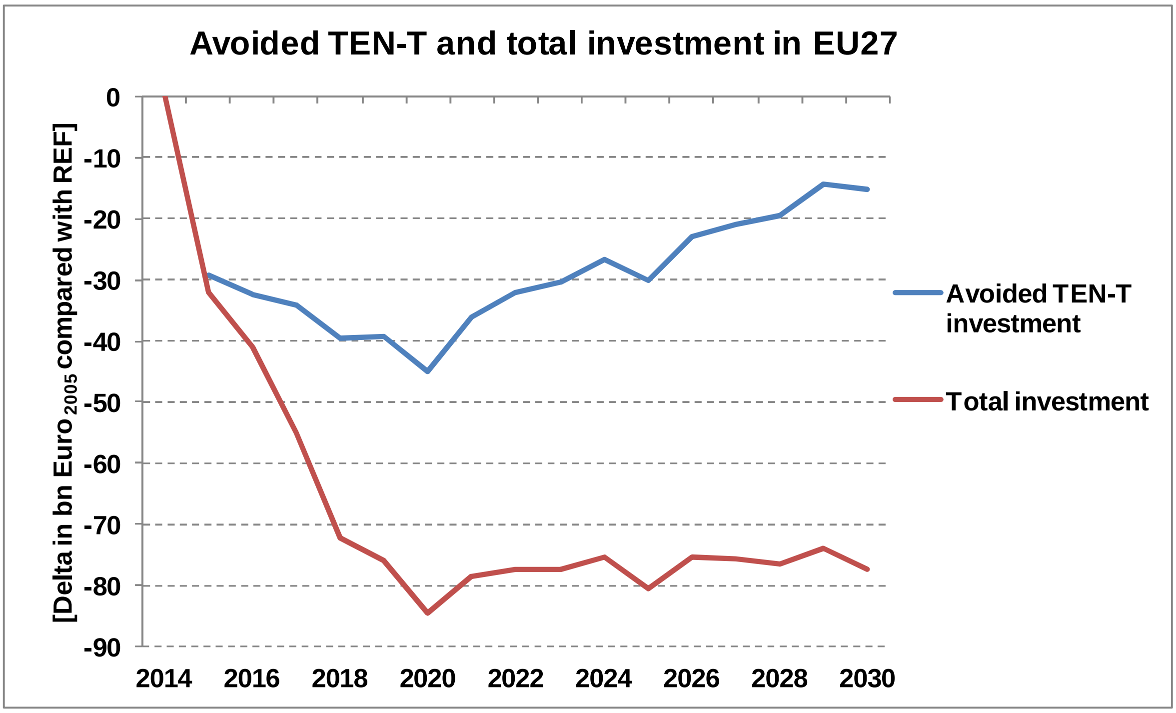


Source: Fraunhofer-ISI

Figure 23: Annual and accumulated loss of GDP as compared with REF in EU27

Such a result of significant impacts of the core TEN-T confirms what other studies argue about the substantial impact that transport could have on the rate of GDP growth. For instance, the so-called Eddington transport study expects that transport via improving productivity accelerates the rate of GDP growth (Eddington 2006). This link between transport, productivity and GDP is actually part of the ASTRA-EC modelling approach.

Figure 24 presents the difference between the avoided CNC investments for EU27 between 2015 and 2030 and the resulting difference in total investments compared with REF. While in 2015, both values are the same, the indirect and second round effects of transport and economic impacts lead to a spread of both curves. Until 2020, ASTRA-EC assesses a decrease of total investments to be nearly double as high as the exogenous input of avoided CNC investments.

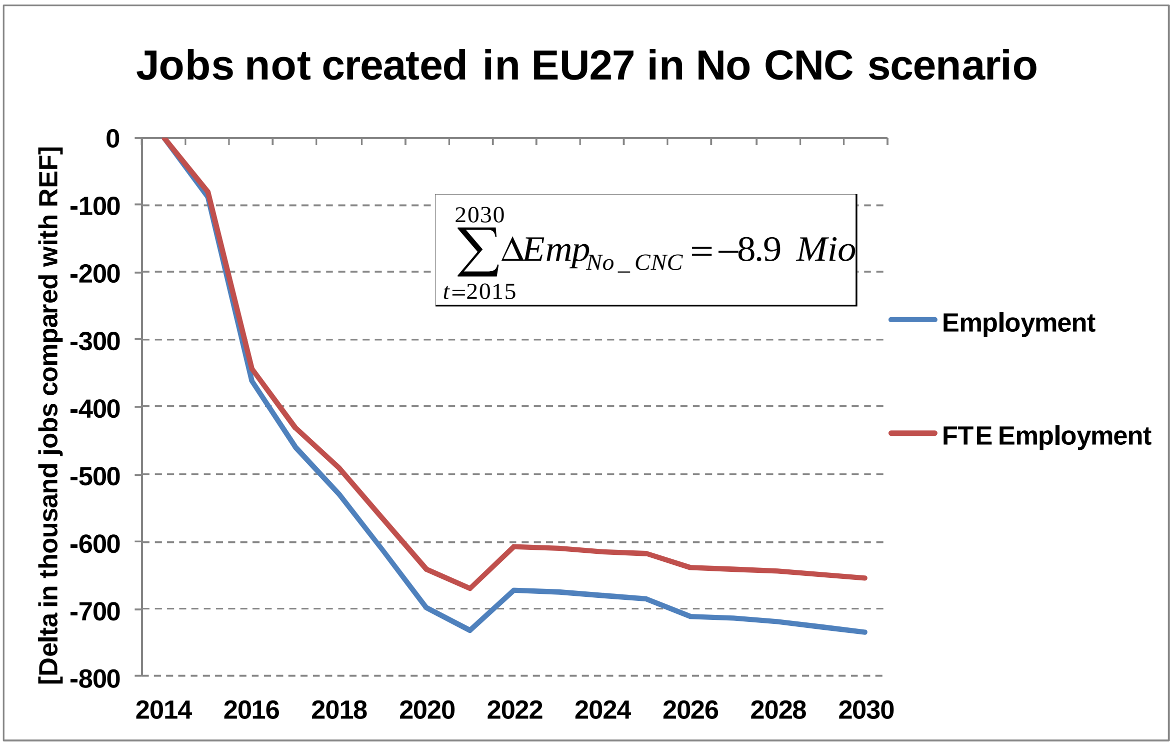


Source: Fraunhofer-ISI

Figure 24: Avoided CNC investment and resulting total investment effect in EU27

Figure 25 shows the assessment results on the impacts of the *No CNC* scenario on the EU27 labour market. A non-completion of CNC is expected to have long-term negative impacts. As compared with the REF scenario ASTRA-EC assesses up to 733 thousand jobs[6] less created in 2030 or expressed in relative terms a decrease of -0.3%. The climax of jobs lost is reached within the first five years after the start of the simulated non-completion of core TEN-T. This development corresponds with the pathway of annual avoided investments until 2030. The delay in the reaction between the start of TEN-T investments not realised and the impacts on the labour market is less than a year such that the direct impacts of lacking investments translates into the steep decrease of employment compared with the REF scenario.

6 The number of jobs considers full-time and part time jobs accounted both as 1 job.

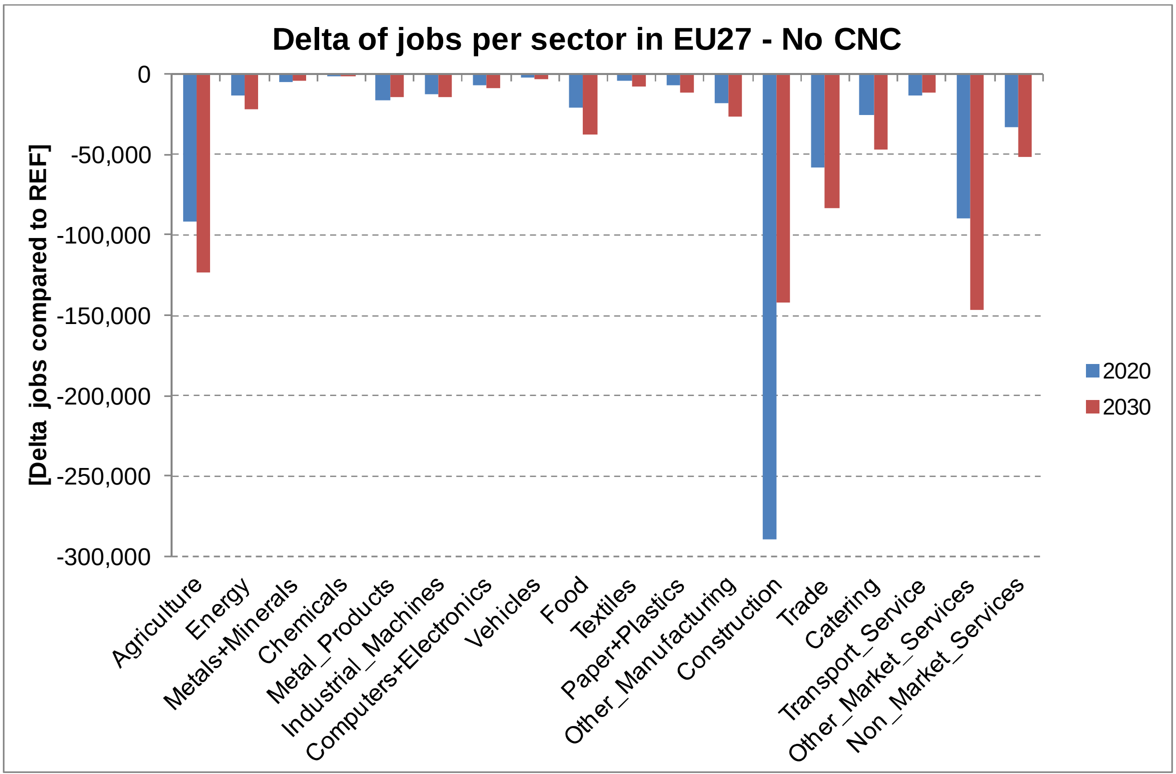


Source: Fraunhofer-ISI

Figure 25: Delta of jobs (total and full-time equivalent) and in EU27 in NO CNC

Besides total employment, ASTRA-EC considers in its calculation a split into full- and part-time employment. The share of part-time employment differs significantly between the 25 economic sectors in ASTRA-EC. Sectors like Agriculture or Construction are supposed to have a higher share of part-time employed persons than on average in the EU member states. Hence, the respective loss of jobs in full-time-equivalents (FTE) is noticeably smaller. A loss of 655 thousand FTE jobs is expected to be the result of *No CNC* for the year 2030. As for wider economic impacts the pathway between 2015 and 2030 plays a role. Therefore, the accumulation of impacts needs to be taken into account as well. The simulation of the *No CNC* scenario with ASTRA-EC leads to an accumulation of annual job losses between 2015 and 2030 for EU27 of about 9.8 million or in terms of full-time-equivalent employment 8.9 million.

The calculation of the economic impacts of a non-completion of the two CNC Scandinavian-Mediterranean and Rhine-Alpine was based on the assumption that all avoided infrastructure investments are assigned to the sector *Construction*. The new revision of ASTRA-EC goes beyond this initial assumption such that the avoided investments are distributed over six economic sectors. The baseline for this distribution is the allocation of the investments into seven categories as described in chapter 5.2. Besides for the categories Innovation and Study, the highest share of avoided investments still belongs to the *Construction* sector. Figure 26 presents the impacts of a non-completion CNC on the different economic sectors simulated in ASTRA-EC. For reasons of visibility, less significant affected sectors are clustered. The differences of jobs per sector reflects the direct impacts of avoided investments and as a direct consequence decreasing gross value added but as well the indirect effects from omitted travel time and cost savings and resulting economic second round effects. A further spread of impacts over all economic sectors takes place via the sectoral interweavement. A reduction of final use in the *Construction* sector leads to decreasing demand for intermediate products and services simulated via input-output tables in ASTRA-EC.



Source: Fraunhofer-ISI

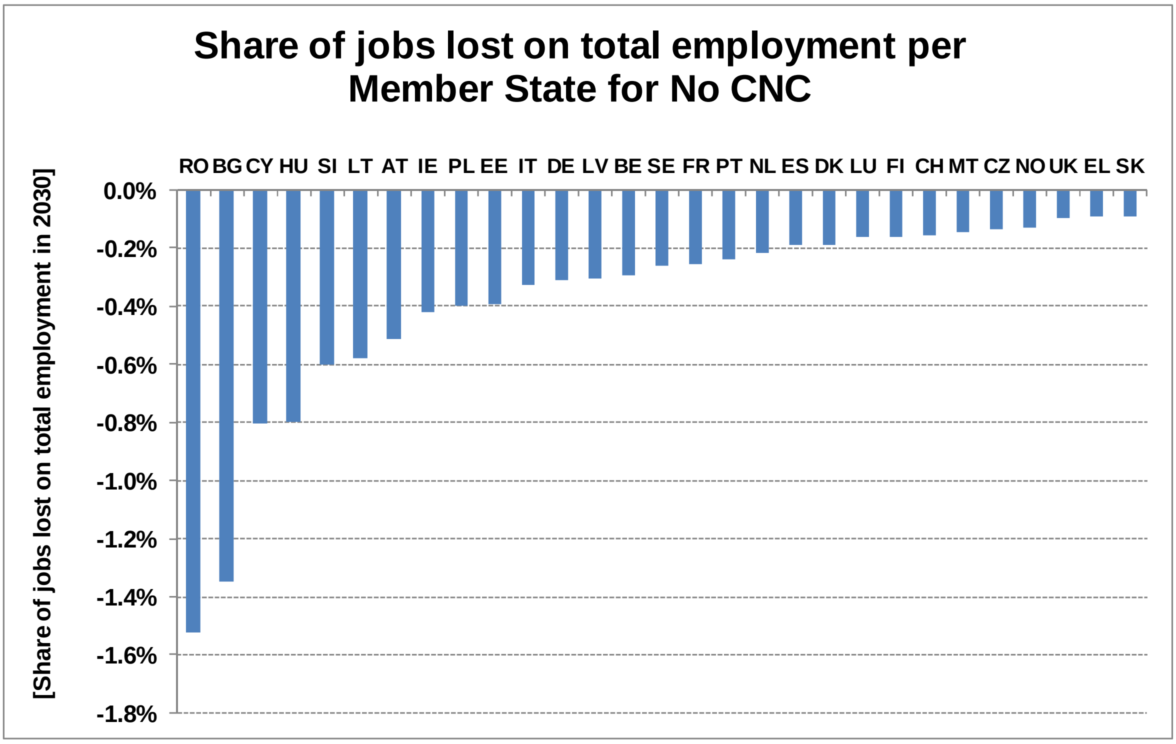
Figure 26: Number of jobs not created per sector in EU27 for *No CNC* as compared with REF

Besides the Construction sector also Other Market Services, Trade, Non Market Services, Catering (which includes tourism) and Agriculture sectors are stronger affected by job losses as compared with the REF scenario in the year 2020 and 2030. At first sight the strong impact of *No CNC* on employment in the Agriculture sector and the small impact on the Transport Service sector seems to be astonishing. The loss of jobs in the Agriculture sector is a second round effect of a decreasing GDP and final demand distributed on all economic sectors. The level of the job impact is a result of the comparably low labour productivity and the high share of part-time employed people in this sector. Labour productivity in the sector Agriculture is in most EU member states significantly lower than the sector with the second lowest labour productivity. As an indirect impact of the CNC impulses, gross value added does not only change in sectors directly affected but in all economic sectors via the input-output tables. Therefore, resulting changes in gross value added (GVA) directly lead to a change of full-time equivalent employment. Even if the impact on GVA is significantly higher for the economic sectors directly affected by the non-completion of CNC (e.g. Construction), the lower impact on GVA in the Agriculture sector results in comparably high number of jobs not created in the Agriculture sector. As ASTRA-EC derives full-time and part-time employment with a fixed share per sector the impact on the total number of jobs (not full-time-equivalent) is even stronger. Employment in the Agriculture sector in EU27 is expected to decrease by -0.7% as against the REF which is significantly higher than the change of total employment in all sectors (-0.3%). Gross value added in the Agriculture sector changes by -1.2% which is exactly the average over all economic sectors. Increasing the growth of labour productivity especially in the sector Agriculture for still underperforming countries like Bulgaria or Romania already in the REF scenario would lead to less strong employment impacts on these sectors. Nevertheless, the growth rates for labour productivity in the REF scenario between 2015 and 2050 are derived from the 2012 Ageing Report which corresponds with the EC *Reference Scenario* from 2013. Therefore, this change has not been made for the analysis of a non-completion of CNC.

The moderate impact on employment in the transport service sector is mainly a result of a modal shift induced by the different level of non-completion of infrastructure investments and resulting time and cost changes for the transport modes. More than 65% of the total planned investments for the CNC between 2015 and 2030 are assigned to railways. The reaction of the transport model is a modal shift, both for passenger and freight transport from rail towards the less affected modes road and maritime transport. Labour productivity in the road transport sector differs from the rail sector which has a higher labour productivity. Therefore, the loss of jobs in the rail sector is supposed to be nearly compensated by the slight increase in the road sector induced by the modal shift.

Due to the unequal distribution of CNC investments by EU member state (see Table 11) and the strong difference of labour productivity among the member states, the impacts on employment varies significantly between the member states. Figure 27 provides an overview of the share on job losses for each member state related to the total employment per member state. The comparably low level of labour productivity in those sectors directly affected in countries like Romania and Bulgaria leads to stronger impacts on these labour markets. As an example the labour productivity in the sector Construction is supposed to be by 55% higher in Germany by than in Romania in 2030. ASTRA-EC assesses that a non-completion of CNC will decrease total employment in Romania by -1.5% respectively by -1.3% in Bulgaria in 2030. In absolute terms of number of jobs lost, Germany, Italy, France, Romania and Poland are expected to be affected strongest by *No CNC* in year 2030. About 60% of the total jobs not created concern the labour markets in these five countries.

An important issue that cannot be simulated with ASTRA-EC is the potential distribution of construction works for the core TEN-T projects among foreign companies. Especially for complex construction works like in the case of large tunnels or bridges, not all member states have a domestic company specialized in these fields. Hence, at least the simulated impact on jobs not created in the Construction sector on member state level could differ in reality.

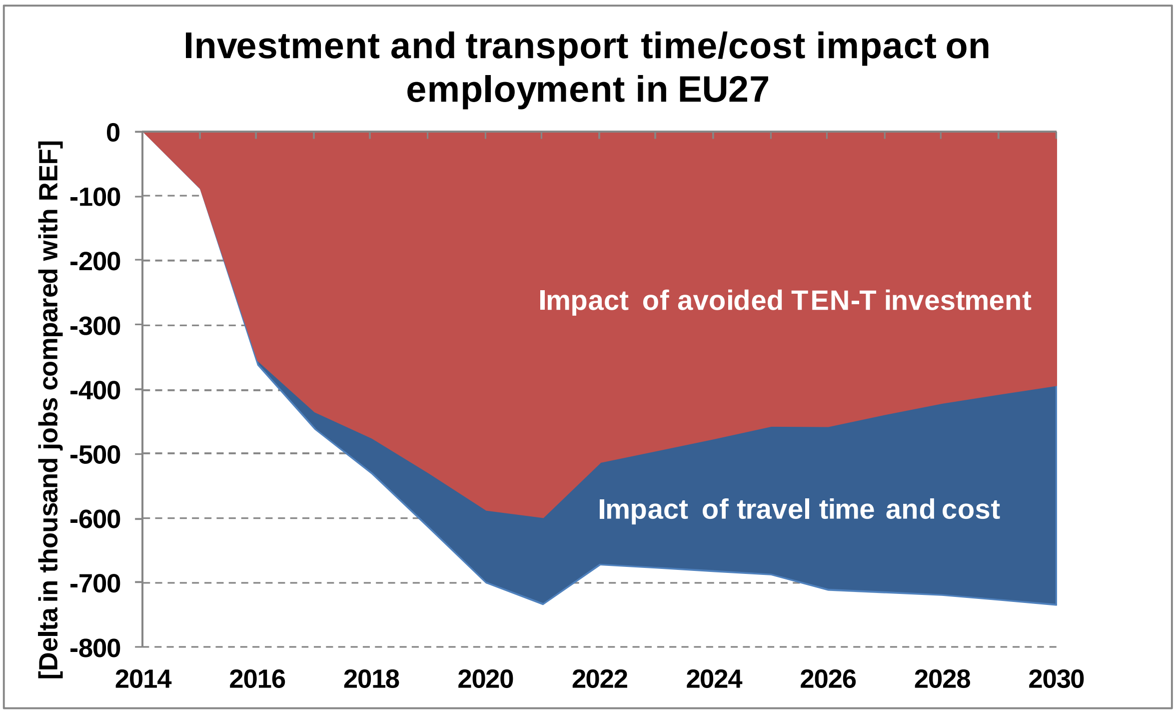


Source: Fraunhofer-ISI

Figure 27: Share of jobs lost on total employment (not FTE) per country for *No CNC* in 2030

Overall, the simulation of employment effects of TEN-T policy with ASTRA-EC benefits from the consideration of all types of impacts: direct, indirect and second-round impacts. On the one hand, ASTRA-EC can help identifying the whole range of influences on labour markets. On the other hand, the share of the three types of impacts can only hardly be quantified separately with ASTRA-EC. Nevertheless, ASTRA-EC allows switching off the impacts of travel time and travel costs on jobs from the non-completion of CNC in EU27 until 2030. Figure 28 illustrates the decomposition into the two major input types. While the direct impacts of avoided investment appear strongly in the first years, the total impact of travel time and cost changes reaches its climax in 2030. In 2020, the avoided CNC investments are by more than 80% responsible for the resulting number of jobs not created as against the REF scenario. In 2030, the impacts of not achieving travel time and cost reduction for the *No CNC* scenario are supposed to reach nearly 50% of the total impacts on jobs.

Having a look at the outcome of the two test cases of TEN-T corridors allows a first interpretation of the relevance of single corridors as regards the employment impacts. While the analysis of the impacts of a non-completion of the Scandinavian-Mediterranean and the Rhine-Alpine corridor in sum led to about 246 thousand jobs not created in EU27 in the year 2030 (or 210 thousand full-time equivalent jobs) as against the REF scenario, the non-completion of the whole CNC is expected to reduce employment by 733 thousand jobs in 2030 (or 655 thousand full-time equivalent jobs). Taking the impact on full-time equivalent job years in relation to the avoided investments, the job impacts are lower for the first two corridors than for the average of the nine corridors. Expressed in number of FTE-job years not created per bn € not invested in CNC the analysis of the two corridors revealed a range between 14,700 FTE-job years not created per bn € avoided CNC investments in the case of the CNC Scandinavian-Mediterranean in EU27 and 25,900 FTE-job years not created per bn € avoided investments for Rhine-Alpine. For the whole CNC, at 19,600 FTE-job years not created per bn € avoided investments expected, the effect is slightly higher than for the CNC Rhine -Alpine. The calculation considers the accumulated number of full-time-equivalent jobs not created as against the REF in the year 2030 and the accumulated annual avoided investments in CNC projects between 2015 and 2030. The stronger impact of the whole CNC on number of jobs is mainly a result of those CNC which include projects in countries with lower labour productivity like some Eastern European member states. The rather strong job impact of the CNC Rhine-Alpine is a result of comparably low investments and high transport demand, both for passenger and freight transport.

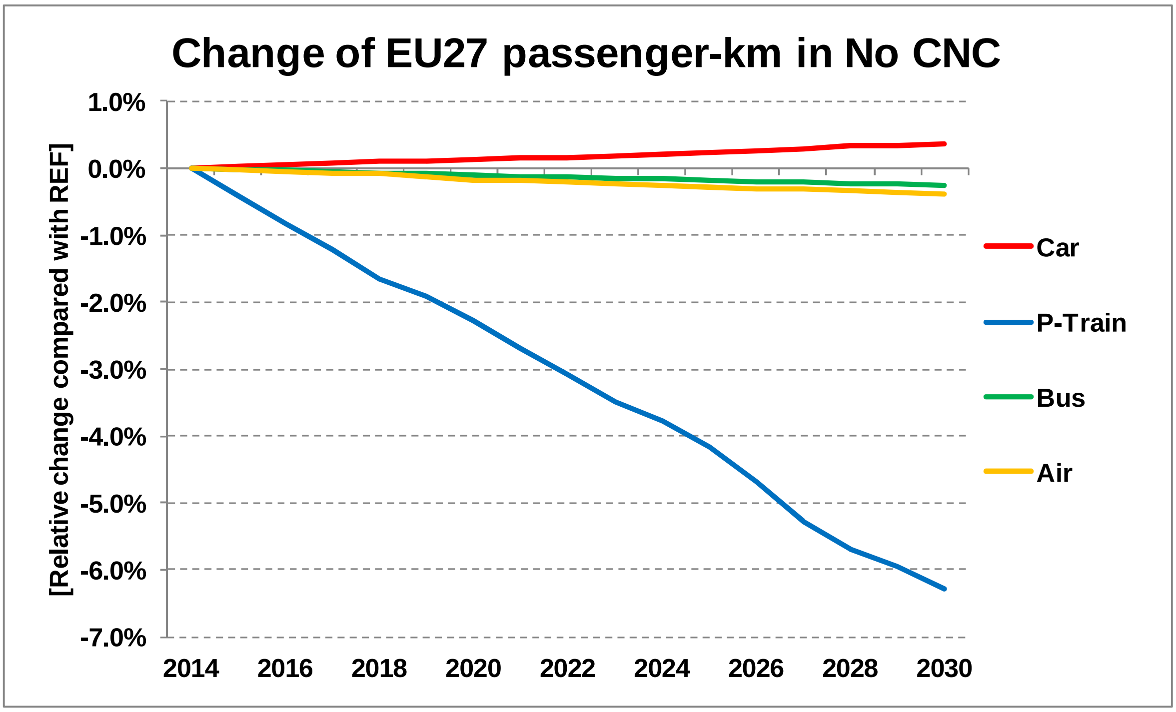


Source: Fraunhofer-ISI

Figure 28: Decomposition of investment and transport time/cost impacts on jobs (not FTE) in EU27

6.1.3 Transport impacts of non-completion of nine CNC

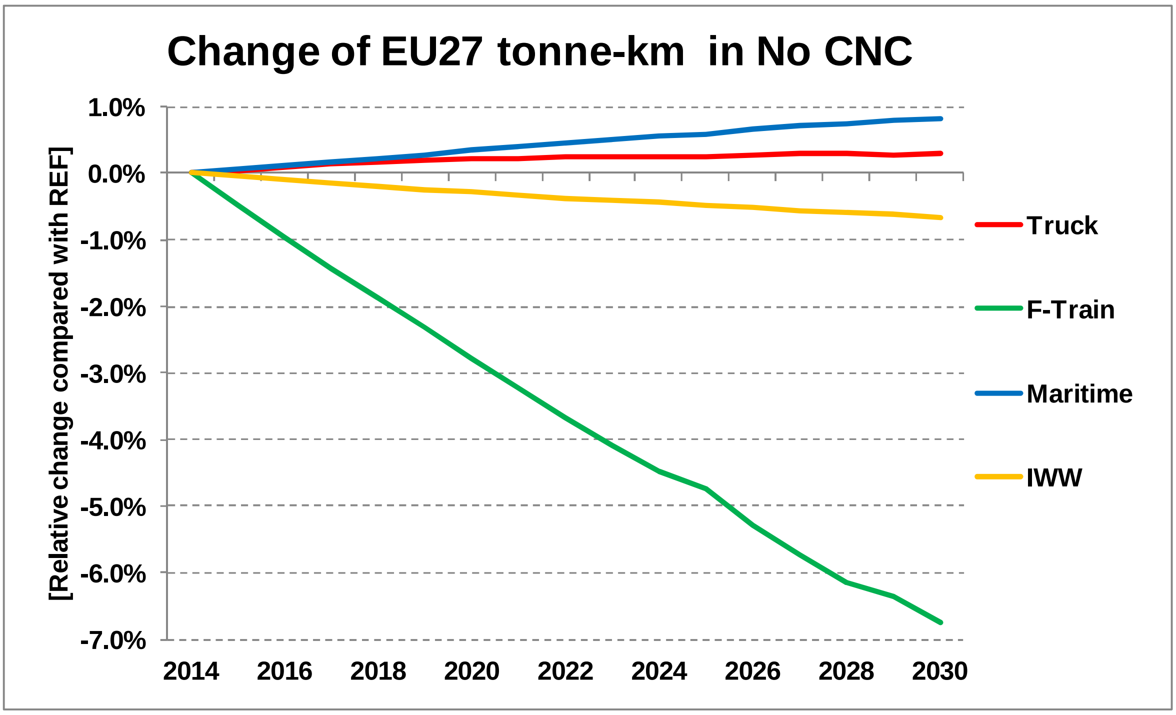
Besides the impulses coming from avoided investments, travel time and cost impacts can be observed via changing transport performances for both, passenger and freight transport. Figure 29 and Figure 30 present the impacts of *No CNC* on total passenger-km and tonne-km travelled per mode for EU27. ASTRA-EC calculates about -0.3% less passenger-km in EU27 in the year 2030 as against the REF with full core TEN-T network. Freight transport is affected similarly by -0.3% in terms of ton-km.



Source: Fraunhofer-ISI

Figure 29: Relative change of passenger-km per mode in EU27 as compared with REF

Especially the mode passenger and freight rail are affected negatively by *No CNC* due to the high proportion of investments into these modes. ASTRA-EC simulates a reduction of travel demand compared with REF in 2030 of about -6.3% for passenger rail. Tonne-km transported by rail freight is supposed to be by -6.7% lower in 2030 than in the REF scenario. Despite the lower investments in all modes, transport performance is not affected negatively for all modes by a non-completion of CNC. As for passenger and freight transport, the lower share of investments into road networks and the resulting lower negative impact on travel time and costs leads to an opposite effect. The modal share of road increases as compared with REF (by +0.4% for car and +0.3% for truck). The resulting effect for passenger and freight transport would counteract the targets of the EU to achieve a modal shift towards rail.



Source: Fraunhofer-ISI

Figure 30: Relative change of tonne-km per mode in EU27 as compared with REF

The following two sections 6.2 and 6.3 deal with specific impacts that can be important for the analysis of cost of non-completion of TEN-T but were not handled within the ASTRA model. This means these impacts will either be assessed building on output from ASTRA (post-processing approach) or are assessed quantitatively or qualitatively in parallel to the ASTRA analysis and will complement the model findings.

6.2 External effects of nine CNC

6.2.1 Methodology

Based on the results of the ASTRA-EC model for the complete network the external costs (or benefits) of the non-completion of the TEN-T core network are assessed.

The main inputs for the calculation are transport performance data (passenger-km, ton-km, vehicle-km) from ASTRA-EC reflecting the change of transport demand in case of non-construction of the TEN-T. The transport data are differentiated per country and transport mode:

- Passenger transport: car, bus, passenger train, air passenger (continental and inter-continental).
- Freight transport: truck (light duty vehicles, heavy duty vehicles (below and above 12 t), freight train, maritime transport, inland waterway transport.

The change in external costs of transport is calculated on the basis of the change in transport demand and specific cost factors from literature. The main data source for cost factors is the updated DG MOVE Handbook on external costs of transport (Ricardo-AEA, DIW econ et al. 2014).

The following categories of external costs are taken into account for calculating the external costs[7]:

- air pollution costs
- noise costs
- climate change costs
- accident costs
- costs of up- and downstream processes (i.e. energy production and transport).

For deriving average external cost factors per transport mode and cost category, information about the vehicle fleet mix (e.g. fuel mix, emission / EURO classes) in 2030, the regional distribution of transport demand (urban, suburban, rural etc.) are taken into account. Main data sources are the Handbook on road transport emissions (HBEFA 2014) and the TREMOVE database (TREMOVE 2010).

The main impact of non-completion of the TEN-T core network corridors on transport is a change in transport demand (pkm, tkm, veh-km). Transport demand of railways is affected most significantly with a reduction of 6-7% in pkm and tkm (see section 6.1). A relative decrease in transport demand is also expected for buses, intercontinental air transport, inland waterway transport and light trucks (below 12 tons). A relative increase in transport demand in case of non-completion of the TEN-T core network corridors is expected for cars and continental air transport, as well as for heavy trucks and maritime freight transport.

Besides the impact on transport demand, the TEN-T core network projects also include investments in fuel shift (see section 7.2) which affects the vehicle fleet mix and as a consequence altering energy consumption factors and emission factors. Technology investments include promotion of charging stations for electric vehicles (EV) in road transport (mainly car and light duty vehicles) as well as alternative fuels for water transport (mainly LNG for shipping). Therefore, it is assumed that the non-completion of the TEN-T core network corridors will lead to a slightly lower share of EV (car, LDV) in road transport and alternative fuels in shipping.

[7] The environmental effects and costs (air pollution, climate change) specifically related to reduced or increased congestion due to non-completion of CNC are not covered in the analysis. The costs of congestion are covered in the main results (ASTRA model) by taking into account the time savings and its effect on travel costs.

6.2.2 Results

The following tables show the total change in external costs due to the non-completion of the TEN-T core network. Table 12 shows the impact on externals costs when only taking into account the change of transport demand (e.g. increase in car transport demand). The total change of external costs as a result of demand change is around € 400 million per year in 2030. This means the non-completion of the TEN-T core network leads to higher externals costs, mainly climate change costs and costs of up- and downstream processes (energy production and transport etc.). The highest increase of external costs can be observed for cars. Additionally, the externals costs caused by heavy trucks, continental air transport and maritime transport are increasing in case of No CNC, too. On the other side, the external costs of rail transport, light trucks and intercontinental air transport are decreasing in the No-CNC case, since transport demand of these modes is falling.

When looking at the different cost categories, the effect on the air pollution costs is only marginal. This is mainly a consequence of the changing road vehicle fleet by 2030. In 2030, the vehicle fleet is dominated by EURO 6 vehicles, which leads to a strong decrease in the emissions of air pollutants (e.g. particulates, nitrogen oxide). The effect on noise and accident costs is also quite small, whereas the climate change impacts and the indirect costs of up- and downstream processes dominate the results.

Table 12: Change of external costs due to change of transport demand (in case of non-completion of TEN-T core network corridors), annual data for 2030.

[€ million per year]		Air pollution	Climate change	Up- and down-stream	Noise	Accidents	Total external costs
Road	Car	26	248	128	14	31	**446**
	Bus	0	-1	0	0	0	**-2**
	LDV	-4	-22	-11	-3	-11	**-51**
	HDV <12t	-2	-9	-4	-2	-3	**-19**
	HDV > 12t	4	43	19	5	6	**77**
	total	24	259	132	13	23	**450**
Rail	passenger	-29	-5	0	-3	-27	**-65**
	freight	-39	-8	-1	-3	0	**-52**
	total	-68	-14	-1	-6	-27	**-116**
Air	continental	4	26	11	1	1	**43**
	intercontinental	-2	-52	-22	-4	-2	**-81**
	total	2	-26	-11	-3	-1	**-38**
Water	inland waterways	-2	-3	-1	0	0	**-6**
	maritime	44	28	9	0	0	**81**
	total	42	25	8	0	0	**75**
Total for all modes		**1**	**245**	**128**	**4**	**-6**	**371**

Source: Infras, own analysis

When assuming additional changes in diffusion of EVs in road transport (car, LDV) and LNG in water transport due to the TEN-T investments, the vehicle fleet mix is altered (different energy consumption and emission factors) and hence externalities are affected, too. In short, in the Non-CNC scenario, the diffusion of alternative fuels would be lower and hence the external costs higher.

The following table shows the shift of external costs when change of transport demand and change of alternative fuel distribution is taken into account. The calculations assume that in case of non-completion of TEN-T core network, the share of electric cars and LDV will be 1% lower in 2030 and the share of LNG in water transport will be 2% lower than in the *Reference Scenario*. To our mind, this shift is at the upper limit of the possible impact of the TEN-T core network on the vehicle fleet. With the growing demand of electricity for EVs, private service stations will more and more provide electricity at their infrastructures (petrol stations) anyway in the next 10-15 years.

In total, the change of external costs will be around € 1.100 million per year in 2030, when also taking into account fuel mix changes such as the distribution of EVs and LNG (Table 13).

Table 13: Change of external costs due to change of transport demand AND change of fuel mix / vehicle fleet (in case of non-completion of TEN-T core network corridors), annual data for 2030.

		Change of externals costs (all cost categories)	
	[€ million per year]	**Only change in transport demand** (see Table 12)	**Change in transport demand AND fuel mix**
Road	Car	446	1.092
	Bus	-2	-2
	LDV	-51	14
	HDV <12t	-19	-19
	HDV > 12t	77	77
	total	**450**	**1.161**
Rail	passenger	-65	-65
	freight	-52	-52
	total	**-116**	**-116**
Air	continental	43	43
	intercontinental	-81	-81
	total	**-38**	**-38**
Water	inland waterways	-6	-3
	maritime	81	81
	total	**75**	**78**
Total for all modes		**371**	**1.083**

Source: Infras, own analysis

6.3 The role of innovative technologies

Innovative technologies both can improve the productivity of the transport system and can become a success of the European exporting industries. Both impacts would generate a positive stimulus to the European economic system driving growth and potentially also employment. Article 33 of the TEN-T guidelines (EC REG No 1315/2013) defines the innovative technologies potentially to be implemented on the core TEN-T network and eligible for co-funding by the CEF and other EU funds. These include:

- Technologies to decarbonize transport (e.g. introduction of alternative propulsion systems including energy supply infrastructure and related telematic applications);
- Technologies to improve safety of passenger and goods transport;
- Technologies to improve interoperability and multimodality of the network (e.g. multimodal ticketing);
- Technologies to provide access to (multimodal) information to all citizens;
- Technologies to reduce external cost, in particular of transport noise;
- Security technologies;
- Resilience to climate change;
- Telematic applications as specific applications are mentioned in article 31: ERTMS, RIS, ERTMS, ITS, VTMIS and SESAR.

Given the repeated mentioning of telematic applications it should be added that the Galileo satellite system constitutes another innovative technology that complements the TEN-T, though not being explicitly mentioned by the TEN-T guidelines. For 2014 to 2020 the European Parliament has decided to support deployment of Galileo with € 6.3 billion.

Table 14 provides an overview on the projects to implement innovative technologies along the 9 CNCs. These projects have been reported by the 9 corridors studies completed at the end of 2014 and published by the EC.[8] The total amount reported to be invested into innovative technologies along the 9 CNCs is about € 22 billion, excluding SESAR, which was not reported on as part of the corridor studies. To our understanding this constitutes a lower boundary compared with the actual investment that will be channelled to implement innovative technologies.

The most relevant investment budget will be dedicated for ERTMS implementation, which is planned to absorb € 14 000 million of investments. The second largest budgets with € 1 800 million each for ITS in road and rail transport, the latter meaning investments other than in ERTMS. In terms of alternative fuel investment LNG for ships plays the most important role with up to € 1 000 million. Major examples of such innovative technologies include LNG fuelling installations e.g. in the Port of Constanţa (€ 180 million), the Port of Dunkirk (€ 97 million). The biggest ITS project on roads seems to be implemented on the Czech road network at which information systems and a tolling infrastructure will be implemented until 2023 at a cost of about € 1 300 million. For shipping the total amount invested in ITS including RIS and VTMIS is lower with about € 270 million the largest investment being planned for the ITS for winter navigation in the Baltic Sea The rail sector plans the largest innovative investment along the CNC with about € 17 billion, the largest part of that being invested into ERTMS deployment. The road sector plans to invest about € 3 billion in innovative technology along the CNCs and the shipping sector about € 2.6

[8] See the zip-files at the end of the website: http://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines/corridors/corridor-studies_en.htm.

billion. It should be pointed out that we expect these numbers to be at the lower end of what will actually be invested.

Table 14: Investment projects for innovative technologies reported by the 9 CNCs - classification by impacts

	Improving travel management.	Improving externalities	Potential for lead markets
LNG for ships (maritime and inland waterway)	No	Yes	Limited
Other alternative fuels for ships (methanol, biofuels, on-shore electricity supply at harbours, etc.)	No	Yes	Limited
Alternative fuel for road transport	No	Yes	(Yes)
Electrification of road transport	No	Yes	Yes
Electrification of rail transport in ES, PL, UK	No	Yes	No
ITS for road transport	Yes	(Yes)	(Yes)
ITS for ship transport	Yes	(Yes)	Yes
ITS for rail transport (excluding ERTMS)	Yes	(Yes)	No
ERTMS (includes ETCS, GSM-R, deployment & studies)	Yes	(Yes)	Yes (ETCS3)
eFreight (developing the digital supply chain)	Yes	No	(Yes)
RIS (inland waterways)	Yes	(Yes)	Yes
VTMIS (maritime transport)	Yes	(Yes)	(Yes)
Noise reduction measures for rail in CZ, DE	No	Yes	No
Railway fleet renewal in LV	Yes/No	(Yes)	No
Ship fleet renewal / extension (icebreakers, tug boats)	Yes	(Yes)	No
Nature protection measures (most in shipping)	No	Yes	No
Explicit multi-modal traffic organisation	Yes	Depends	Depends

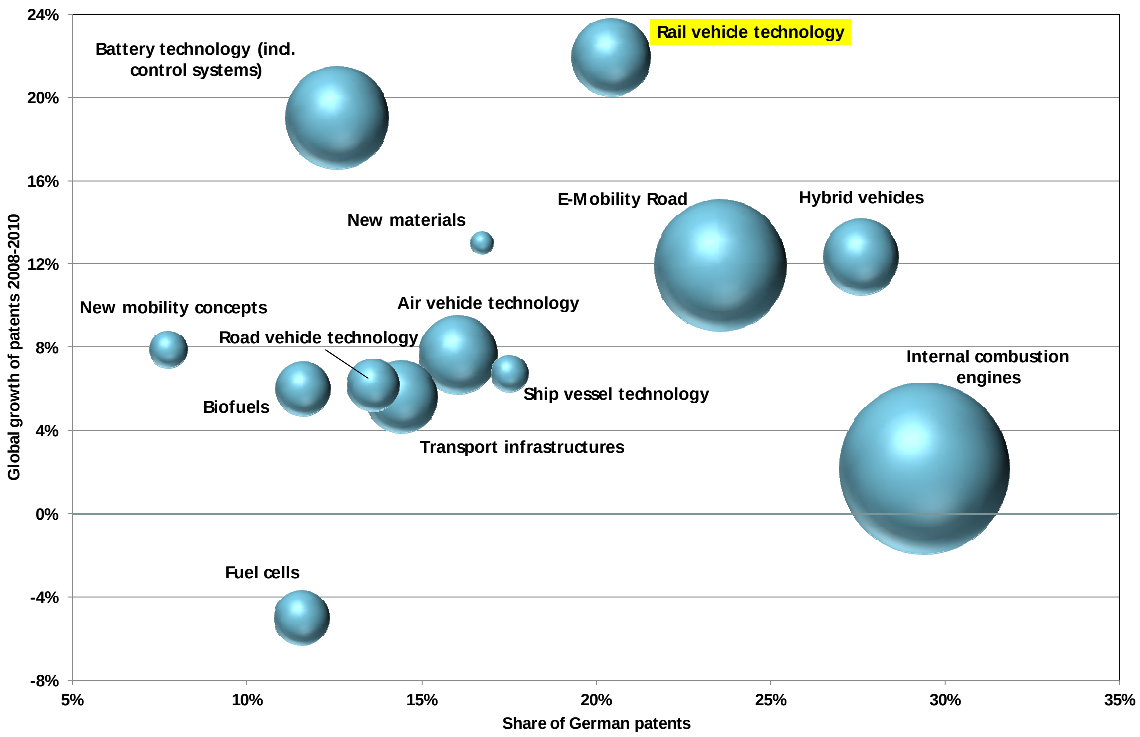
Source: Fraunhofer ISI, own analysis of CNC studies from 12/2014

Due to the bottom-up approach for the development of work plans of the CNCs it can reasonably be expected that investments for the short term are reported more comprehensively than those for the medium and long-term. Also for those investments explicitly required by the legislation (like ERTMS) the planning will be more elaborated than for "voluntary" technologies. Therefore the actual investments in innovative technologies along the CNCs will be substantially higher than reported in the workplans of the CNCs. The gap between planned and already reported and still to be planned investments into innovative technologies will thus increase over time, in particular after 2020.

6.3.1 Innovation systems in the transport sector – the modal view

Generating innovations is one of the important drivers for competitiveness of industries and countries. The literature discussing how innovations emerge looks at the so-called innovation system. As with the analysis of competitiveness looking at both the industry level and the country level also the discipline of innovation system analysis has developed two points of departure: (1) the national innovation systems (NIS) looking at a whole country, its R&D and education systems, the governance structure and the economic structure, and (2) the technological innovation systems (TIS) looking at one technology, R&D efforts of this sector and the industrial and political actors related to a technology. In-between there would be the sectoral innovation systems (SIS) which is the least developed of these three approaches. In the transport sectors SISs could be analysed for each mode, and the TISs for specific technologies like electric road vehicles, ERTMS or SESAR.

Examples of innovation system analysis of the transport sector are limited. The GHG-TransPoRD project analysed the innovation systems of all four modes, with a specific focus on their innovative capacity to mitigate greenhouse gas emissions as well as looking in greater detail at the automotive industry (Leduc et al. 2010, Wiesenthal et al. 2012). The innovation system of low carbon cars and of the German automotive industry were the topics of two other innovation studies, the former being rather a technological study (TIS) and the latter a sectoral study (SIS) (Köhler et al. 2012, Schade et al. 2014a). Mobility is also one of the five pillars of the German High-Tech Strategy defined by the Ministry of Research and Education. The analyses of patents, R&D activities and publications form part of the research on the success and modification of the High-Tech Strategy. The results confirm that Mobility is one of the innovative sectors, and both Germany and the EU play an important role to drive innovation in the sector. For example, the six European countries with the highest shares on global patents in mobility together account for 35.6 % of global patents, with Japan accounting for 29.1 % and the US for 19.1 %. I.e. the EU in general is a leader in innovation in the transport sector, though this will not hold for any sector and field of technology. In terms of dynamics of patenting, which is an indicator for innovativeness, the global rail sector in 2008-2010 reveals the highest dynamics, albeit at a lower absolute level of patent activity than for road transport (Frietsch et al. 2013).



Source: *Fraunhofer ISI analysis of EPO Patstat data (*Frietsch et al. 2013)

Figure 31: Patenting activity in different modes and transport technologies –analysis in relation to German patenting activities

Taking the above studies into account and having the question in mind, which markets could become lead markets for which European TEN-T policy could provide a stimulus, the Table 15 presents a classification of the modal innovation systems with a focus on vehicles. In most but possibly not all cases the classification should also work for infrastructure and organization of the sector. It seems that the innovation systems for road and air transport are structured to provide innovations to the sector, without stimulus by the TEN-T policy. For road this is the case due to the large markets with competition and the private actors on these markets framed by stimulating regulations. For air, this is the growth expectation of the markets and the technology complexity combined with required high levels of safety. For rail and ship modes the innovations systems are less elaborated to proactively stimulate innovations. Smaller markets, lower growth expectations, limited regulation in the case of ship mode and the oligopolistic supply side together with a demand side of mainly public actors of rail mode hamper the innovativeness of the sectors. Thus this could be the modes in which TEN-T policy could be more required and more successful to stimulate innovations and generate lead markets.

Table 15: Characteristics of the sectoral / modal innovation systems (MIS) – focus vehicles

	Road	Rail	Air	Ship
Size of market	Large, global	Moderate, regional	Moderate, global	Moderate, global
User type	Private, Industry	Public, Industry	Industry	Industry
Producer style	Large Oligopoly, strong networks, private	Oligopoly, private, large companies	Duopoly, public/private, large companies	Competitive, medium companies
Market type (supply-to-demand interaction)	Competitive (several-to-many)	Policy driven (few-to-several)	Supplier market (very few-to-several)	Demander market (several-to-fewer)
Research approach	Private, high R&D intensity	Public, medium R&D intensity	Public, high R&D intensity, link with space and military R&D	Public, low R&D intensity
Technology complexity	Medium	Medium	High	Low
Needs for standardisation	Medium (fuels, safety, etc.)	High, but diversity of regional fences (interoperability)	High, but well established (safety)	Low
Organisational complexity of mode	Low	High	Medium	Medium
Overall innovation system status	**Private, stimulated by regulation**	**Public, hampered by limited markets, future growth**	**Private/public stimulated by growth & safety**	**Private, hampered by limited regulation**

Source: Fraunhofer ISI, own analysis

Currently there is developing a new literature on the innovation in infrastructure systems. Though most of it is rather in their infancy a common conclusion can be observed: innovations of infrastructure systems are more complex and are more difficult to understand. They require the science of complexity and their transformation should be seen as a parallel socio-technical process (Markard 2011, Bolton/Foxon 2013, Hansman et al. 2015). It seems also that the combination with new ICT services will affect the speed of infrastructure systems innovations and will improve the service that the infrastructures are able to provide (Oughton/Tyler 2013). This could be another stimulus by European TEN-T policy to complement transport infrastructure by a capability enhancing IT infrastructure.

The literature expects that a well established national innovation system will generate new technologies and services that are first tested and deployed in the domestic markets. Given that successful implementation it will lead to significant additional exports of the new technology or service to other countries. This is then called the lead market effect. For instance such exports could be observed for wind energy technologies in the energy system. These have been stimulated by regulation that fostered the innovations and generated the lead market in Germany (Walz 2007). However, recent literature points out that a domestic market might not be sufficient to generate lead market exports due to the competition with producers in emerging markets (Quitzow et al. 2014).

6.3.2 ERTMS – innovative technology invested in heavily by CNCs

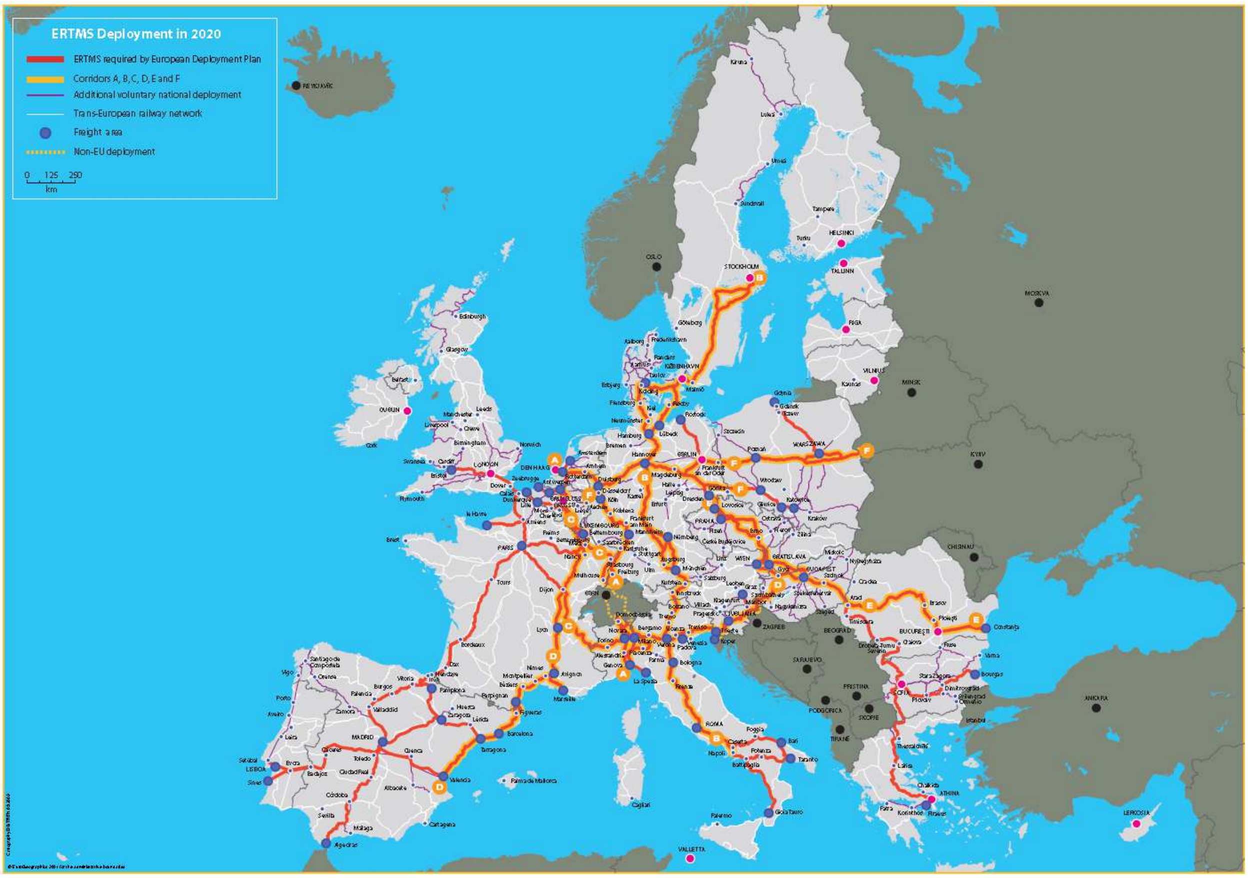
We have concluded that support by TEN-T policy could be most effective to stimulate innovations in the rail and ship mode and when it affects the combination of infrastructure with ICT technology. ERTMS technology ideally fulfils these criteria:

- ERTMS supports the rail mode.
- ERTMS is a complementing ICT technology to rail infrastructure.
- ERTMS reveals the biggest innovative investment along the TEN-T corridors.

The installation of ERTMS is progressing both in Europe and in other world regions. UNIFE reports that outside Europe more than 29,000 km of track are equipped with ERTMS (UNIFE 2013, EC 2014a). Actually the biggest share of that is installed in China.[9]

Figure 32 presents the European ERTMS deployment map as presented by the ERTMS website of the European Commission.

[9] See the world deployment map at: http://www.ertms.net/



Source: EC ERTMS website: http://ec.europa.eu/transport/modes/rail/interoperability/ertms/doc/edp/ertms_map.pdf

Figure 32: ERTMS deployment map

In Europe the implementation of ERTMS is making progress, but not all decisions are finally taken, yet. For instance the Netherlands are discussing different implementation scenarios for ERTMS until 2030. It was estimated in the Dutch railmap for ERTMS deployment that equipping the lines that are compulsory by EU guidelines (i.e. TEN-T core, RFC) with ERTMS would require investments of € 0.85 billion for their country, while for equipping the full Dutch network the cost would be € 5.15 billion. In terms of travel time the Dutch railmap estimates a saving of follow-up times of up to 41% with an average of 25% through ERTMS. Overall the savings of journey times are estimated at the level of 3% (MinIE 2014).

The ERTMS deployment map shows that Germany is one of the central countries due to its involvement in many of the corridors. Thus, it will be important that Germany moves ahead with ERTMS implementation to avoid a spatially fragmented system thus not reaping the benefits of ERTMS.

ERTMS technology could in principle become a lead market technology according to our analysis. This will in particular be the case when the most recent technological levels of ERTMS (e.g. ETCS level 3) are implemented at larger scale in Europe. Other promising technologies to generate lead market effects are: (1) RIS and VTMIS, (2) tunnel boring as several of the world's largest tunnels implemented using different tunneling technologies will be constructed as part of the CNCs, (3) systemic ICT & infrastructure combinations, and (4) LNG for ships (though with a more moderate potential to generate lead market effects).

6.4 Extension of economic impacts to full core network

The nine CNCs account for 75% of the TEN-T core network in terms of length of the network. To assess the impact of non-completion of the full core network we need to extrapolate our findings related to the 9 CNC to the full core network. We start with the assumption that the 25% missing of the core network reveals the same structure of the infrastructure as the average of the 9 CNCs. Thus the investment for the remaining core network would amount to € 155 billion, and the total of investment required to implement the full core network (Full-Core-Scenario) by 2030 would amount to € 623 billion.

We then look at relevant output indicators of the three infrastructure scenarios comprising all types of infrastructures: *No CNC* scenario, the implementation of Scan-Med Corridor and of Rhine-Alpine corridor. Table 16 presents the output indicator for FTE job years generated per billion € of investment, which is between 14,683 person-years/bn € for Scan-Med and 25,935 person-years/bn € for Rhine-Alpine corridor. The *No CNC* Scenario is rather in the middle such that we take as an upper range assumption that the missing part of the full core network reveals the same structure as the 9 CNCs. A more pessimistic view would argue that the non-CNC elements of the core network are the less productive parts of the infrastructure such that a lower multiplier should be used for these. As a lower range we suggest to apply half of the *No CNC* Scenario, i.e. 9,798 person-years/b€.

For the GDP multiplier calculated from the additional GDP divided by the required investment we observe that both corridors provide higher GDP multipliers than the 9 CNC altogether. Assuming that the missing part of the network is at maximum as economically effective as the average of the CNC provides the upper range for estimates (i.e. a multiplier of 5.65). Applying the precautionary principle and expecting the remaining part to be half effective compared with the 9 CNCs means to apply the GDP multiplier of 2.83 for the benefit estimates of the full core network by extrapolation.

Table 16: Relevant output indicators used to estimate the full core network scenario

Output Indicator	Scenario	Value	Unit
FTE-Job-Years per Billion Investment	No_CNC	**19,596**	Person-Years/B€
	No_CNC_ScanMed	14,683	Person-Years/B€
	No_CNC_RhAlp	25,935	Person-Years/B€
	50% of No_CNC	**9,798**	Person-Years/B€
Accumulated GDP gain per Investments	No_CNC	**5.65**	B/C ratio
	No_CNC_ScanMed	7.46	B/C ratio
	No_CNC_RhAlp	13.16	B/C ratio
	50% of No_CNC	**2.83**	B/C ratio

Source: Fraunhofer-ISI – based on ASTRA-EC model

Table 17 shows the impacts of the non-completion of the full TEN-T core network. The non-completion of the 25% of TEN-T that are not part of the 9 CNCs would generate a loss of between 1.5 and 3 million person-years of employment. The loss of GDP would amount to between 440 and 880 billion €.

The figures for non-completion of the full TEN-T network would accordingly amount to between 10.4 and 11.9 million person-years of employment not generated. The total loss of GDP would be between 2,940 and 3,380 billion €.

Table 17: Impacts for the non-completion of the full TEN-T core network

Scenario	Output Indicator	MIN value	MAX Value	Unit
25%-Core Network missing	FTE-Job-Years (2015 to 2030)	1,520,000	3,040,000	Person-Years
	Accumulated GDP gain (2015 to 2030)	440	880	Billion €
Full Core Network	FTE-Job-Years (2015 to 2030)	10,420,000	11,940,000	Person-Years
	Accumulated GDP gain (2015 to 2030)	2,940	3,380	Billion €

Source: Fraunhofer-ISI – based on ASTRA-EC model

6.5 Funding of TEN-T core network

6.5.1 Historic and planned split of TEN-T funding sources

Between 2000 and 2013 the overall investment in the TEN-T network has reached close to € 800 billion, which means about € 60 billion per year. As the split into core network and comprehensive network appeared with the new TEN-T guidelines, in 2013, historic figures separated out for the core network are not available. For the next funding period 2014 until 2020 it is estimated by the EC legislation that € 500 billion would be invested in the

TEN-T, of which € 250 billion would be invested into the core network, which is in the focus of analysis in this study. Broadly this investment budget would be consistent with our analyses of the CNC workplans.

The EIB in 2014 made some preliminary forecast on the investments of the Member States for TEN-T. These would indicate annual investment of € 52 billion, or a 13% lower level of investment (see also Table 18). Until now the share of rail investments has been 48%, which would increase to 54% according to the plans until 2020. Given the political momentum that is initiated by the European Fund for Strategic Investments (EFSI) proposed by the new European Commission these numbers will have to be updated as the EFSI is planned to generate additional investment of up to € 315 billion in the EU (European Commission 2015).

Table 18: TEN-T financing over time and preliminary planning (EIB 2014)

	2000-2006		2007-2013		2014-2020	
	EUR bn	%	EUR bn	%	EUR bn	%
TEN-T budget line / CEF	4.4	1%	8.0	2%	26.3	7%
CF+ERDF	25.1	8%	44.2	10%	33.0	9%
EIB	44.3	15%	56.8	13%	45.5	13%
Other (public and private)	231.1	76%	320.0	75%	257.7	71%
Total TEN-T Financing	304.9	100%	429.0	100%	362.5	100%

Source: EIB 2014 based on various sources

Table 18 provided an indication of how the TEN-T investments were expected to be funded. The share of EC funding is expected to increase to 16% for the next period 2014 to 2020, the increase stemming from the higher TEN-T funding provided by the CEF. The EIB is expected to participate with 13% at the financing. The remaining financial sources have to come from national or regional governments or from private funds. This differentiation is not yet implemented in the ASTRA-EC modelling, which prioritized national funding sources.

The project structure in the past demonstrates that Member States tend to prioritize projects within their countries as in general most of the benefits of these projects go to their countries, while cross-border projects are assigned lower priorities as in the national assessment schemes they achieve lower ranks (see also the discussion on European added value and spillovers in section 4.2). Therefore the EC co-funding over the different funding periods is focusing more and more towards developing and funding the cross-border projects. In the next funding period these could expect EC co-funding of up to 40% of eligible investments.[10]

When setting-up the legislation for TEN-T co-funding the EC envisaged already a rough distribution of the funds, with about € 8.5 billion for the large cross-border projects and at least € 11.3 billion that need to be spent in cohesion countries by the CF. However, the emergence of EFSI will also alter these preliminary planning figures.

6.5.2 Attracting private investment funds

Close to one third of investment funds of TEN-T could be sourced from TEN-T funds and the EIB. This means two thirds need to come either from national governments or private funds. In a situation in which Europe is facing a situation with slow growth or even recession, tight government budgets and a lack of investment on the one hand, while on the other hand substantial investment capital is seeking for investment opportunities it is obvious that the private sector should participate with a larger share of funds to TEN-T then before. This imbalance is also recognized by the initiative of the European Commission to establish the European Fund for Strategic Investment (EFSI) with the objective to attract private investors and increase investment activity in Europe.

We also believe that a lack of investment capital is not the problem, but rather to attract the available capital to (co-)fund European transport infrastructures. However, for products or services that do not generate any revenue as they are provided as a public good it will be difficult to attract private capital. At least some kind of return will obviously be expected by the investors. In particular, road infrastructure is often provided as public good, while for other transport infrastructures charges have to be paid by the direct users.

European transport policy intends to foster rail mode as opposed to road mode due to the environmental benefits gained by this modal-shift. The Swiss example of the heavy goods vehicle charge used to fund the rail infrastructure investment provides an example of successfully combining the objectives of modal-shift towards environmental friendly modes and of funding investment, in this case by cross-funding between modes. However, also this approach requires that road transport – at least for some transport users – is not provided as a public good, but as a good having a price tag. Thus the old slogan of the debate on externalities "getting the prices right" by internalization through a price tag on e.g. emissions can be emphasized by "getting the prices right for investment".

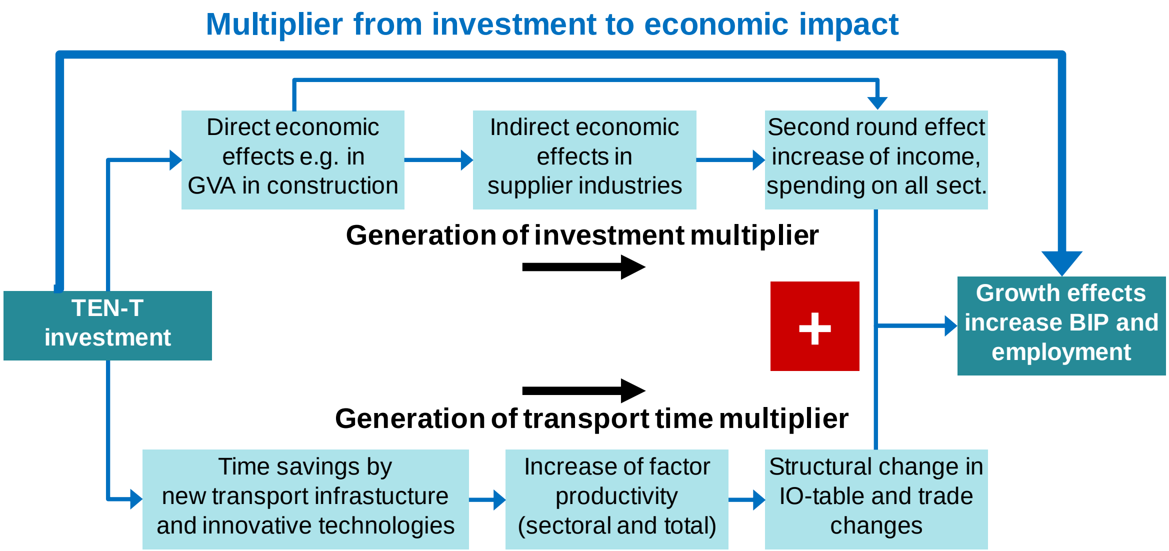
6.6 Comparing results with the cost-of Non-Europe studies

The European Parliament has run a number of studies to estimate the cost of no further European integration, the so-called cost-of-non-Europe studies. These cost have been

[10] Projects eligible for cohesion funding could even obtain higher co-funding rates of up to 85%.

recently also estimated for transport by the EPRS (2014). Referring to the Single European Transport Area (SETA) they estimated a cost of about € 5.5 billion. According to our analysis of the cost of *NO CNC* scenario this cost is by far too low as we estimated them to be about 50 times higher in 2030 (about € 300 billion). The Single European Transport Area is actually defined by the Transport White Paper and is much broader than the efficiency gains considered by the EPRS study. We would rather agree to the quoted council position "*that eliminating regulatory barriers and tackling bottlenecks and missing cross-border links is essential in order to guarantee the efficient operation of the single market*". In fact, transport would be producing the same impact as the impact of delivering the Single Market would be. This seems not too surprising as the Single Market to a large extent depends on transport.

Our analysis of the nine CNCs estimated a loss of GDP of close to € 300 billion for in 2030 and of € 2,570 billion accumulated loss of GDP (see Figure 13). One might argue that with a similar investment package of about € 460 billion into other infrastructures the stimulated economic result would have been roughly equal. However, Figure 28 shows that according to the analysis of our model reactions close to half of the economic multiplier would not result from the direct and indirect effects of the investment, but from the travel time savings through improved TEN-T. The latter economic multiplier of travel time savings could not be generated by an alternative investment than the analysed TEN-T investment. Figure 33 explains the two impact chains generating the economic impact together leading to the economic multiplier that is then composed out of the impact (1) of the investment i.e. the Euros spent, and (2) of the productivity changes within the transport system and in other transport using sectors. Our analysis revealed that in 2030 both multiplier chains are of rather equal relevance.



Source: presentation after Schade/Krail 2015

Figure 33: Differentiation of the economic multiplier according to two causes: pure investment budget and transport-economic system impact

It should be reminded that the TEN-T investment consists of a mix of investments into network infrastructures, terminal/station infrastructures and innovative technologies improving the operation of the networks.

7 Assessing the impacts on quality of jobs

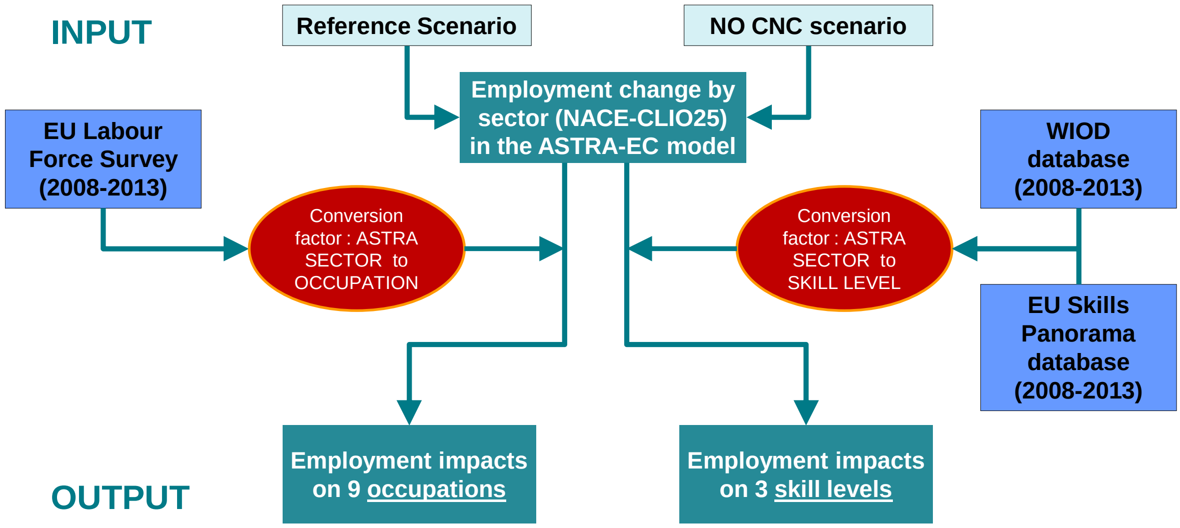
As pointed out in the literature, an important output of project evaluation is not only calculating the number of jobs generated by constructing the new infrastructure, but also the types of employment generated. Subdivisions in this respect are generally established according to the level of education required for getting each job or the skill level associated with it. This section deals with type and quality of jobs lost in the *NO CNC* scenario.

7.1 Methodology

In our case, data available has been an important limitation to establish the subdivisions regarding the skill level of employment generated through the ASTRA-EC model, and thus different assumptions were needed to be made. In order to collect data concerning economic sectors and skill levels within the European Union, and matching them with the economic sectors considered in the ASTRA-EC model, three main sources were used:

- European Union Labour Force Survey (EU LFS): the EU LFS constituted the key document to approach the occupation level present within each economic sector. According to the Eurostat database, a total of 10 different occupations could be differentiated. In order to avoid potential inter-annual heterogeneity of data and get a more representative overview of the relationship between economic sectors and occupations, average values were calculated for the 2008-2013 period. Nevertheless, results proved to be fairly constant over time. Average values adopted in this research are shown below (see Table 19).
- EU Skills Panorama (European Commission): the EU Skill Panorama database provided useful information about the percentage of the workforce, sorted by economic sector, assigned to three different levels of education:
  - Levels 0-2: Less than primary, primary and lower secondary education.
  - Levels 3-4: Upper secondary and post-secondary non-tertiary education.
  - Levels 5-6: Tertiary education.
- World Input-Output Database (WIOD): the WIOD database included information regarding the total hours worked within different economic sectors, sorted by a total of three skill levels:
  - High skilled persons.
  - Medium-skilled persons.
  - Low-skilled persons.

Figure 34 presents the approach how employment impacts calculated by the ASTRA-EC model at sectoral level are used to quantify impacts at the level of nine occupations and for three education levels. As explained above three external databases (blue rectangles) have been used to develop conversion factors (red circle) that convert from sectoral level to the two different levels that provide proxies for the quality of a job.



Source: Fraunhofer ISI

Figure 34: Approach to estimate quantitative effects on job quality

Table 19 presents the starting point for the conversion from sectors to the level of occupations. In particular the manufacturing sector of the EU Labor Force Survey (LFS) is much more detailed in ASTR-EC than in the LFS.

Table 19: Distribution of occupations (%) across economic sectors. Average values for the 2008-2013 period

Sector	Occupation Sector in %										
	Manag-ers	Pro-fes-sional s	Techni-cians and associ-ate profes-sionals	Cleri-cal sup-port work-ers	Ser-vice and sales work ers	Skilled agricul-tural, forestry and fishery work-ers	Craft and re-lated trade s work ers	Plant and ma-chine opera-tors and as-sem-blers	Elemen-tary occupa-tions	Arme d forc-es oc-cupa-tions	TOTA L
Agriculture, forestry and fishing	2.4	1.0	1.9	1.1	0.8	73.8	1.3	3.3	14.3	0.0	100.0
Mining and quar-rying	6.0	10.6	11.5	5.4	1.1	0.0	28.1	31.8	5.5	0.0	100.0
Manufacturing	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100.0
Electricity, gas, steam and air conditioning supply	7.2	17.9	25.9	13.9	1.5	0.0	23.2	7.5	3.0	0.0	100.0
Water supply; sewerage, waste management and remediation activities	6.5	6.5	14.7	10.0	1.4	0.0	11.9	22.7	26.3	0.0	100.0
Construction	6.7	4.9	8.9	5.2	0.7	0.1	58.7	6.4	8.4	0.0	100.0
Wholesale and retail trade; repair of motor vehicles and motorcycles	11.9	4.3	12.9	11.2	38.7	0.3	9.5	3.9	7.2	0.0	100.0
Transportation and storage	5.6	3.6	9.2	21.3	4.3	0.0	4.2	42.9	8.9	0.0	100.0
Accommodation and food service activities	15.8	0.9	3.8	5.4	56.3	0.2	1.7	1.2	14.7	0.0	100.0
Information and communication	10.8	43.2	24.8	11.1	2.1	0.1	3.9	0.7	3.1	0.0	100.0
Financial and insurance activi-ties	14.2	17.2	30.6	35.0	1.3	0.0	0.3	0.2	1.3	0.0	100.0
Real estate activities	13.9	6.1	39.2	16.8	7.0	0.7	3.7	0.7	11.9	0.0	100.0
Professional, scientific and technical activities	8.5	44.6	26.1	14.4	1.6	0.2	2.1	0.8	1.7	0.0	100.0
Administrative and support service activities	6.9	5.6	10.1	14.1	14.8	5.5	6.2	3.6	33.3	0.0	100.0
Public administra-tion and defence; compulsory social security	4.8	18.1	25.2	17.0	14.1	0.9	2.4	1.5	7.4	8.6	100.0
Education	3.3	61.3	12.3	4.9	9.7	0.2	0.7	0.3	7.3	0.0	100.0
Human health and social work activi-ties	2.8	24.5	30.3	6.4	26.8	0.2	1.0	1.1	7.0	0.0	100.0
Arts, entertain-ment and recrea-tion	8.1	26.8	23.6	15.2	11.2	2.1	3.4	0.9	8.7	0.1	100.0
Other service activities	5.9	12.1	12.4	8.6	40.3	1.0	7.7	3.6	8.2	0.0	100.0
Activities of households as employers	0.0	0.7	1.1	0.9	22.1	2.4	1.4	0.4	71.0	0.0	100.0
Activities of extraterritorial organisations and bodies	16.5	28.2	19.6	19.7	4.9	0.0	0.6	2.2	3.4	4.8	100.0

Source: authors´ elaboration based on EULFS (2008-2013)

Three main problems were identified when managing the data from the last sources, prior to the calculus of the distribution of occupations and skill levels across economic sectors in the ASTRA model:

- Economic sectors included in the databases referred above do not wholly match with the classification adopted in the ASTRA model. For few cases, subsectors appearing alone in the ASTRA model belong to a wider category. In other cases, information belonging to different subsections needs to be merged to replicate an ASTRA category. In order to solve this problem, new values for the ASTRA subdivision have been obtained by weighting the available figures. Weights used correspond to the workforce belonging to each detailed economic subsector, according to the classification included in Eurostat (2013).
- A situation also found is the lack of useful data available concerning an ASTRA subdivision. In these cases, we assigned the skill distribution of a subsector with reasonably similar characteristics, e.g. pharmaceutical industry was assigned the same skill distribution as chemical industry.
- Some skill distribution data available are referred to total jobs, while other information regards to total hours worked. Given the goal of the analysis, the highest priority was given to the information available at the job level. When more detailed information was needed, such as in the manufacturing sector, hourly data were used. In order to take into account potential differences in labour intensity across different sectors (hours worked/person), hourly data was weighted by the workforce belonging to each subsector, according to Eurostat (2013).
- Depending on the source used, employment across economic sectors is divided by skill level (WIOD) or by level of education required (EU Skill, EU LFS). In order to cover all the economic sectors considered in the ASTRA model, it was necessary to assume similarity between divisions in level of education and skill levels, e.g. low-skill jobs correspond to workers with a lower level of education, etc. Despite not being a strongly rigorous hypothesis, it can be reasonably assumed given the constraints present in the data available.

Next, the results of employment reduction across occupations and skill levels due to the non completion of the nine CNC are displayed.

7.2 Results of job quality impacts by occupation level

Given the data availability constraints and assumptions commented above, the conversion matrix linking the ASTRA sectors and occupation levels can be estimated (see Table 20). As can be seen, the same figures have to be adopted for different subsectors, mainly regarding industrial activities, such as textiles, paper, plastics, etc. This fact is due to the lack of detailed data availability for industrial subsector in the European databases.

Table 20: Conversion matrix linking the occupation distribution across the economic sectors considered in the ASTRA model

	Occupation Sector (%)										
Sector	Manag-ers	Profes-sionals	Techni-cians and associate profes-sionals	Clerical support workers	Service and sales work-ers	Skilled agricul-tural, forestry and fishery workers	Craft and related trades work-ers	Plant and machine operators and assem-blers	Elemen-tary occupa-tions	Armed forces occupa-tions	TOTAL
Agriculture	2.4	1.0	1.9	1.1	0.8	73.8	1.3	3.3	14.3	0.0	100
Energy	6.7	13.6	19.6	10.6	1.5	0.0	23.4	17.2	7.3	0.0	100
Metals	6.2	9.2	13.2	6.9	2.1	0.1	30.2	25.6	6.5	0.0	100
Minerals	6.2	9.2	13.3	7.0	2.1	0.1	30.3	25.3	6.5	0.0	100
Chemicals	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Metal Products	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Industrial Machines	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Computers	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Electronics	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Vehicles	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Food	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Textiles	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Paper	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Plastics	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Other Manufac-turing	6.3	8.3	14.3	7.9	2.7	0.2	31.6	21.5	7.1	0.0	100
Construction	6.7	4.9	8.9	5.2	0.7	0.1	58.7	6.4	8.4	0.0	100
Trade	11.9	4.3	12.9	11.2	38.7	0.3	9.5	3.9	7.2	0.0	100
Catering	15.3	1.1	4.2	5.9	53.8	0.5	2.0	1.4	15.8	0.0	100
Transport Inland	5.6	3.6	9.2	21.3	4.3	0.0	4.2	42.9	8.9	0.0	100
Transport Air &Maritime	5.6	3.6	9.2	21.3	4.3	0.0	4.2	42.9	8.9	0.0	100
Transport Auxiliary	5.6	3.6	9.2	21.3	4.3	0.0	4.2	42.9	8.9	0.0	100
Communication	5.6	3.6	9.2	21.3	4.3	0.0	4.2	42.9	8.9	0.0	100
Banking	14.2	17.2	30.6	35.0	1.3	0.0	0.3	0.2	1.3	0.0	100
Other Market Services	5.8	34.3	20.0	9.4	13.9	1.0	2.6	1.2	11.8	0.0	100
Non Market Services	3.8	32.1	23.0	9.2	18.2	0.4	1.8	1.5	7.6	2.3	100

Source: authors´ elaboration

According to the employment reduction results obtained through the ASTRA model, changes in level of occupations as a result of not completing the nine CNC can be easily calculated:

$$O_i = \sum_j M_{ij} E_j$$

Where: O_i: changes in occupation level i.
M_{ij}: conversion matrix linking economic sector j and occupation level i.
E_j: employment change in economic sector j, due to the no implementation of the TEN-T.

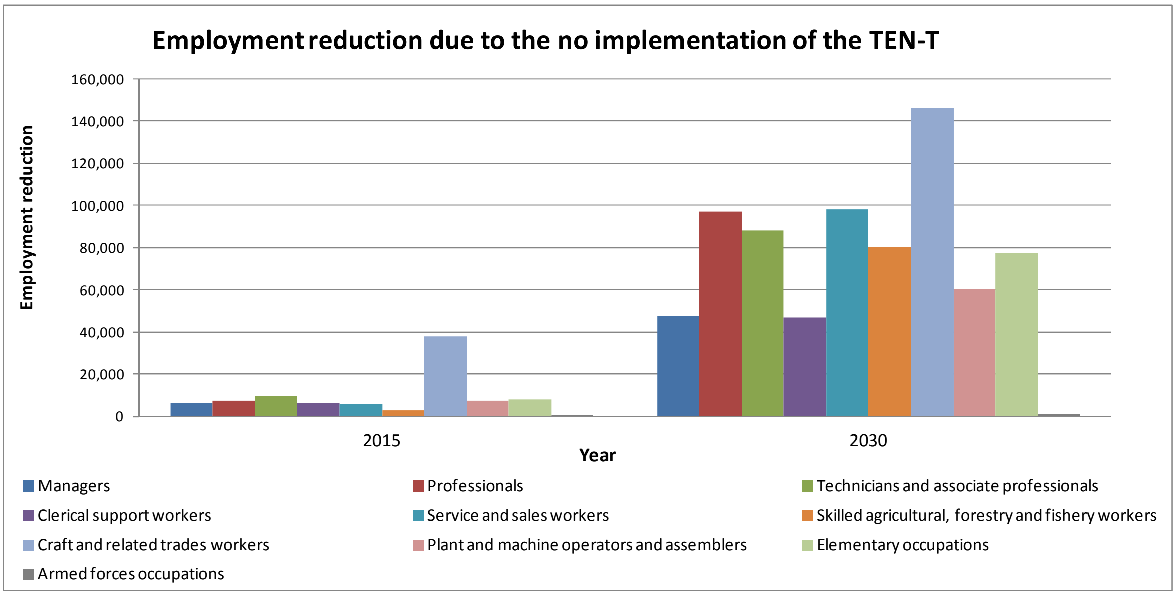
The results obtained through this calculus are displayed for different scenarios over time (see Table 21 and Figure 35), along the 2015-2030 period. As can be seen, the higher long-run net impacts are identified in occupations such as craft and related trade workers (19.6% of total reductions) or technicians and sales workers (13.1%). On the other hand, armed forces or clerical supporters would be among the less affected occupations, with only 0.2% and 6.3% of total reductions, respectively. When compared to the *Reference Scenario*, we observe that skilled agricultural, forestry and fishery would be the occupation more affected by the no implementation of the TEN-T, with reductions around 0.63%. Employment decreases would also be significant in craft and related workers (-0.46%) and elementary occupations (-0.38%). By contrast, the relative impact would be, again, lower for armed forces (-0.13%) and clerical support workers (-0.21%).

Table 21: Employment reduction due to the non completion of the nine CNC, sorted by occupation levels

Occupation level	Item	Year			
		2015	2020	2025	2030
Managers	Net Employment reduction	-6,247	-45,292	-43,770	-47,381
	% reduction (Ref. case)	-0.04	-0.29	-0.28	-0.31
Professionals	Net Employment reduction	-7,162	-71,436	-83,181	-97,169
	% reduction (Ref. case)	-0.02	-0.20	-0.24	-0.27
Technicians and associate professionals	Net Employment reduction	-9,691	-76,967	-79,420	-88,133
	% reduction (Ref. case)	-0.03	-0.22	-0.23	-0.26
Clerical support workers	Net Employment reduction	-5,939	-43,614	-43,366	-47,006
	% reduction (Ref. case)	-0.03	-0.20	-0.20	-0.21
Service and sales workers	Net Employment reduction	-5,436	-63,234	-82,701	-97,961
	% reduction (Ref. case)	-0.02	-0.20	-0.25	-0.30
Skilled agricultural, forestry and fishery workers	Net Employment reduction	-2,641	-61,437	-81,041	-80,173
	% reduction (Ref. case)	-0.02	-0.49	-0.64	-0.63
Craft and related trades workers	Net Employment reduction	-37,786	-215,792	-150,703	-145,880
	% reduction (Ref. case)	-0.12	-0.68	-0.47	-0.46
Plant and machine operators and assemblers	Net Employment reduction	-7,368	-57,662	-57,441	-60,584
	% reduction (Ref. case)	-0.04	-0.28	-0.28	-0.29
Elementary occupations	Net Employment reduction	-7,922	-68,369	-71,254	-77,263
	% reduction (Ref. case)	-0.04	-0.34	-0.35	-0.38
Armed forces occupations	Net Employment reduction	-49	-796	-1,084	-1,250
	% reduction (Ref. case)	0.00	-0.08	-0.11	-0.13
Total	Net Employment reduction	*-90,240*	*-704,599*	*-693,963*	*-742,802*
	% reduction (Ref. case)	*-0.04*	*-0.31*	*-0.31*	*-0.33*

Source: authors´ elaboration

Figure 35 presents the changes of employment by occupation for two reference years. It reveals that apart from armed forces occupations in 2030 the changes of employment for the other occupations will be in the range from 47,000 until 146,000, with occupations in craft and related trades are affected most strongly. However, this occupation is even more strongly reduced by 2020 with a loss of 215,000 jobs (see Table 21).



Source: own elaboration

Figure 35: Employment reductions as a result of non-completion of the nine CNC, sorted by occupation

7.3 Results of job quality by skill level

Following the same methodological approach adopted in the previous subsection, employment changes sorted by skill level can be estimated as a result of not implementing the TEN-T. As pointed out above, some data regarding skill level distribution are sorted by employed persons per level of education, while other sources are referred to total hours worked by skill level. Then, the conversion matrix between economic sectors and skill levels, before assuming equality between education and skill level distribution, would be as presented in Table 22.

Table 22: Conversion matrix linking the skill level distribution across the economic sectors considered in the ASTRA model

SECTOR	LEVEL OF EDUCATION: Less than primary, primary and lower secondary education	LEVEL OF EDUCATION: Upper secondary and post-secondary non-tertiary education	LEVEL OF EDUCATION: Tertiary education	SKILL LEVEL: Hours worked by low-skilled persons engaged	SKILL LEVEL: Hours worked by medium-skilled persons engaged	SKILL LEVEL: Hours worked by high-skilled persons engaged	TOTAL
Agriculture	42.5%	46.6%	10.8%				100.0%
Energy				23.1%	54.2%	22.7%	100.0%
Metals				31.3%	52.7%	16.0%	100.0%
Minerals				32.8%	51.5%	15.7%	100.0%
Chemicals				29.9%	50.8%	19.3%	100.0%
Metal_ Products				30.5%	52.3%	17.2%	100.0%
Industrial_Machines				29.1%	53.4%	17.5%	100.0%
Computers				28.1%	54.1%	17.7%	100.0%
Electronics				28.1%	54.1%	17.7%	100.0%
Vehicles				28.2%	53.1%	18.7%	100.0%
Food				31.5%	50.8%	17.7%	100.0%
Textiles				46.0%	42.0%	12.0%	100.0%
Paper				28.8%	51.7%	19.5%	100.0%
Plastics				27.8%	54.2%	17.9%	100.0%
Other_ Manufacturing				31.8%	51.1%	17.2%	100.0%
Construction	28.7%	56.8%	14.6%				100.0%
Trade	22.5%	59.5%	18.0%				100.0%
Catering	32.4%	55.0%	12.6%				100.0%
Transport_Inland				28.4%	55.0%	16.6%	100.0%
Transport_Air_Maritime				29.8%	51.6%	18.6%	100.0%
Transport_Auxiliary				28.0%	55.4%	16.5%	100.0%
Communication				28.7%	54.2%	17.1%	100.0%
Banking	6.1%	45.3%	48.6%				100.0%
Other_Market_Services	14.4%	38.1%	47.5%				100.0%
Non_Market_Services	12.9%	40.9%	46.2%				100.0%

Source: authors´ elaboration

Again, employment reductions by skill level can be calculated when considering the results from the ASTRA model:

$$S_i = \sum_j M'_{ij} E_j$$

Where: S_i: changes in skill level i.

M'_{ij}: conversion matrix linking economic sector j and occupation level i.

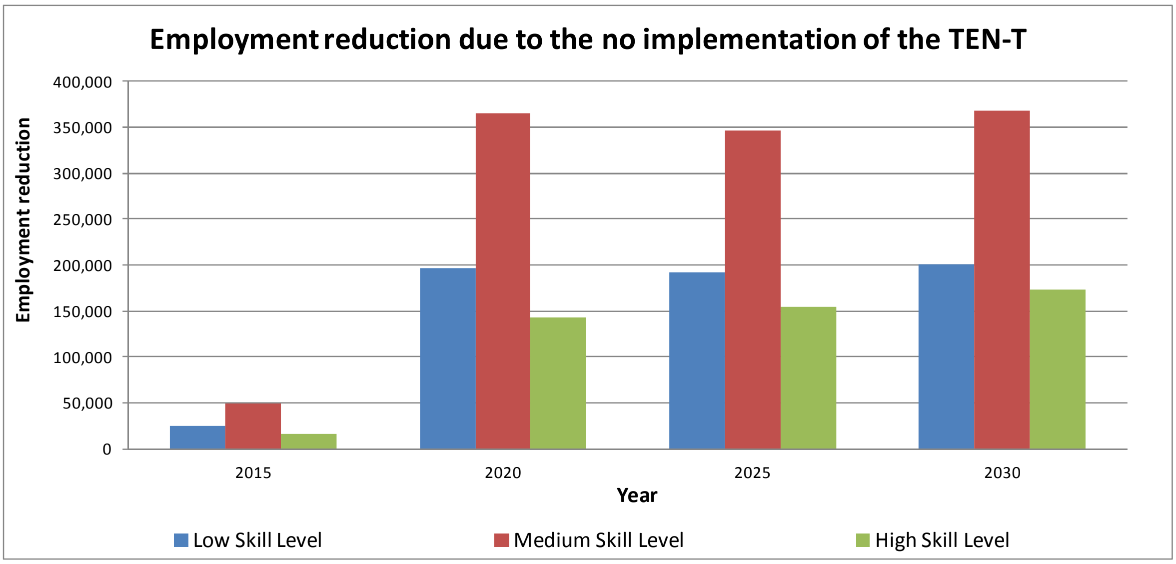
E_j: employment change in economic sector j, due to the non-completion of the nine CNCs.

Table 23 and Figure 36 display the results regarding employment reduction over time, along the 2015-2030 period. We can conclude that medium-skilled workers would be the sector more affected in absolute numbers as a result of non completion of the nine CNC, with 367,000 jobs lost representing around 49.5% of net employment reductions in 2030. By contrast, reductions would present a smaller share for high-skilled (23.0%) and low-skilled workers (-27.0%). When compared to the *Reference Scenario*, we find that the highest relative change would correspond to low skill levels, with reductions of around 0.38% in 2030. It would be followed by medium jobs, which would be reduced by 0.33. By contrast, the impact would be significantly lower for high skill jobs (-0.13%).

Table 23: Employment reduction due to the non completion of the nine CNC, sorted by skill levels

Skill level	Item	YEAR			
		2015	2020	2025	2030
Low Skill Level	Net Employment reduction	-24,936	-196,761	-192,258	-201,008
	% reduction (Ref. case)	-0.05	-0.37	-0.36	-0.38
Medium Skill Level	Net Employment reduction	-48,819	-364,569	-347,069	-367,753
	% reduction (Ref. case)	-0.05	-0.33	-0.32	-0.33
High Skill Level	Net Employment reduction	-16,484	-143,269	-154,635	-174,040
	% reduction (Ref. case)	-0.02	-0.13	-0.14	-0.16
Total	*Net Employment reduction*	*-90,240*	*-704,599*	*-693,963*	*-742,802*
	% reduction (Ref. case)	*-0.04*	*-0.31*	*-0.31*	*-0.33*

Source: authors´ elaboration



Source: own elaboration

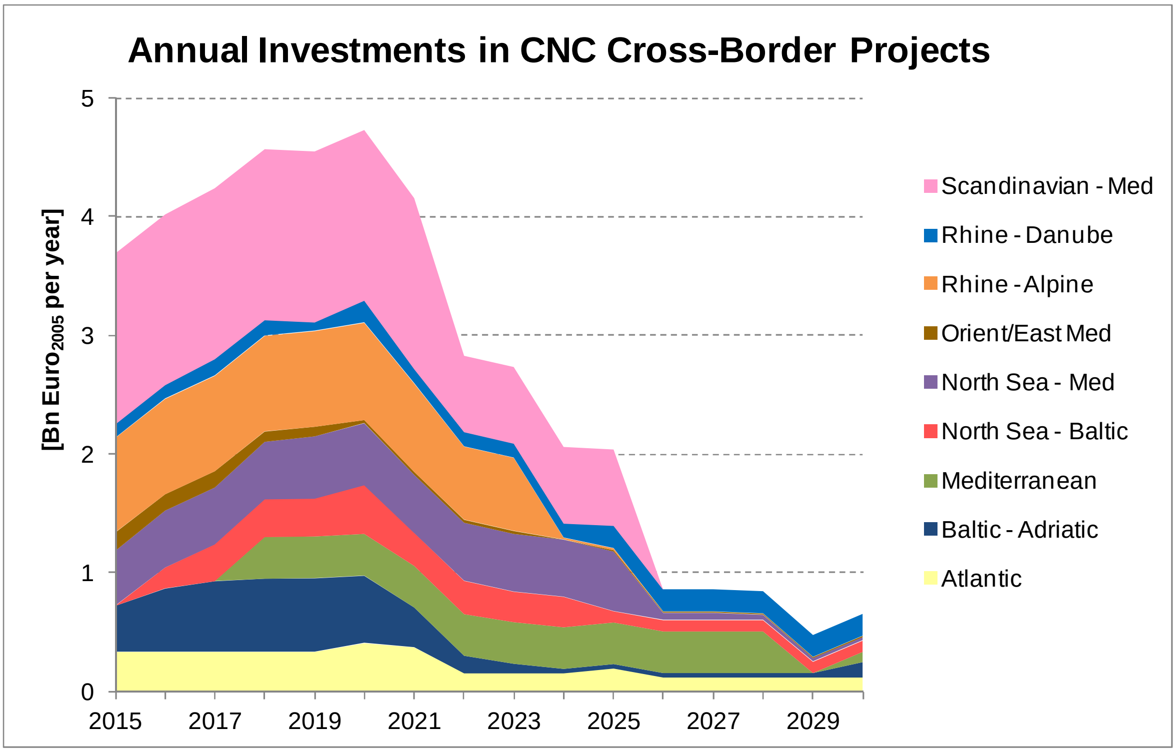
Figure 36: Employment reductions as a result of non-completion of the nine CNC, sorted by skill level

8 Sensitivity analyses of major elements of TEN-T

This chapter elaborates the potential impacts if important building blocks of the TEN-T policy would not be implemented between 2015 and 2030, and finally synthesizes the findings of all analysed scenarios to provide conclusions on the cost of non-completion of TEN-T. While the first scenario assesses wider economic impacts of a non-completion of major cross-border projects, the second scenario focuses on the impacts of a non-delivery of horizontal priorities respectively innovative technologies within the CNC.

8.1 Impacts of large cross-border projects

TEN-T infrastructure projects crossing borders of EU member states play a significant role in the design of the TEN-T policy and for the purpose of overcoming bottlenecks and stimulating international transport. Bottlenecks at borders and resulting impacts on travel time can be caused by missing transport links, but also by different standards like for gauge, for travel management systems, etc. Closing these gaps and overcoming the bottlenecks can have significant impacts on travel time. Therefore, the wider economic impacts of these cross-border projects in relation to money invested are most probably higher than for a single CNC or the non-completion of all nine CNC.



Source: EC/Fraunhofer-ISI

Figure 37: Annual CNC investments in cross-border projects per CNC

As for the assessment of all previous scenarios, the assessment of a non-completion of large CNC cross-border projects (called *No CNC Cross-Border* scenario) builds on the list of CNC projects produced and delivered by the EC in December 2014. Again, the *No CNC Cross-Border* scenario presumes that CNC cross-border projects being part of the *Reference Scenario* are not realised such that we are speaking about avoided investments. The EC experts involved in the CNC analyses selected 141 CNC infrastructure projects belonging to the category of “cross-border” projects based on the definition in the work plans of the nine single CNC. They do not need to be large in the sense of amount of money planned for the project but in the sense of their impact on cross-border transport activities. According to the most recent list of investments of the nine CNCs, the 141 selected cross-border projects are supposed to cost about € 43.3 billion[11] between 2015 and 2030 for EU28 (€ 43.2 billion for EU27) which is less than 10% of the total investments planned for the nine CNC (€ 467 billion).

Figure 37 shows the pathway of avoided investments for cross-border projects for each CNC between 2015 and 2030 for EU28. About 29% of the avoided CNC investments in this scenario are assigned to Scandinavian-Mediterranean corridor which is mainly a result of the two large cross-border projects (Fehmarn-Belt fixed link and Brenner base tunnel). The CNC Rhine-Alpine and North Sea-Mediterranean follow with 16% respectively 13% of the total avoided CNC cross-border investments. As for the CNC Scandinavian-Mediterranean, the pathway of planned investments in cross-border projects is driven by large projects like the Base Tunnel of Lyon-Turin or the rail project Karlsruhe-Basel. The timing of the investments shows a peak around the year 2020 and a steep decrease after 2025. The timing of the annual investments between 2015 and 2030 influences the final outcome in such a way that investments being realised earlier induce higher second and third round effects in the year 2030.

Table 24 provides an overview of the avoided CNC investments in cross-border projects by EU member state. About € 9.4 billion less CNC cross-border investments are supposed for France between 2015 and 2030, about € 7.1 billion are less invested in German cross-border projects and € 5.6 billion in Denmark. Austria and Italy follow by avoided investments of about € 4.6 billion respectively € 4.2 billion. As opposed to the *No CNC* scenario, not all EU member states are affected directly by avoided investments in this scenario. The list of avoided CNC cross-border projects does not cover projects in Cyprus, Greece, Ireland, Luxemburg, Malta, Sweden, United Kingdom.

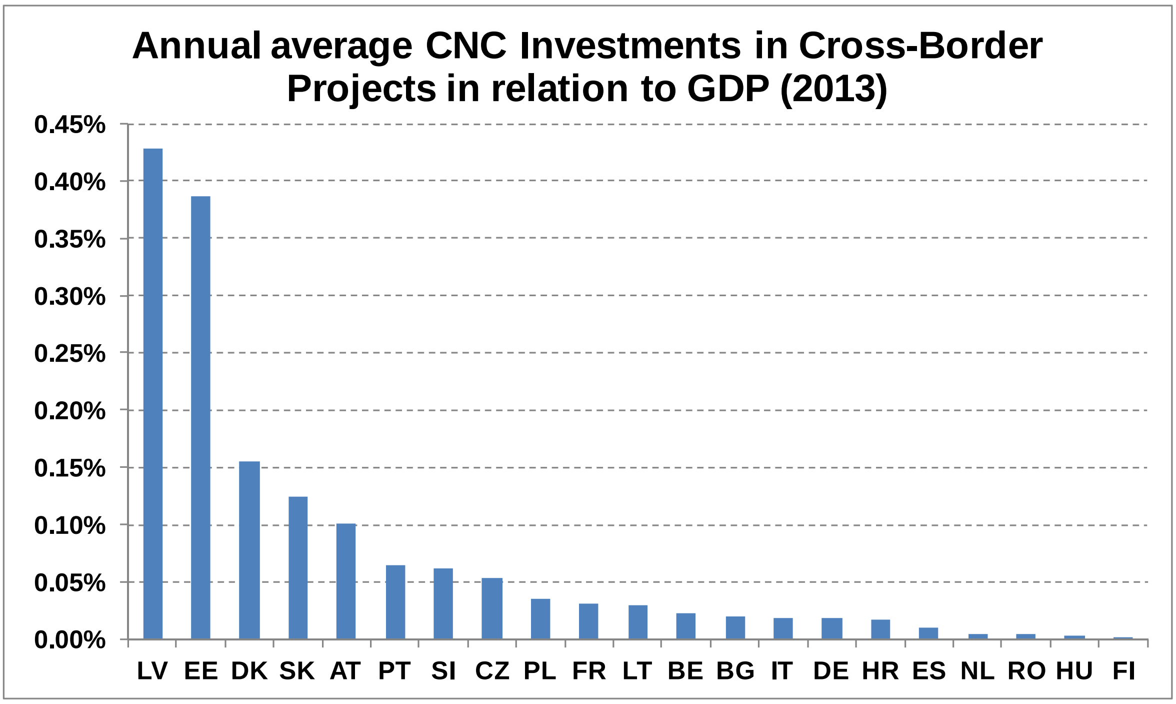
[11] All monetary values in ASTRA-EC are expressed in real terms as constant Euro 2005 using an EU27 deflator of 0.9016 for conversion from current to constant Euro 2005

Table 24: Avoided investments per member state for *No CNC Cross-Border* [Mio $Euro_{2005}$]

MS	2015-2020	2021-2025	2026-2030	MS	2015-2020	2021-2025	2026-2030
AT	2,771	1,650	129	HU	49	0	0
BE	714	448	53	IT	2,451	1,697	85
BG	115	0	0	LT	102	49	0
CZ	769	228	156	LV	801	641	0
DE	3,722	2,453	971	NL	359	60	0
DK	4,771	795	0	PL	1,677	311	0
EE	94	471	471	PT	1,316	219	0
ES	661	398	398	RO	89	0	0
FI	2	0	0	SI	316	0	0
FR	3,773	4,222	1,404	SK	1,164	135	0
HR	74	36	0				

Source: EC/Fraunhofer-ISI

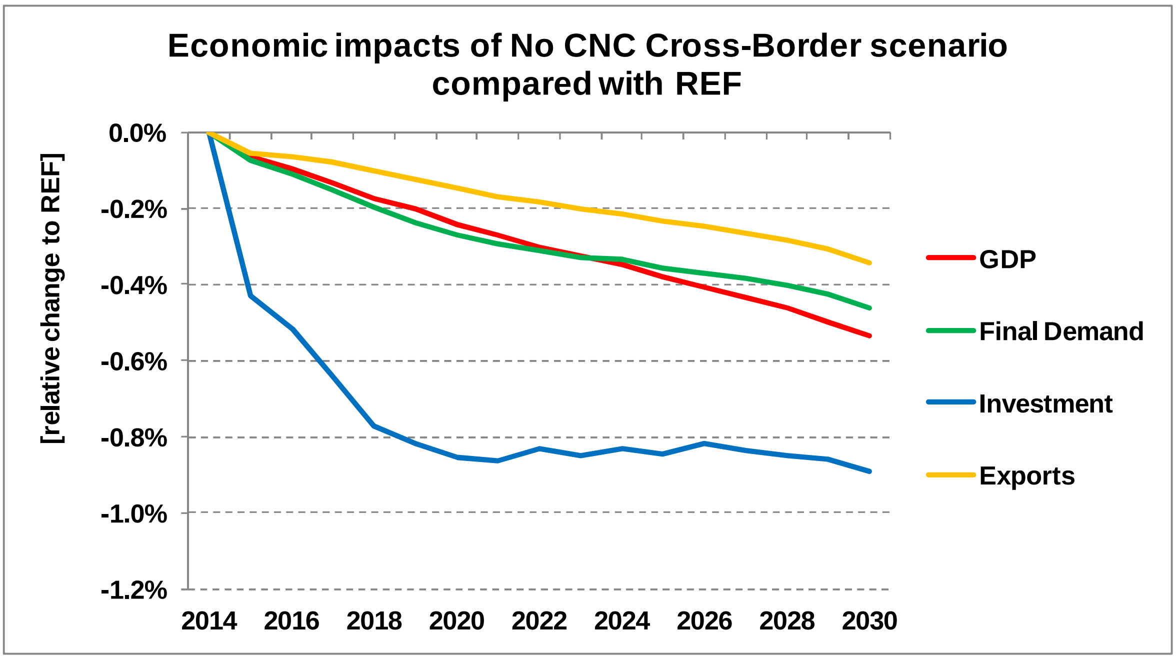
Besides the member states mentioned above especially Latvia, Estonia, Slovakia and Czech Republic are outstanding when comparing the average annual avoided investments in CNC cross-border projects with GDP (of the year 2013). This indicator highlights the effort for each member state (see Figure 38). In the case of Latvia the average annual CNC investments in cross-border projects compared with GDP are by 0.43% the highest followed by Estonia and Denmark.



Source: Fraunhofer-ISI

Figure 38: Annual average CNC cross-border investments in relation to GDP

Figure 39 shows the wider economic impacts for the *No CNC Cross-Border* scenario for EU27 between 2015 and 2030. The impacts are presented in terms of relative change compared with the *Reference Scenario* (REF) development (see chapter 5.2).

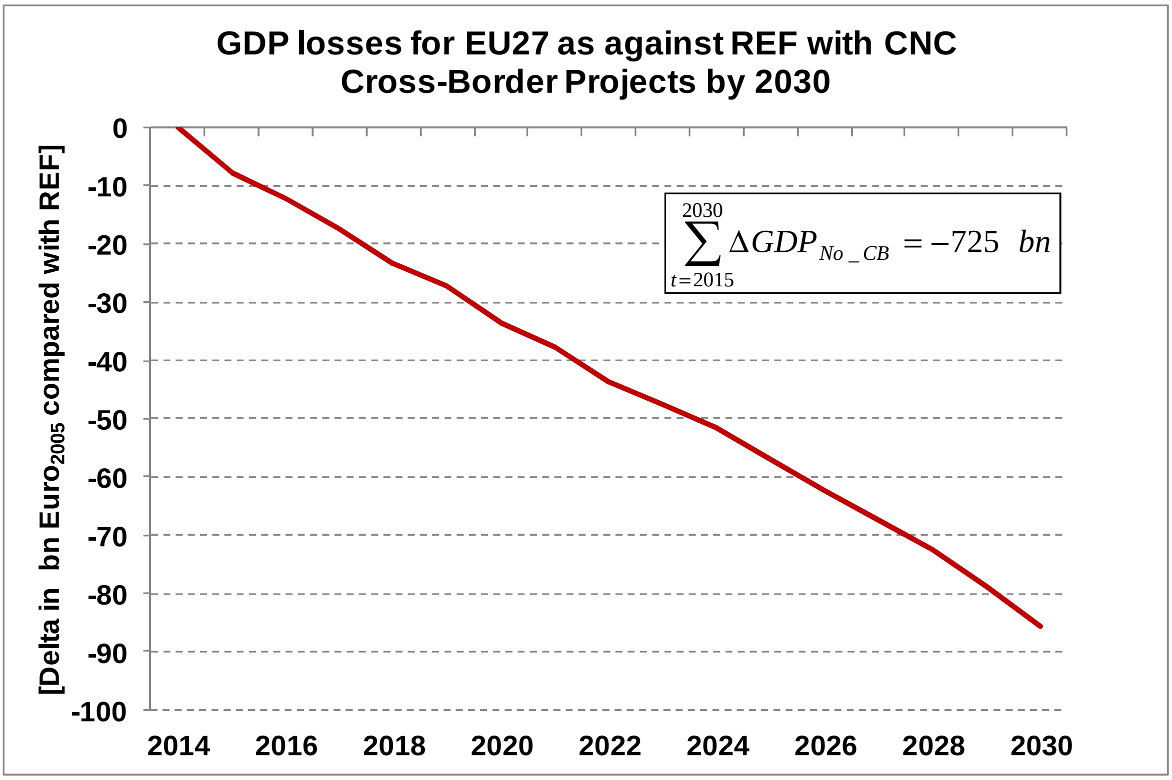


Source: Fraunhofer-ISI

Figure 39: Relative change of major economic indicators as compared with REF in EU27

The combination of avoided CNC cross-border project investments, not realized travel time and cost improvements creates negative impulses on GDP of -0.5% as compared with REF in the year 2030. ASTRA-EC assesses a decrease of GDP in absolute terms of about € 86 billion for *No CNC Cross-Border* compared with the REF scenario in 2030. Accumulating the annual losses of GDP for EU27 between 2015 and 2030 as compared with the REF scenario would amount to about € 725 billion (see Figure 40). Expressed in less average annual growth of GDP it would be about -0.03 percentage points less for the period between 2015 to 2030. The combination of direct avoided investments, indirect effects on investments in other sectors and second-round effects on investments less strong growth of GDP ends up at about -0.9% less investments in EU27 in the year 2030.

The reaction of the ASTRA-EC model on Exports within the EU in this scenario is similar to the reaction of the two CNC analyses and the assessment of the non-completion of all nine CNC. The negative impact of not realized travel time and cost reduction on exports is measureable but limited. Exports between EU member states are supposed to be stronger affected by labour productivity per sector and the GDP level of the trading partners. As compared with the REF scenario, exports are expected to decrease in the *No CNC Cross-Border* scenario by about -0.4% in 2030.

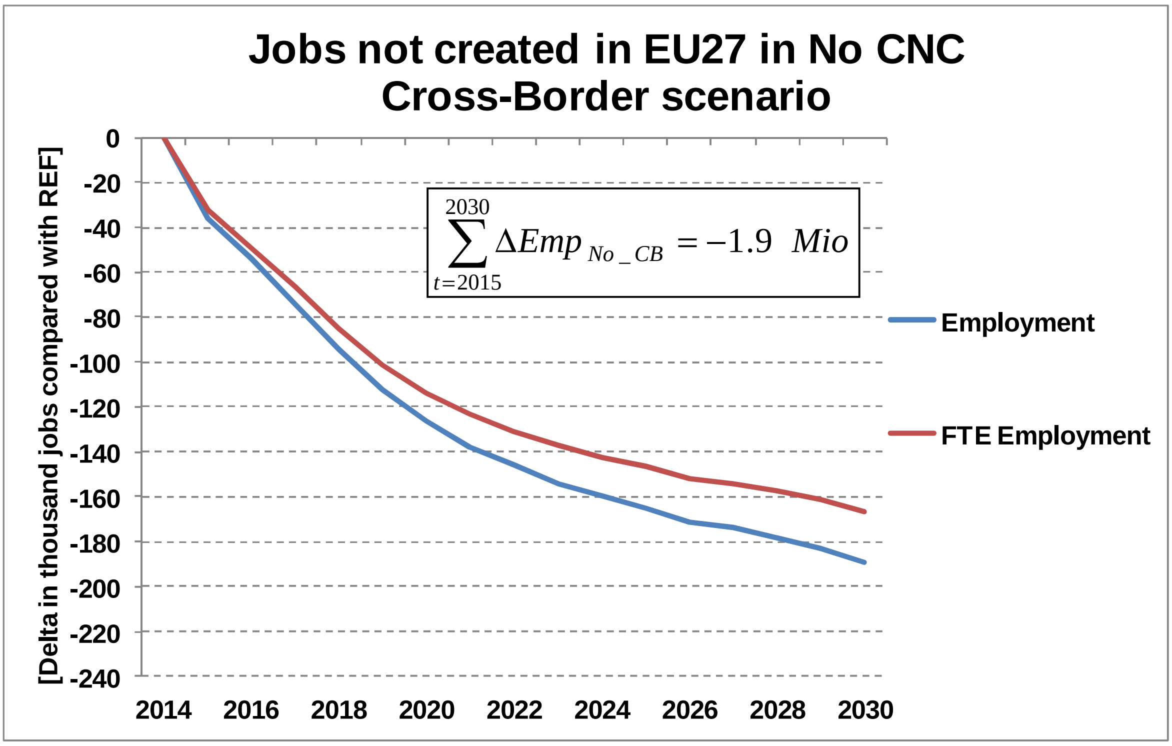


Source: Fraunhofer-ISI

Figure 40: Annual and accumulated loss of GDP as compared with REF in EU27

The impact chain of the *No CNC Cross-Border* scenario leading to long-term negative impacts on EU27 labour market is the same as for the three previous scenarios. Figure 41 illustrates the number of jobs not created in EU27 due to the non-completion of CNC cross-border projects. The calculation with ASTRA-EC shows that the non-completion of CNC cross-border projects will lead to a reduction of about 166 thousand full-time equivalent jobs compared with REF in 2030. Expressed in total jobs (counting full-time and part-time jobs both as one) about 188 thousand jobs could be less created in 2030. Expressed in relative terms, this is equal to a decrease of -0.1% compared with REF. The difference between the decrease of full-time equivalent and total jobs is mainly driven by the high share of part-time employment in the Construction sector which is the economic sector strongest affected by the *No CNC Cross-Border* scenario.

As for wider economic impacts the pathway of labour market changes between 2015 and 2030 is important. Therefore, the accumulation of impacts needs to be taken into account as well. The simulation of the *No CNC Cross-Border* scenario with ASTRA-EC leads to an accumulation of annual full-time equivalent job losses (FTE-yob years) between 2015 and 2030 for EU27 of about -1.9 million.

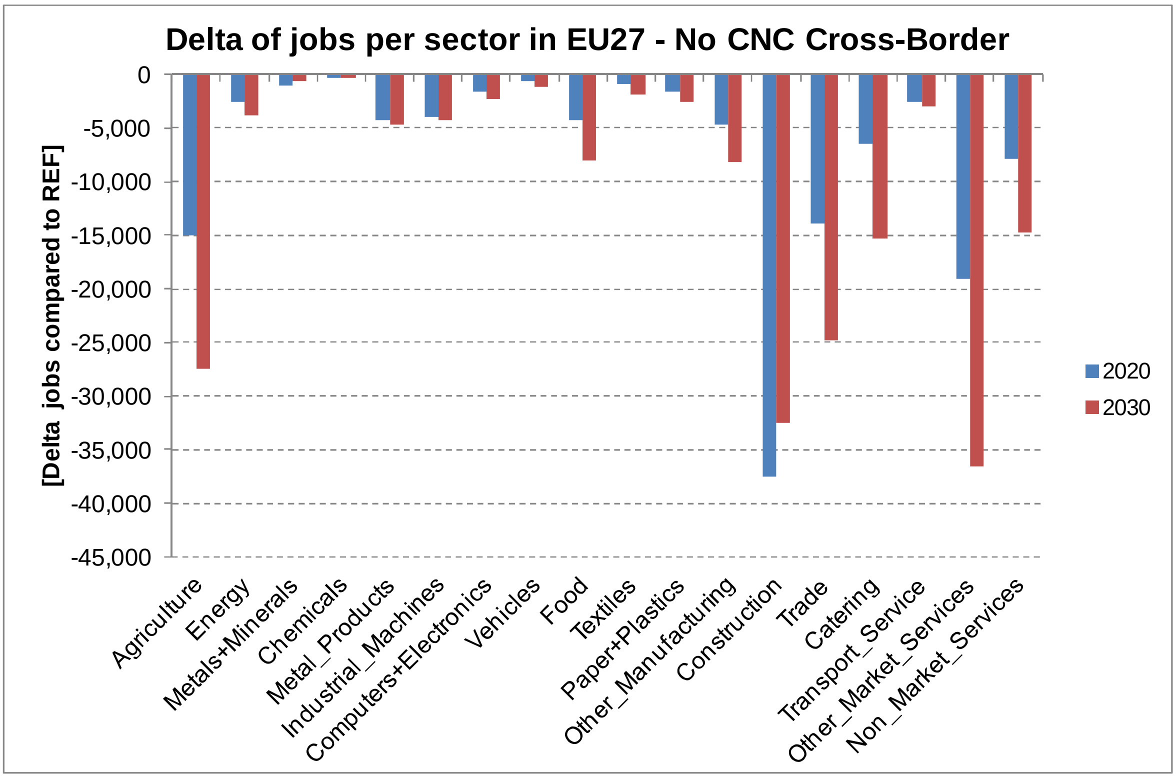


Source: Fraunhofer-ISI

Figure 41: Delta of jobs (total and full-time equivalent) and in EU27 in *No CNC Cross-Border*

Like in the case of the *No CNC* scenario, the avoided investments in CNC cross-border projects were at first stage assigned towards six economic sectors. The share of investments going into the six sectors depends on the type of investment (e.g. bridge, tunnel, etc.) as described in chapter 5.2. Besides for the categories *Innovation* and *Study*, the highest share of avoided investments still belongs to the *Construction* sector. Figure 42 provides an overview of the impacts of a non-completion of the selected 141 CNC cross-border projects on the different economic sectors covered by ASTRA-EC. It presents the changes in terms of jobs not created per sector in EU27 for the year 2020 and 2030. It shows the reaction on total jobs, not full-time equivalent jobs. Like for the previous scenario assessment results, the figure allows a first estimation about direct and indirect effects of the *No CNC Cross-Border* scenario. Direct effects only concern the changes of employment in the six sectors that have to cope with avoided investments: *Metal Products, Industrial Machines, Computers, Electronics, Construction* and *Other Market Services*. Besides the direct negative impacts from avoided infrastructure investments, not realizing travel time and cost reductions affects the labour market indirectly via the change of input-output table coefficients and further second-round effects (described in chapter 5.1). As an example: A reduction of investments in the *Construction* sector leads to decreasing demand for intermediate products and services simulated via input-output tables in ASTRA-EC.

Figure 42 proves that the impulses from the *No CNC Cross-Border* scenario negatively affect employment in all sectors. Besides the *Construction* sector also *Other Market Services*, *Trade*, *Non Market Services*, *Catering* (which includes tourism) and *Agriculture* sectors are stronger affected by job losses as compared with the REF scenario in the year 2020 and 2030. ASTRA-EC projects for *No CNC Cross-Border* about 37 thousand jobs less in the *Other Market Service* sector in EU27 in 2030, about 33 thousand jobs less in the *Construction* sector and around 25 thousand jobs less in the *Trade* and the *Agriculture* sector. The reason for the strong impact on employment in sectors with lower labour productivity is already being discussed in the analyses of the three previous scenarios.

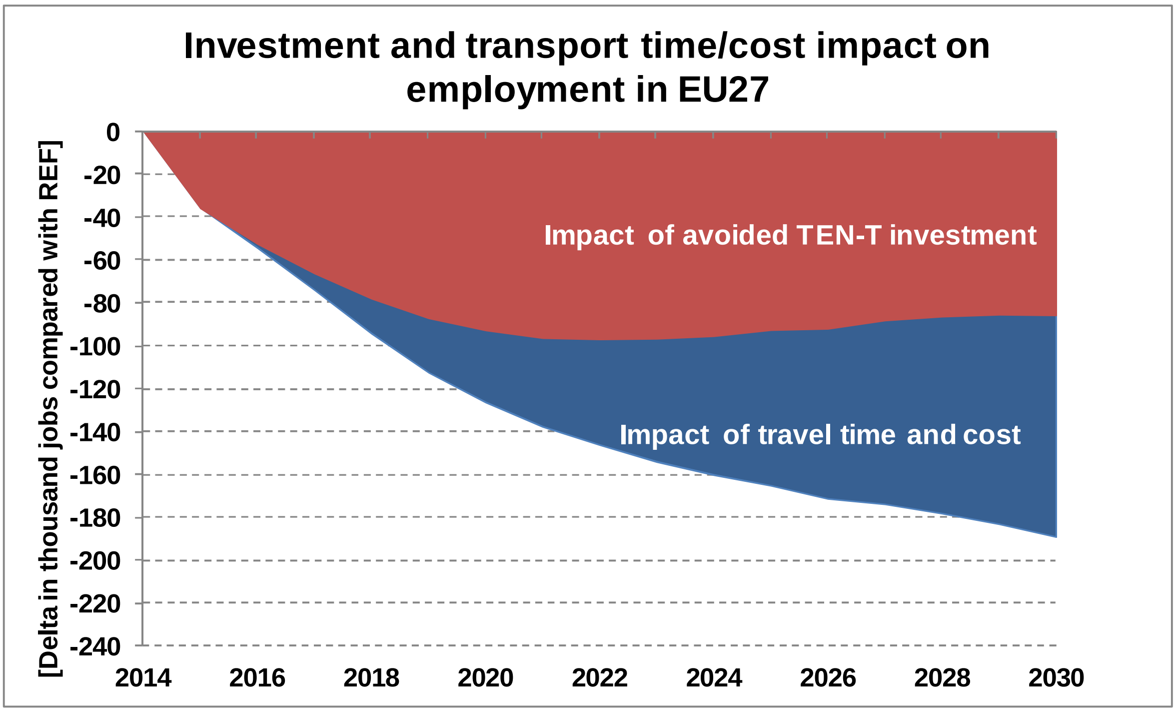


Source: Fraunhofer-ISI

Figure 42: Number of jobs not created per sector in EU27 for *No CNC Cross-Border* as compared with REF

Like for the previous three scenarios of this study, the expected change of employment in the *Transport Service* sector is moderate for the *No CNC Cross-Border* scenario. The impact on employment in the transport service sector is mainly a result of a modal shift induced by the different level of non-completion of infrastructure investments and resulting time and cost changes for the transport modes. As the highest share of CNC cross-border investments are planned for rail, ASTRA-EC reacts as a consequence with a modal shift, both for passenger and freight transport from rail towards the less affected modes road and maritime transport. Labour productivity in the road transport sector differs from the rail sector which has a higher labour productivity. Therefore, the loss of jobs in the rail sector is supposed to be nearly compensated by the slight increase in the road sector induced by the modal shift.

The displayed impacts on employment and the wider economic impacts cover all types of impacts: direct, indirect and second-round impacts. Thus, it can be considered as net impact which is supposed to be closest to reality. While the three types of impacts can only hardly be isolated, ASTRA-EC enables switching off the impacts of travel time and travel costs on jobs in order to show the pure economic impact of avoided investments. Figure 43 provides a decomposition of the number of jobs not created in the *No CNC Cross-Border* scenario in EU27 as compared with the REF scenario. Direct impacts of avoided investment appear strongly in the first years. Travel time and cost changes reaches its climax only in 2030. While in the previous *No CNC* scenario investments are by 55% responsible for the employment impact, travel time and cost changes in the *No CNC Cross-Border* scenario are by 55% responsible for the negative change of employment. This highlights the effectiveness of the cross-border projects in terms of travel time and cost reduction potential as compared with investments.



Source: Fraunhofer-ISI

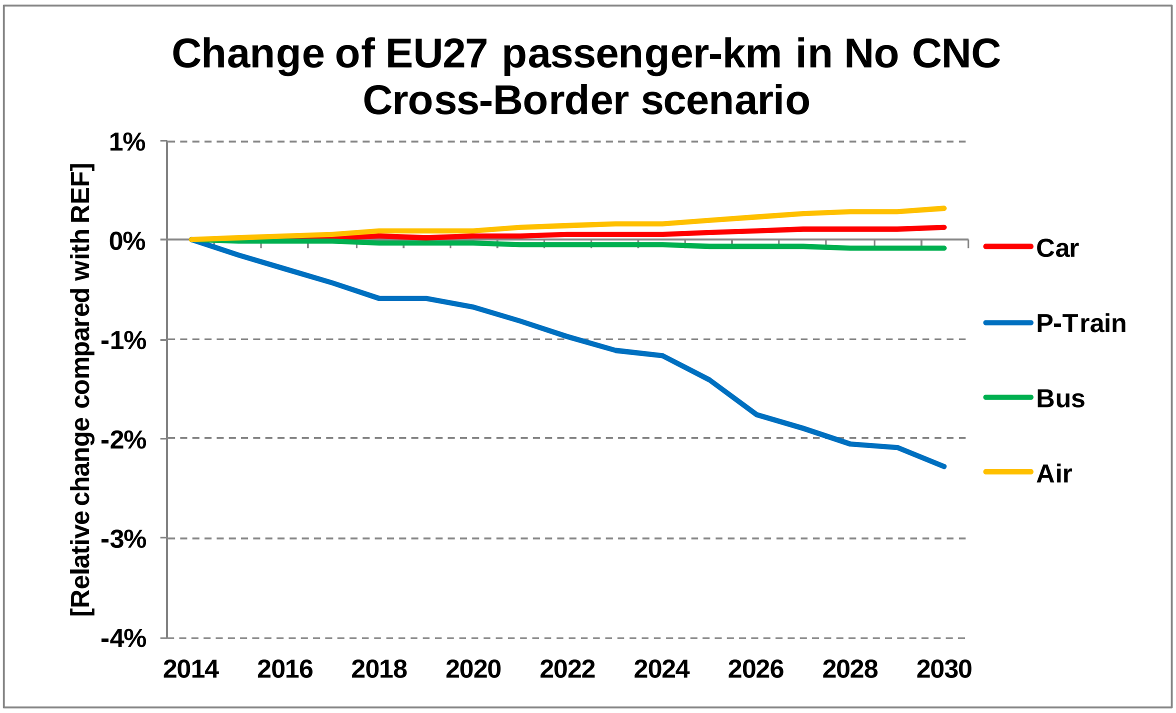
Figure 43: Decomposition of investment and transport time/cost impacts on jobs (not FTE) in EU27

Taking the job impact in relation to the avoided investments, the job impacts are significantly lower for the first three scenarios (*No CNC ScanMed*, *No CNC RhAlp* and *No CNC*) than for *No CNC Cross Border*. Expressed in number of FTE-job years not created per bn € not invested in CNC the analysis of the first three scenarios revealed a range between 14,700 FTE-job years not created per bn € avoided CNC investments in EU27 in and

25,900 FTE-job years not created per bn € avoided investments. As for the *No CNC Cross-Border*, even 44,500 FTE-job years not created per bn € avoided investments in EU27 is the result of the simulation with ASTRA-EC. Even if some CNC cross-border projects are comparably expensive, they almost all bear a high travel time and cost reduction potential which is the driver of the higher effectiveness of this project type.

As for all five scenarios the same, the calculation considers the accumulated number of full-time-equivalent jobs not created as against the REF in the year 2030 and the accumulated annual avoided investments in CNC cross-border projects between 2015 and 2030.

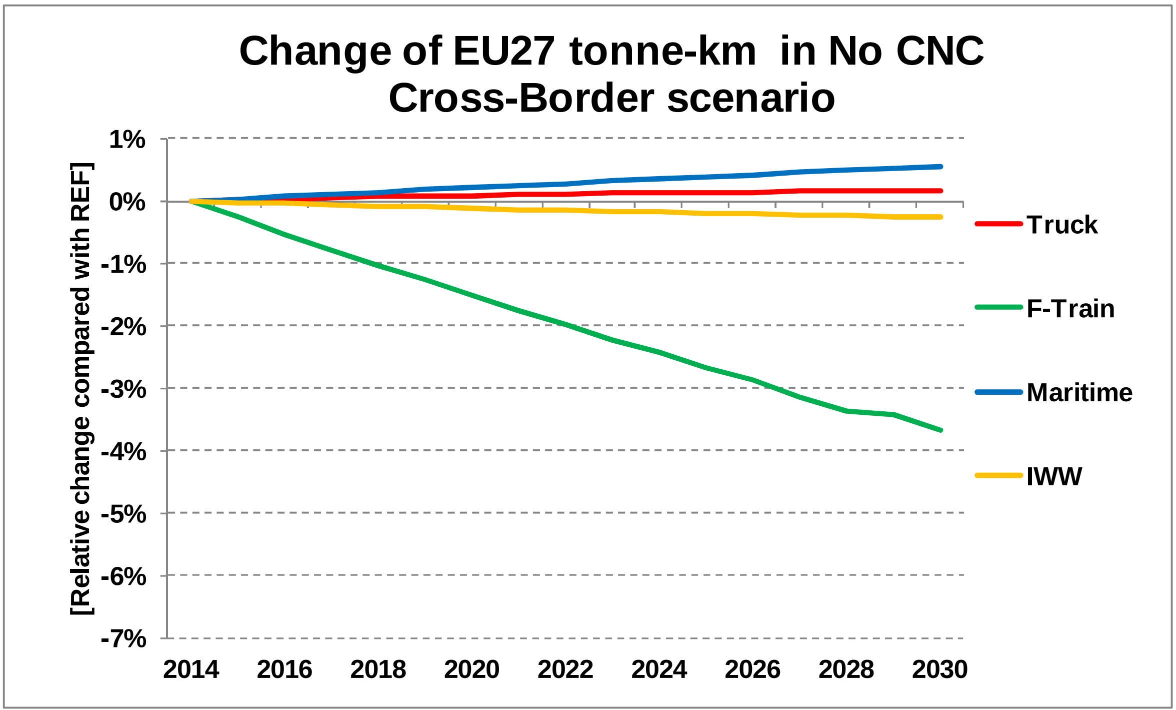
Travel time and cost changes are supposed to change exports and total factor productivity in a minor way. The major impulse from the change of travel time and costs are obviously the direct impacts on travel demand. It changes the distribution choice over time and leads to increasing demand on those O/D relations benefiting from an infrastructure measure via reduction of travel time and costs. Furthermore, the modal shift on the respective relation but also on the total transport performance for both, freight and passenger transport is influenced directly.



Source: Fraunhofer-ISI

Figure 44: Relative change of passenger-km per mode in EU27 as compared with REF

Figure 44and Figure 45 illustrate the impacts of *No CNC Cross-Border* on total passenger-km and tonne-km travelled per mode for EU27 as compared with the REF scenario. ASTRA-EC estimates a moderate decrease of total passenger-km and tonne-km in EU27 in the year 2030. They are both expected to be by about – 0.1% lower in 2030 than in the REF with full core TEN-T network.



Source: Fraunhofer-ISI

Figure 45: Relative change of tonne-km per mode in EU27 as compared with REF

A similarity between the previously presented three scenarios and the *No CNC Cross-Border* scenario is the reaction on the different modes. Like for the non-completion of all nine CNC, the majority of the number of cross-border infrastructure projects as well as the amount of investments planned in this scenario are rail projects followed by IWW projects. Only few projects directly change the transport performance of road modes. Air and maritime transport are not even part of the list of CNC cross-border projects defined by the EC. Hence, the transport model reacts on a non-completion of major CNC cross-border projects via a modal shift from rail towards road for both, passenger and freight transport. In the case of passenger transport, air transport benefits most. For freight transport, tonne-km by ship is expected to increase slightly.

8.2 Impacts of innovative technologies

The last of the five scenarios conducted in this study deals with the non-deployment of innovative technologies within the nine CNC as defined by Article 33 of the TEN-T guidelines (EC REG No 1315/2013). This sensitivity scenario is called *No CNC Innovation* scenario and compares the case without deploying innovative technologies as planned in the work plans of the nine CNC with the reference case considering all nine CNC with innovative technologies. According to the definition, they include mainly technologies for decarbonising transport, for making transport smarter, safer and less noisy, for improving interoperability and multimodality and for optimising transport flows via telematic applications. The latter are part of Article 31 and tackle ERTMS, RIS, ITS, VTMIS and SESAR.

In order to identify the sections that in the core TEN-T network that are expected to be deployed with innovative technologies in the period from 2015 and 2030, those projects in the list of investments provided by the EC were selected that included an innovative technology in the sense of Article 33. As the work plans of the nine CNC included also projects consisting not only of an innovative technology but also of a classical infrastructure measure, the share of investment requested for the innovative technology was assessed. This referred mainly to ERTMS projects such that in this case the length of the section was multiplied by an average cost factor for deploying the single parts of ERTMS (ECTS and GSM-R)[12]. As the list of CNC projects did not cover investments in SESAR, the deployment of SESAR was added. The impacts in terms of travel time changes as well as the requested investments were taken from SESAR Joint Undertaking (2011). The requested total investments for the deployment of SESAR of about € 23.1 billion[13] were split by member state using the statistics on number of passenger departures for major European airports for the year 2013.

In total, about 450 projects of the long list of 2,679 CNC investments are at least partly containing an innovative technology as defined by Article 33 of the TEN-T guidelines. According to the list of investments and the planned timing of the deployment of innovative technologies, about € 40.9 billion are requested for the deployment of innovative technologies for EU28 in the period from 2015 and 2030. A large share of the investments is planned for the deployment of SESAR and ERTMS.

Table 25 provides an overview of the distribution of investments in CNC innovative technologies among the 28 EU member states. The highest investments for the period from 2015 to 2030 are planned for Germany (€ 4.7 billion), United Kingdom (€ 4.7 billion), Spain (€ 4.4 billion), Italy (€ 4.2 billion) and France (€ 3.8 billion).

12 The cost factors are derived from EC (2013): Is Commercial Cellular Suitable for Mission Critical Broadband? Final report of the study on use of commercial mobile networks and equipment for "mission-critical" high-speed broadband communications in specific sectors for the EC. SCF Associates LTD, 2013.

13 All monetary values are expressed in constant Euro 2005 deflated with an EU27 deflator from Eurostat.

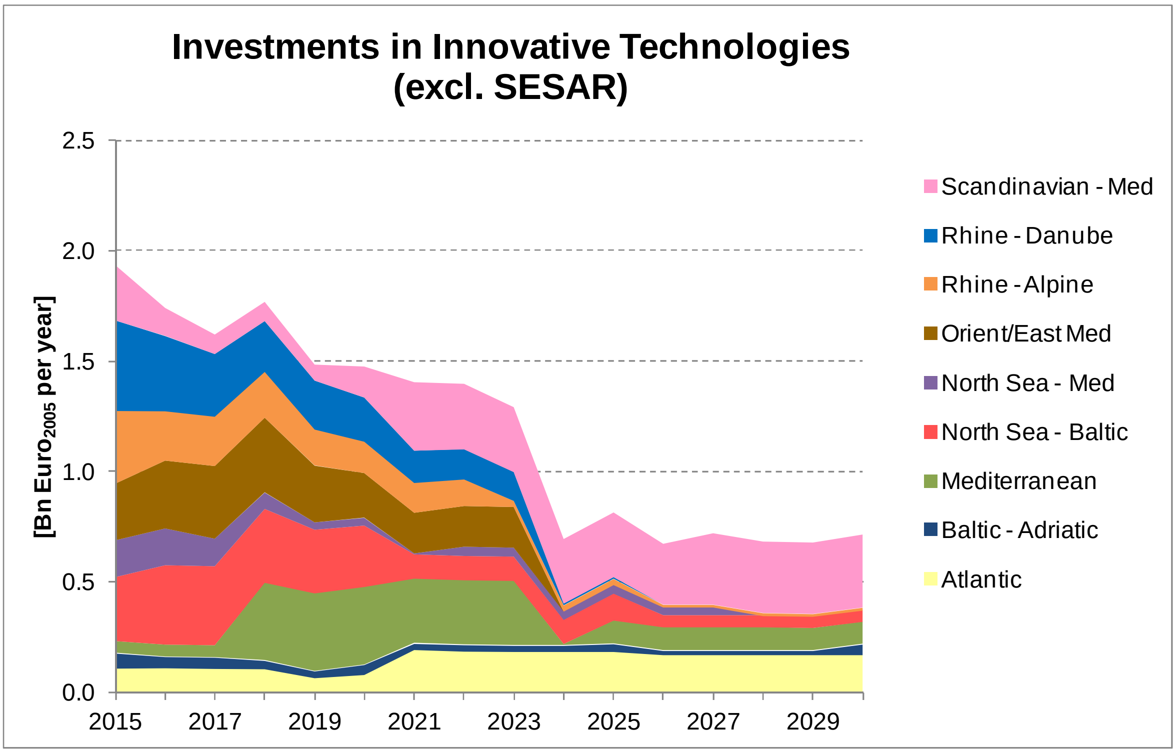
Table 25: Avoided investments per member state for *No CNC Innovation* [Mio Euro$_{2005}$]

MS	2015-2020	2021-2025	2026-2030	MS	2015-2020	2021-2025	2026-2030
AT	346	117	143	IE	168	109	109
BE	1,111	629	117	IT	1,480	1,450	1,270
BG	52	16	16	LT	77	8	8
CY	37	16	16	LU	6	5	5
CZ	2,241	950	26	LV	760	224	224
DE	2,209	1,260	1,206	MT	15	9	9
DK	149	1,261	1,261	NL	884	470	514
EE	115	4	4	PL	250	180	166
EL	186	150	150	PT	223	824	817
ES	1,791	1,367	1,220	RO	501	71	22
FI	876	74	74	SE	266	140	329
FR	1,620	1,180	1,022	SI	143	70	3
HU	680	485	19	SK	131	4	3
HR	22	27	9	UK	1,872	1,404	1,404

Source: EC/Fraunhofer-ISI

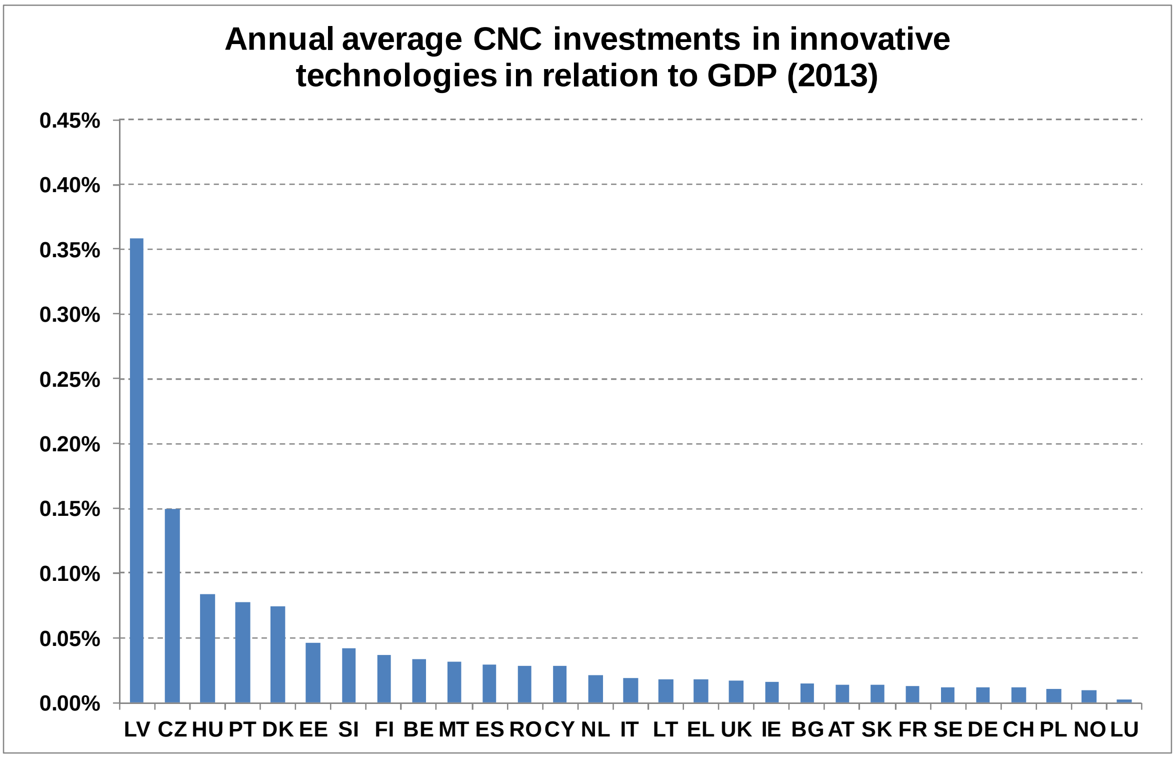
The shape of the pathway of avoided investments in CNC innovative technologies is similar to the development of the previous scenarios. The largest share of investments is requested for the period between 2015 and 2023. Especially for the three CNC Rhine - Danube, Rhine – Alpine and Orient – East Mediterranean, there are only few investments in innovative technologies planned after 2023.

Figure 46 illustrates this pathway of investments and the distribution of the CNC investments in innovative technologies per corridor over time. Investments in the deployment of SESAR are excluded in this figure as they are not part of the work plans of the single CNC and, thus, could not be allocated to them. In total about 20% of the total investments (€ 3.8 billon) in innovative technologies are planned for CNC Scandinavian-Mediterranean. The share on total investments for CNC North Sea – Baltic, Mediterranean, Atlantic, Orient – East Mediterranean and Rhine – Danube range between 11% and 14% (between € 2.1 billion and € 2.8 billion).



Source: EC/Fraunhofer-ISI

Figure 46: Annual CNC investments in innovative technologies (excl. SESAR) per CNC

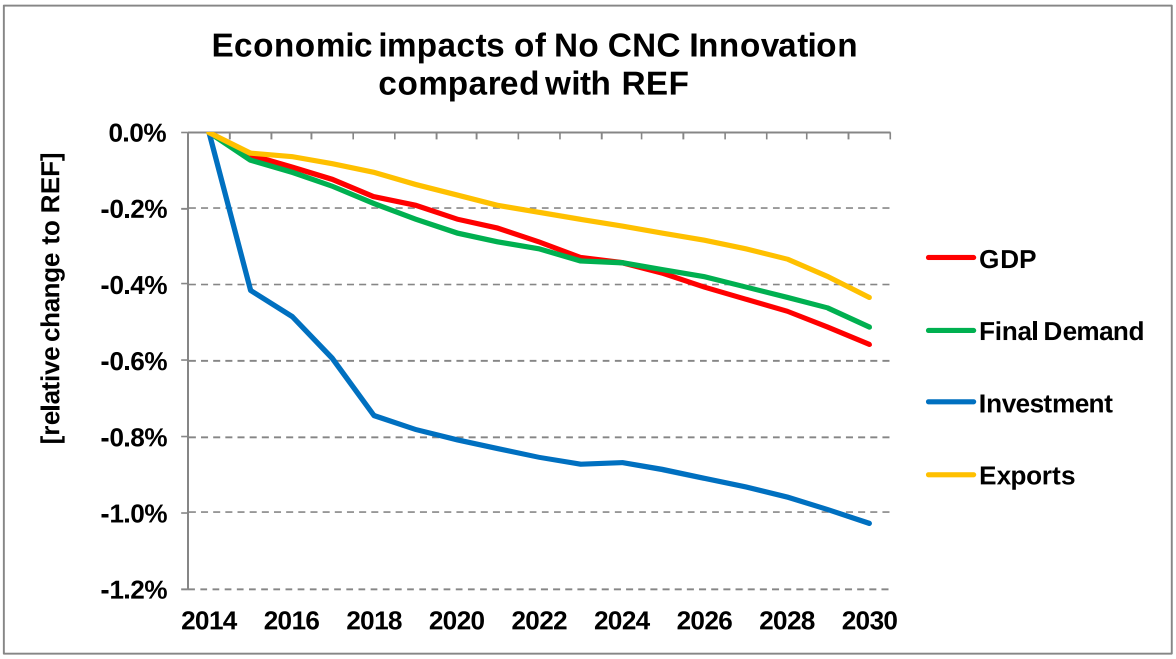


Source: Fraunhofer-ISI

Figure 47: Annual CNC investments in innovative technologies in relation to GDP

Besides the larger EU economies, some smaller EU member states have to compensate high investments in innovative technologies compared with GDP. The planned deployment of innovative technologies accumulate in Latvia and Czech Republic to € 1.2 billion respectively € 3.2 billion. On average over all 16 years between 2015 and 2030, Latvia hast to spend about 0.35% of GDP in the deployment of CNC innovative technologies, Czech Republic about 0.15%.

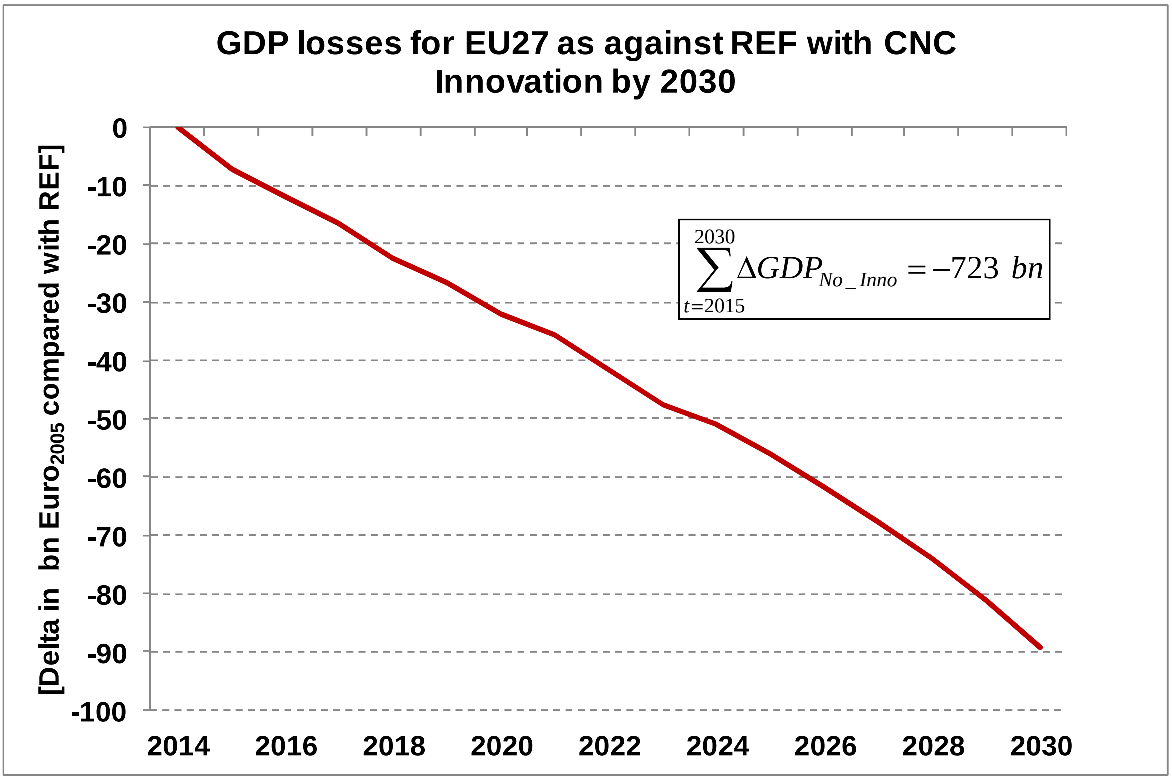
The overall economic development in the *No CNC Innovation* scenario is compared with the *Reference Scenario* negative. ASTRA-EC assesses the negative impulses of avoided investments, not achieved travel time and cost reduction by about -0.6% lower GDP compared with REF for EU27 in 2030. The combined direct, indirect and second-round effects of *No CNC Innovation* on investments accumulate to -1% less investments as compared with REF in 2030. Exports are less affected by the non-deployment of innovative technologies and are expected to decrease by – 0.5% in 2030. Obviously, the reaction on exports would be stronger when considering missing lead market effects. An assumption on the potential of the single innovative technologies for being attractive to transport systems outside the EU was not made.



Source: Fraunhofer-ISI

Figure 48: Relative change of major economic indicators as compared with REF in EU27

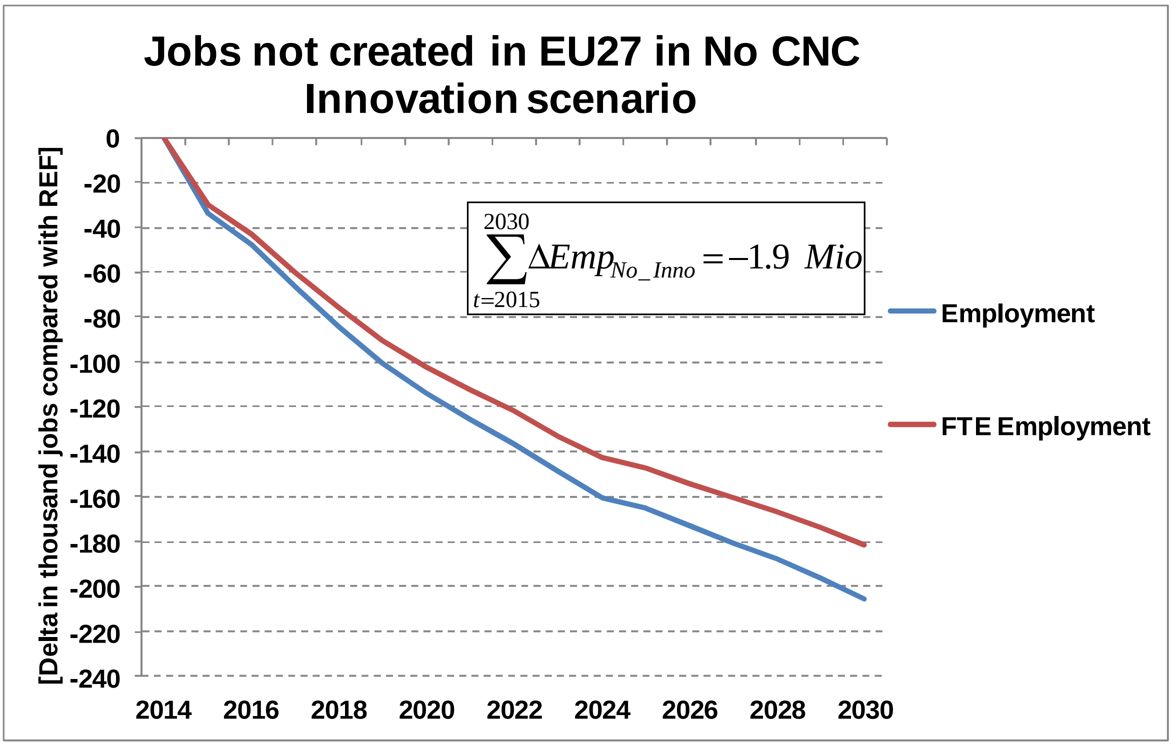
In absolute terms, not deploying the CNC with requested innovative technologies like SESAR, ERTMS, etc. would lead to GDP being by about € 89 billion lower than in the REF in 2030. Summing up all not realized gains in GDP would amount to € 723 billion for EU27 between 2015 and 2030.



Source: Fraunhofer-ISI

Figure 49: Annual and accumulated loss of GDP as compared with REF in EU27

Even if the level of avoided investments is by € 40.9 billion for the *No CNC Innovation* scenario compared with the analysis of *No CNC* and the two CNC Scandinavian-Mediterranean and Rhine-Alpine comparably low, the impacts on employment are significant. This highlights the importance of impulses coming directly from the reduction of travel times and costs. Figure 50 shows the change of employment (total employment and full-time equivalent employment) in EU27 compared with REF. ASTRA-EC calculates up to 181 thousand full-time equivalent jobs less in the *No CNC Innovation* scenario in EU27 in the year 2030. Accounting part-time and full-time employed persons as one, even 206 thousand jobs would be created less without innovative technologies being part of CNC in 2030. Expressed in relative terms, this is equal to a decrease of -0.1% compared with REF in 2030, both for total and FTE employment.

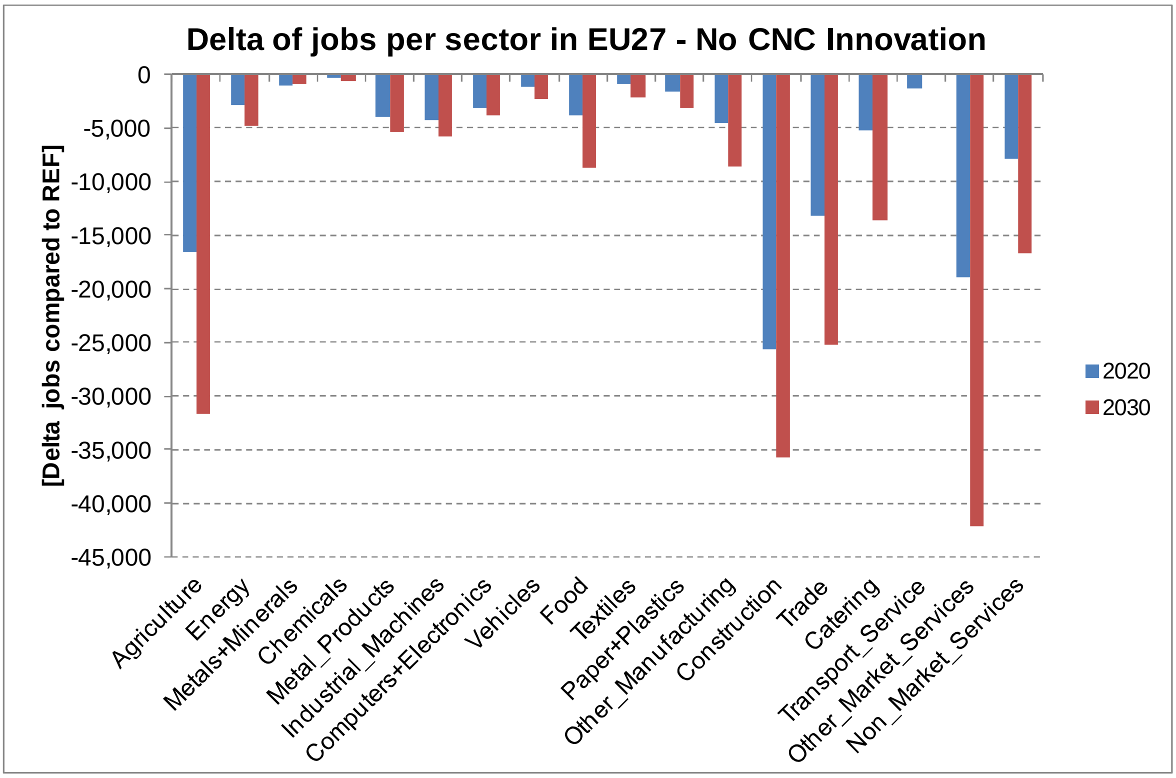


Source: Fraunhofer-ISI

Figure 50: Delta of jobs (total and full-time equivalent) and in EU27 in *No CNC Innovation*

Figure 51 demonstrates the sectoral impact of a non-deployment of CNC innovative technologies for EU27. The graph shows the deltas in total jobs not created for the economic sectors covered with ASTRA-EC. The differences of jobs per sector reflects the direct impacts of avoided investments and as a direct consequence decreasing gross value added but as well the indirect effects from omitted travel time and cost savings and resulting economic second round effects.

Even if the sectors Computers and Electronics are directly influenced by avoided investments in innovative technologies, the comparably high labour productivity in both sectors lead to an only moderate decrease of number of jobs in EU27 in these two sectors. The strongest impacts of the *No CNC Innovation* scenario can be observed in the Construction, the Other Market Service, the Trade and the Agriculture sector. The reason for this effect was already elaborated in chapter 6.1 and chapter 8.1. The result of *No CNC Innovation* would be about 50 thousand jobs less in the Other Market Service sector, about 36 thousand jobs less in the Construction sector and 25 thousand jobs less in the Trade sector compared with REF in EU27 in the year 2030.

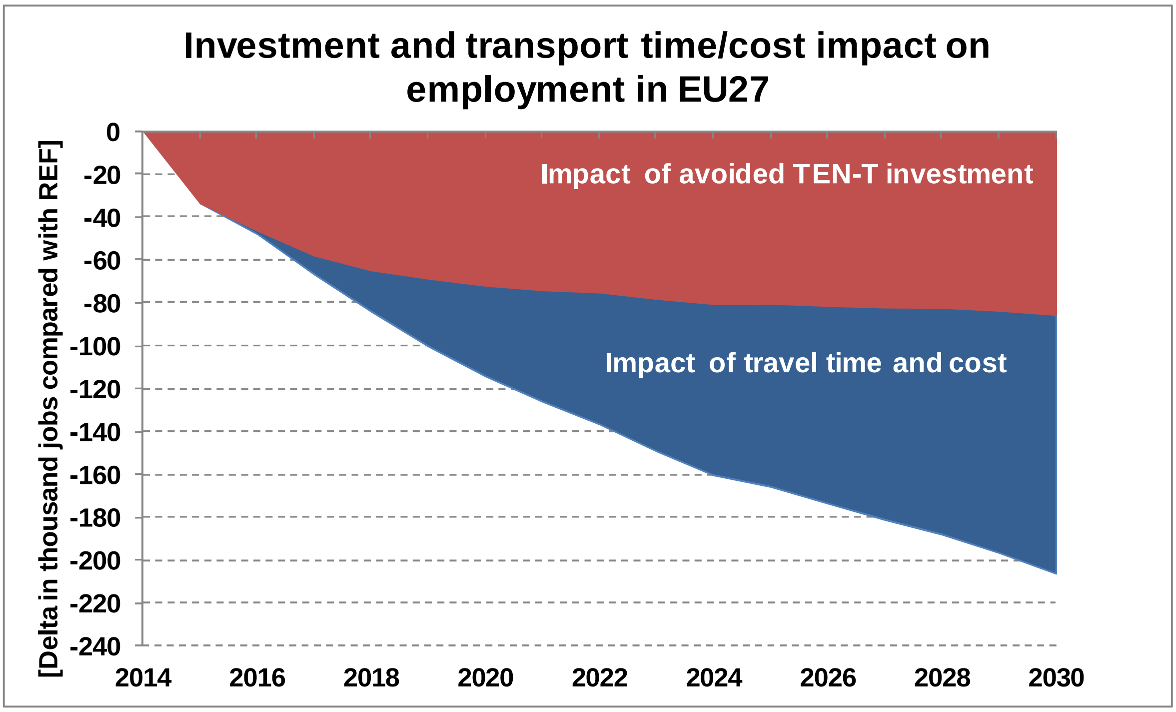


Source: Fraunhofer-ISI

Figure 51: Number of jobs not created per sector in EU27 for *No CNC Innovation* as compared with REF

Differentiating the impulses coming from avoided investments and the impulses starting with not achieved travel time and cost reduction per mode leads to a slightly different picture in the case of *No CNC Innovation* compared with the *No CNC* scenario. The decomposition of the two major impulses is shown by Figure 52. It shows the change of total employment in EU27 whether with only investment impulses or only transport impulses. As opposed to the *No CNC* scenario, the influence of not realized travel time and cost reduction on total employment is significantly higher than the impact of avoided investments. Assuming no changes in travel time and costs would lead to a decrease of total employment of about 85 thousand jobs. This represents only about 40% of the total effect such that travel time and costs affect the loss of employment by 60% in the year 2030.

Having a closer look on the relation between travel time changes to be expected by and investments for the deployment of innovative technologies can help understanding this difference. Less than 9% of the total investments planned for the nine CNC are allocated towards the deploying innovative technologies for the period from 2015 to 2030. Nevertheless, especially technologies like ERTMS and SESAR bear comparably high travel time optimization potentials. Deploying 2^{nd} level ERTMS could improve travel time on some corridors significantly. As indicated for the CNC Rhine-Alpine, the travel time saving is expected to be around 18% (Kritzinger et al. 2013). According to SESAR Joint Undertaking (2011), the deployment of SESAR could save air travel time for average flights by around 10%. Achieving travel time optimization of such intensity by building new transport infrastructure (new motorways, new railway tracks, etc.) would require significantly higher investments. Therefore, the share of employment impact of travel time and cost optimization on the total employment impact is for the deployment of innovative technologies higher than for all CNC projects.

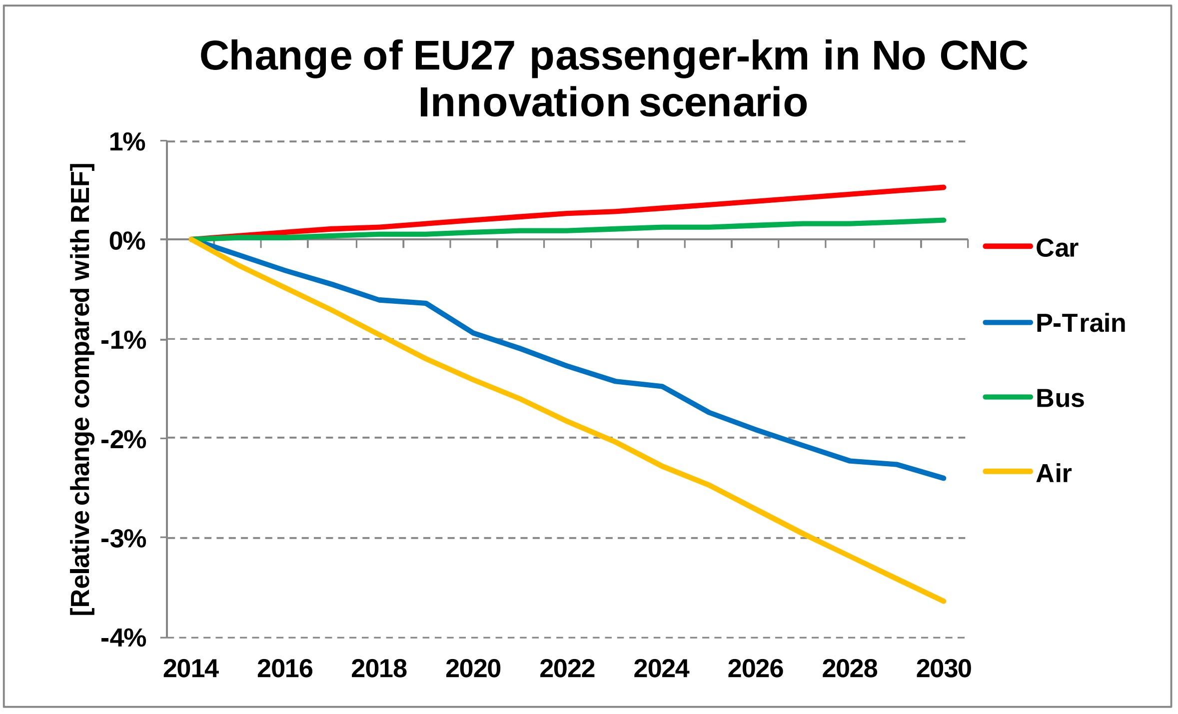


Source: Fraunhofer-ISI

Figure 52: Decomposition of investment and transport time/cost impacts on jobs (not FTE) in EU27

The efficiency of travel time and cost impulses induced by the deployment of innovative technologies in relation with the requested investments is in the case of this scenario even higher than in the *No CNC Cross-Border* scenario. Expressed in number of FTE-job years (full-time equivalent employment) not created per billion € not invested, the *No CNC Innovation* scenario ranges by about 46,400 on the top of all CNC scenarios which have been assessed in this study.

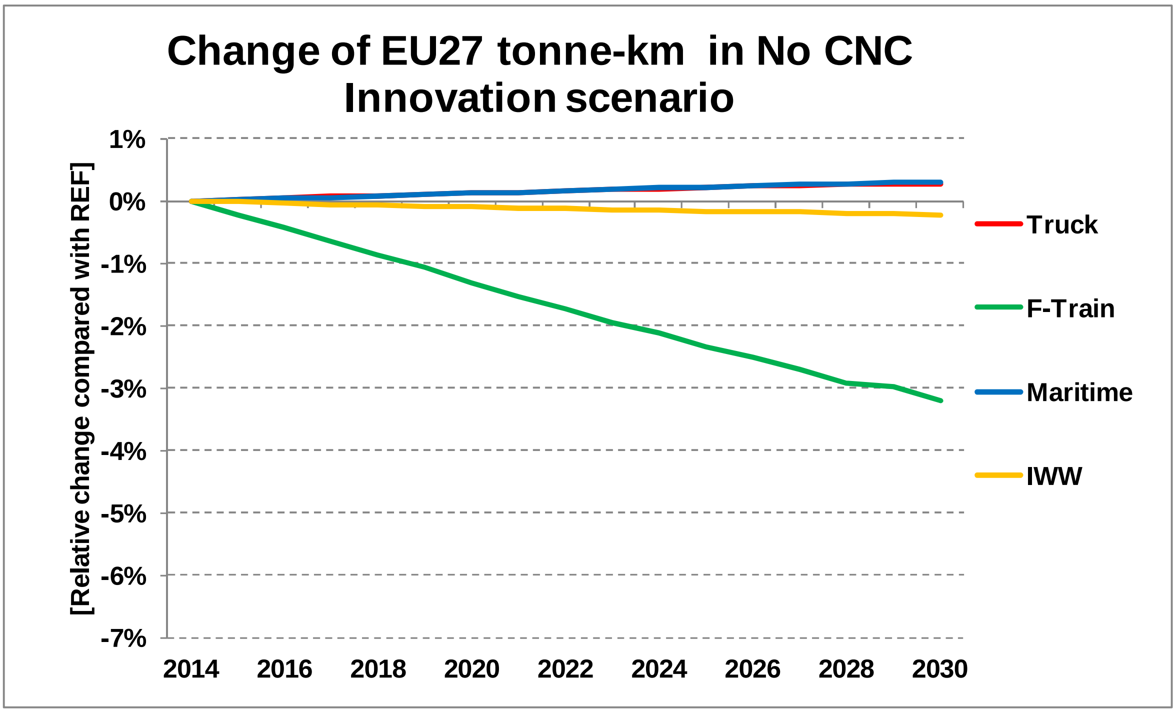
Passenger transport changes in the *No CNC Innovation* scenario in a similar way like for the previous four scenarios with one exemption: ASTRA-EC calculates a significant decrease of passenger-km for air for *No CNC Innovation* as compared with REF until 2030. The simulation shows that about 28 billion passenger-km will be made less in 2030 for air which is equal to a decrease of about 3.5% compared with REF in EU27 in 2030 (see Figure 53). This effect is obviously driven by the high share of investments requested for the deployment of SESAR and the resulting travel time reduction of -10%. ASTRA-EC assesses a decline of rail passenger-km of about -16 billion passenger-km compared with REF in the year 2030. A shift towards road transport is the logic consequence of the lacking investments, travel time and cost optimization for air and rail transport in the case of a non-deployment of innovative technologies. In total, passenger-km only marginally change by -0.2% compared with REF in 2030.



Source: Fraunhofer-ISI

Figure 53: Relative change of passenger-km per mode in EU27 as compared with REF

The change in freight transport per mode in the *No CNC Innovation* scenario compared with REF is very similar to the changes induced by the *No CNC Cross-Border* scenario. ASTRA-EC assesses a marginal reduction of total tonne-km of -0.1% for EU27 compared with REF in 2030. Like for passenger transport, the non-deployment of ERTMS technology leads to an increase of travel time and costs for rail freight transport compared with REF. This leads to a modal shift from rail towards road transport. Rail tonne-km are expected to be by about 18 billion tonne-km lower than in the REF scenario while tonne-km transported by trucks on roads grow by 4.5 billion tonne-km in 2030 compared with REF.

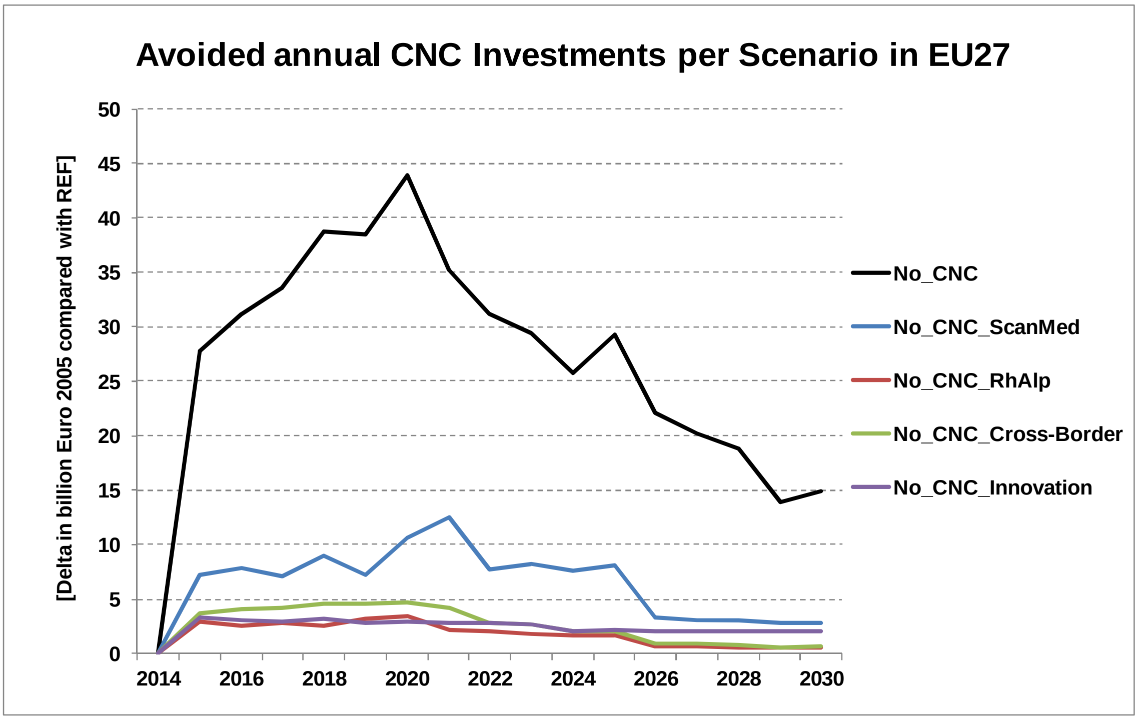


Source: Fraunhofer-ISI

Figure 54: Relative change of tonne-km per mode in EU27 as compared with REF

9 Overview on the impacts in the non-completion scenarios

This report elaborated on wider economic impacts of two test cases, one main scenario and two sensitivity scenarios. In this section we consider them as five scenarios to compare and provide an overview on their results. Common for all five scenarios was the assessment of a non-completion of different parts of CNC between the year 2015 and 2030. As opposed to classical scenario setting, the scenarios were not characterized by adding new transport policy measures but by assuming a failure of existing TEN-T policy in different levels. The most obvious differences between the five scenarios dealing about the non-completion of investments in CNC infrastructure is the level of avoided investments for each scenario. Figure 55 provides an overview of the avoided CNC investments for EU27 compared with the *Reference Scenario* (REF) assuming a completion of CNC on an annual basis.



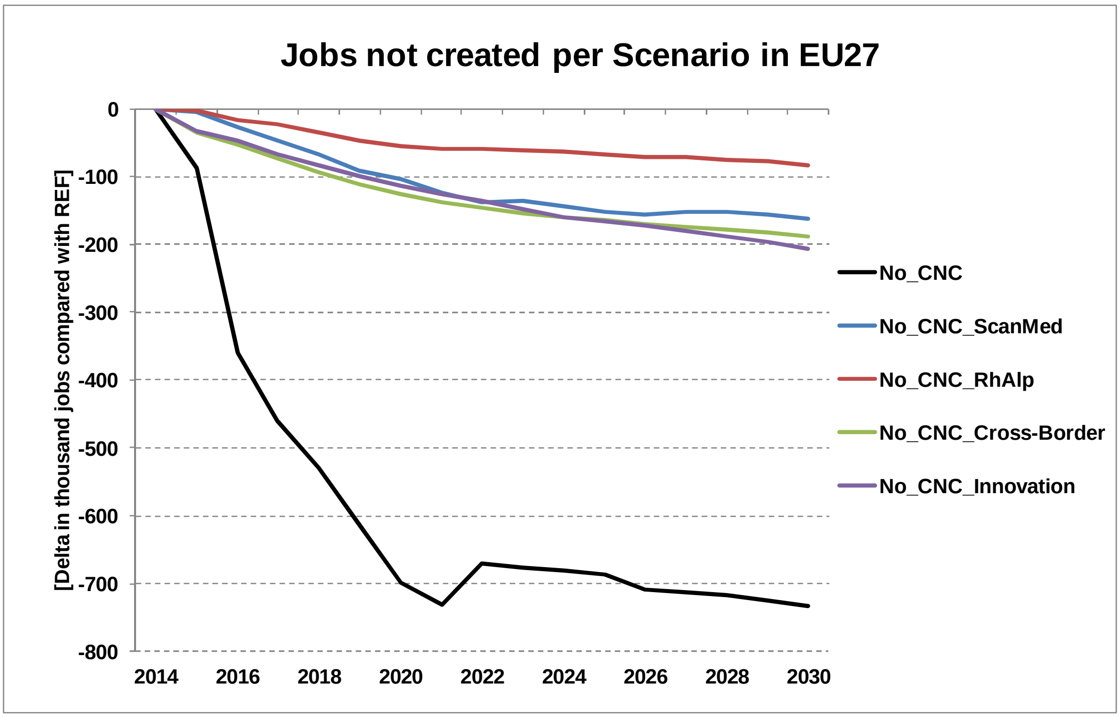
Source: Fraunhofer-ISI

Figure 55: Avoided CNC investments in EU27 per scenario [Billion $€_{2005}$]

The time series of avoided investments differentiated by country and economic sector was taken away from the planned investments in the REF in all scenarios for the period from

2015 to 2030. The lowest level of avoided investments (€ 29.2 billion[14]) was subtracted for the simulation of the non-completion of the CNC Rhine-Alpine (called *No CNC RhAlp*) for EU27. The negative investment impulses for the second scenario analysing the non-completion of CNC Scandinavian-Mediterranean (called *No CNC ScanMed*) were by EUR 108.2 billion for EU27 significantly higher. Assuming a non-completion of all nine CNC (called *No CNC*) was simulated with ASTRA-EC by reducing the REF investments by about € 454 billion in EU27. The level of avoided investments in the two sensitivity scenarios analysing on the one hand the non-completion of large CNC cross-border projects (called *No CNC Cross-Border*) and on the other hand the non-completion of innovative technologies (called *No CNC Innovation*) was comparably moderate by EUR 43.2 billion and EUR 40.8 billion, respectively, for all EU27 between 2015 and 2030.

The detailed description of the outcome of the scenario simulation described the differences in impulses from investments and from resulting travel time and travel cost changes. In terms of the number of jobs not created due to the non-completion, the picture resembles at first sight the development and the level of avoided investments per scenario. Figure 56 presents the changes in employment in all EU27 member states for all five scenarios between 2015 and 2020. The numbers presented refer to the total number of jobs not created as compared with REF accounting part-time employed persons as one.



Source: Fraunhofer-ISI

Figure 56: Jobs not created in EU27 per scenario

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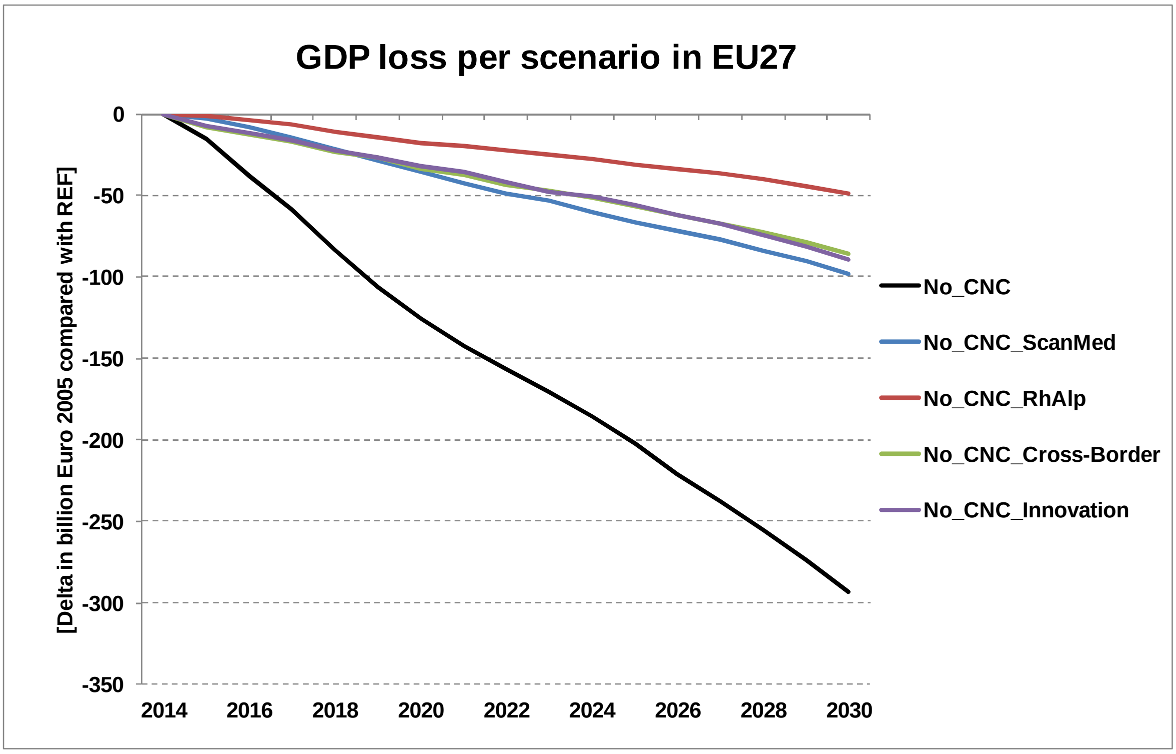
14 All monetary values are expressed in constant Euro 2005 (deflated using an EU27 deflator from Eurostat).

According to the assessment of the *No CNC* scenario with ASTRA-EC, about 733 thousand jobs less compared with REF can be expected in 2030 (or 654 thousand full-time equivalent jobs less). *No CNC ScanMed* leads to a reduction of about 163 thousand jobs (or 139 thousand FTE jobs) in 2030 while *No CNC RhAlp* results in a loss of 83 thousand jobs (or 71 thousand FTE jobs) in 2030. The employment impact of the two sensitivity scenarios in relation to the avoided investments is stronger for the two sensitivity scenarios. ASTRA-EC calculates a reduction of about 189 thousand jobs (or 166 thousand FTE jobs) for *No CNC Cross-Border* and even 206 thousand jobs (or 182 thousand FTE jobs) less for *No CNC Innovation* in EU27 in 2030.



Source: Fraunhofer-ISI

Figure 57: GDP losses in EU27 per scenario [Billion $€_{2005}$]

The projected loss of GDP caused by the non-completion scenarios is substantial in all five cases. *No CNC* leads to an about € 294 billion lower GDP than in REF. The single CNC analysis revealed a loss of GDP for all EU27 in 2030 between € 98 billion (*No CNC ScanMed*) and € 48.5 billion. Not completing large CNC cross-border projects is expected to result in a € 86 billion lower GDP than in the REF. According to the ASTRA-EC calculations, a similar impact on GDP with minus € 89 billion in 2030 could be the result for non-deploying innovative technologies in the context of CNC. These findings are summarized in Table 26.

Table 26: Summary of economic impacts for the year 2030 and the EU28 in the five scenarios

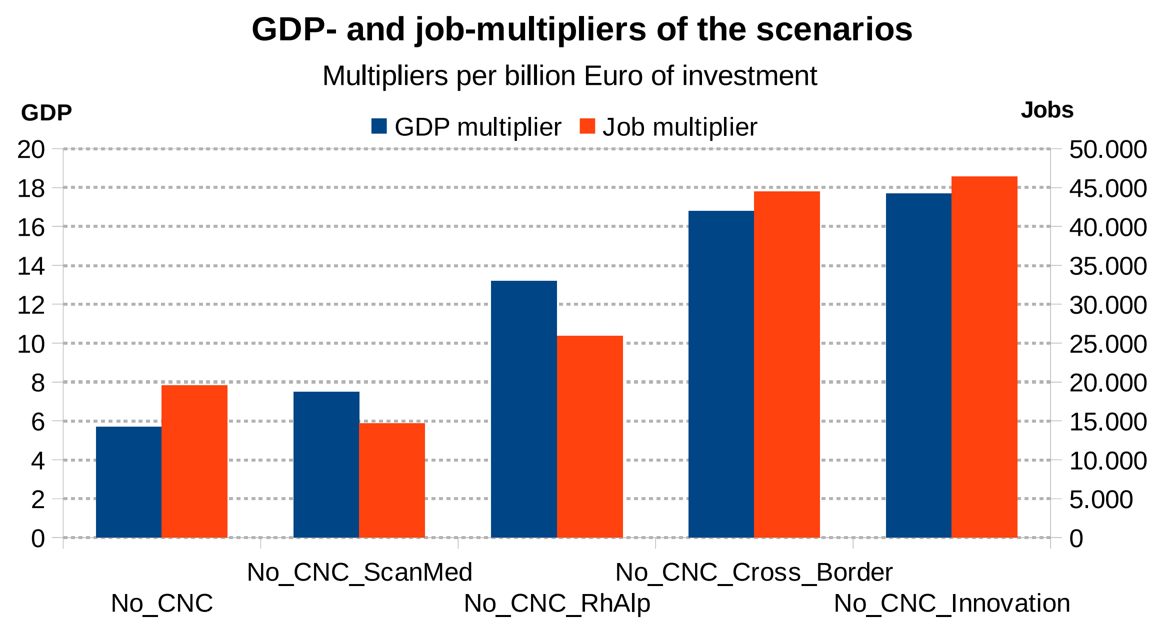
Scenario	Avoided investments	Loss of GDP	Loss of GDP	Jobs not generated	Job-years not generated
Period	2015 to 2030	2030	2015 to 2030	2030	2015 to 2030
Unit	Billion €	Billion €	Billion €	Persons	Persons
No_CNC	**457**	**294**	**2,570**	**733,000**	**8,900,000**
No_CNC_ScanMed	105	98	807	163,000	1,590,000
No_CNC_RhAlp	29.2	48.5	384	83,000	758,000
No_CNC_Cross_Border	43.2	86	725	189,000	1,920,000
No_CNC_Innovation	40.8	89	723	206,000	1,900,000

Source: Fraunhofer-ISI

Comparing the level of avoided investments with the accumulation of annual GDP losses on the one hand and with not created FTE-job years on the other hand demonstrates the differences between the scenarios. Figure 58 provides an overview on the relation between FTE-job years not created per billion avoided investment (the job multiplier) and the multiplier between the accumulated GDP losses per avoided investments for EU27 between 2015 and 2030 (the GDP multiplier). The latter can be interpreted as an economic multiplier and can be used for assessment as discussed in section 4.2. The minimal number of FTE-job years per billion € invested is expected for the *No CNC ScanMed* scenario (14,700 FTE-job years per billion €). The *No CNC* scenario and the *No CNC RhAlp* scenario follow by 19,600 respectively 25,900 FTE-job years per billion €. Significantly higher impacts on the creation of jobs per invested money reveal the sensitivity analyses of the *No CNC Cross-Border* (44,500 FTE-job years per billion €) and the *No CNC Innovation* scenario (46,400 FTE-job years per billion €). The variation of this indicator between the scenarios is caused by a number of structural differences between the scenarios. The moderate employment impact compared with the invested money for the two CNC analyses of single corridors is mainly caused by the location of the corridors. They only cross countries with comparably high labour productivity such that the direct effect of investments on the creation of new jobs is not as high as for countries with lower labour productivity (e.g. Romania or Bulgaria). The difference between the two corridor results is mainly caused by the different travel demand on the corridors and the travel time saving achieved or in the case of the scenarios not realized travel time and cost saving. The high job impact per investment of the *No CNC Cross-Border* scenario and especially of the *No CNC Innovation* scenario is influenced by the travel time saving potential within both scenarios and the type of investments in the latter scenario. A number of large CNC cross-border projects are planned to close gaps and eliminate bottlenecks such that the impact on international travel demand can be considered to be substantial. As for the *No CNC Innovation* scenario, the travel time savings taken from literature for ERTMS and SESAR are as well significant such that the job impact is strongly driven by the travel time and cost changes.

As for the economic multiplier, the model calculates the lowest of 5.7 for the *No CNC* scenario followed by 7.5 for the *No CNC ScanMed* and 13.2 for the *No CNC RhAlp*. The highest multiplier in terms of accumulated GDP per investment cost is expected for the *No CNC Cross-Border* and the *No CNC Innovation* scenario. The driving parameters for these differences are again the location of the investments, the impact on travel demand, the level of travel time savings and the structure of the investments in terms of sectors directly influenced by CNC investments. The latter does play a significant role for the non-completion of innovative technologies. The investments assumed to be not completed in this scenario do not reveal the structure of conventional infrastructure projects mainly focussing on the *Construction* sector. They are partly requiring investments in sectors like *Electronics*, *Computers* and *Vehicles*. These sectors are having a stronger impact on Total Factor Productivity that besides labour supply and capital is driving the potential output of an economy and by doing so also pushes the supply side of GDP. Fotakis/Peschner (2015) show that due to the demographic change to maintain growth it will be important to improve productivity. Therefore a transport policy that promotes also productivity gains goes into the right direction also considering the connected aspects of productivity growth and demographic change in Europe.

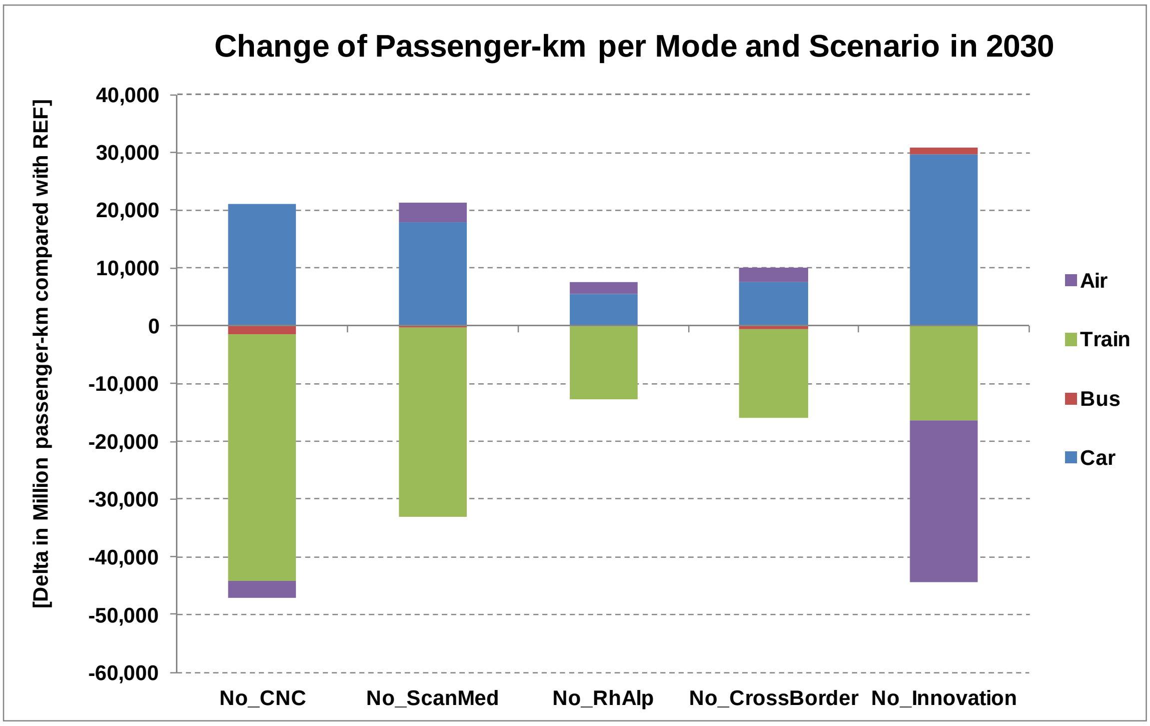
As the ASTRA model is conceived to use real term values the presented economic multipliers per invested money are calculated in real terms using a common GDP deflator for EU27. Economists often argue with time preferences that value a benefit in the near future higher than a benefit that can only be expected in the medium to long-term. They recommend to apply discounting of future values to calculate the net present value (NPV) of an investment. We could also calculate the impact of discounting to today's values for our GDP multiplier. This requires to calculate the net present values for both, avoided investments and GDP loss. The choice of the proper discount rates is one of the most debated issues amongst economist in such analyses. We apply the discount rates of the German Federal Transport Infrastructure Plan (FTIP). The most recent FTIP from 2014/15 applies a discount rate of 1.7% and the previous FTIP from 2003 used a discount rate of 3%. Applying the former rate of 1.7% would reduce the GDP multiplier of the *No CNC* scenario from 5.7 to 5.3 due to the different time profiles of investments and GDP impacts where investments react earlier, while GDP is affected stronger in the long run. In case of using the higher discount rate of 3.0% the GDP multiplier of the *No CNC* scenario would decrease to 5.1. In both cases we would argue that our findings are not altered substantially, in particular as we are neglecting that also after 2030 further GDP benefits will occur, which would increase the GDP multiplier again since no further investments need to be made but the GDP increase will be sustained for future years as well.



Source: Fraunhofer-ISI

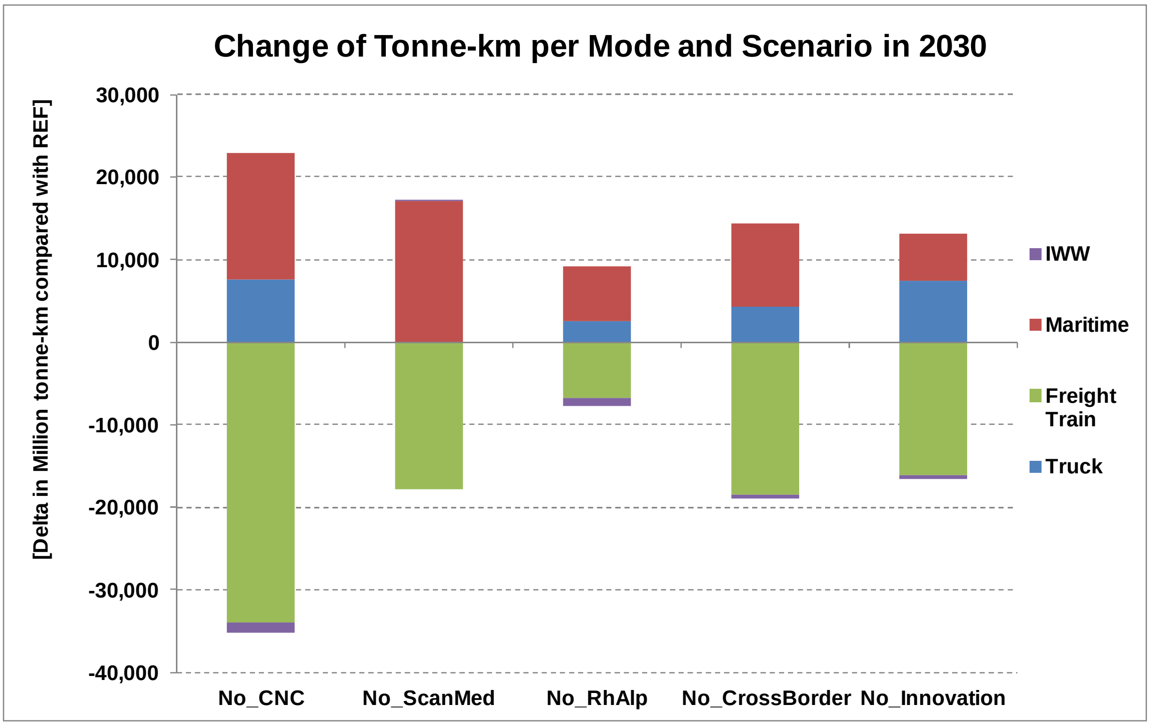
Figure 58: FTE-jobs created and GDP multiplier per Billion Euro invested per scenario

Obviously, assuming a non-completion of large transport infrastructure projects like in the case of core TEN-T network corridors leads to changes in the transport performances. The simulation of the five scenarios showed that a substantial change in modal split could be result of a non-completion of CNC infrastructure. Figure 59 and Figure 60 provides an overview of potential changes of transport performances per mode, both for passenger and freight transport. The changes compared with REF are presented in terms of Million passenger-kilometre and Million tonne-kilometre per mode for EU27 in the year 2030. Common for all scenarios is a significant modal shift from railways towards road, both for passenger and freight transport. The reason for this shift is the high share of CNC investments planned for improving railway infrastructure and technology in all five scenarios. Hence, the assumed improvement of travel time and cost saving for the rail model in the REF scenario cannot be realized in the non-completion scenarios, at least on different levels. Travel time and cost saving potential of CNC infrastructure investments for road freight and passenger transport are in all five scenarios limited such that the non-completion does not impact road transport significantly which leads to the shift towards road. While for most scenarios, air transport benefits from a non-completion of the specific setting of CNC projects, the situation for *No CNC* and especially for *No CNC Innovation* is different. The non-deployment of SESAR and the not realized travel time and cost changes for air lead to a shift not only from rail, but also from air to road.



Source: Fraunhofer-ISI

Figure 59: Change of passenger-km per mode in EU27 per scenario [Mio passenger-km]



Source: Fraunhofer-ISI

Figure 60: Change of tonne-km per mode in EU27 per scenario [Mio tonne-km]

Table 27 presents the change of GHG emissions and for major air pollutant emissions induced by the changing transport performances in the five scenarios as estimated by ASTRA-EC. A positive value means that the completion of the respective CNC investments reduces the emissions. The strong impact of air transport on GHG emissions and on air pollutant emissions can be seen by the high negative values for *No CNC Innovation*. ASTRA-EC assesses that air transport benefits strongly from the 10% travel reduction on average EU flights achieved by the deployment of SESAR.

Table 27: Change of GHG and air pollutant emissions per scenario [tonne]

Scenario	CO_2	CO	NO_x	VOC
No CNC	1,237,671	8,133	-911	4,061
No CNC ScanMed	-68,237	-584	-256	-280
No CNC RhAlp	745,178	48,708	970	24,796
No CNC Cross-Border	695,679	28,337	-504	14,396
No CNC Innovation	-1,534,851	-299,005	-12,107	-154,318

Source: Fraunhofer-ISI

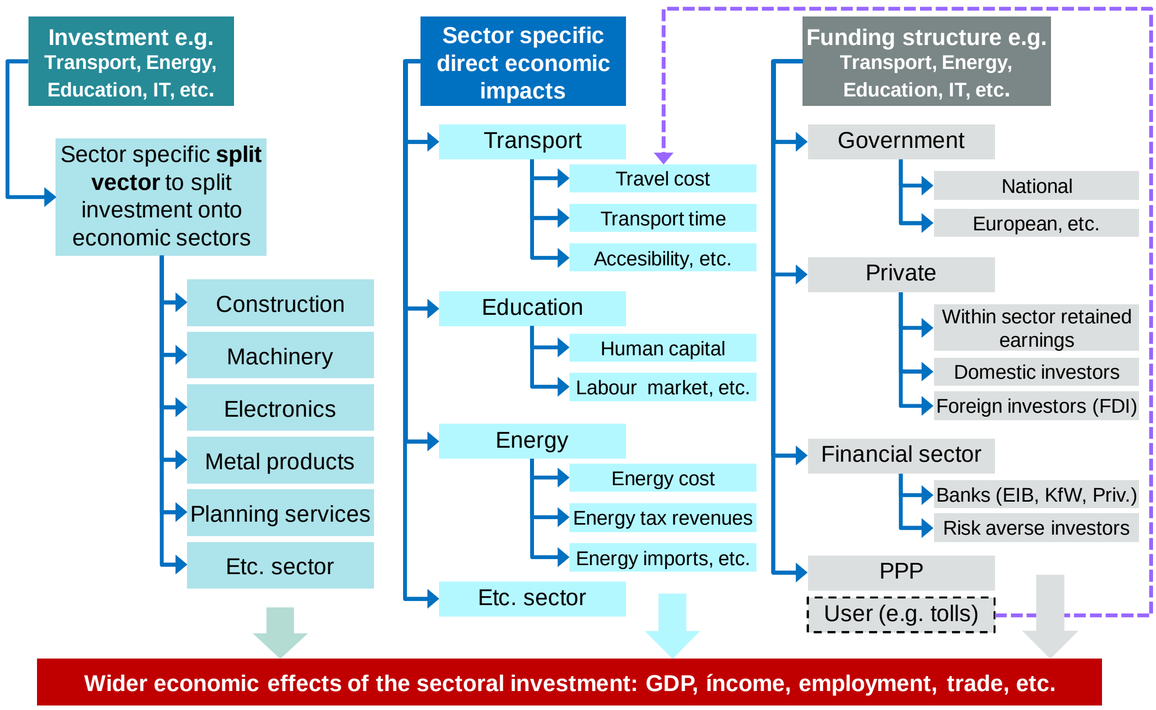
10 Impacts of the core TEN-T network

This report so far explains and assesses the impacts of not completing the TEN-T core network and components thereof, respectively. This section inverts the point of view and elaborates on the impacts of implementing the TEN-T. Overall our analysis revealed a significant positive stimulus by the implementation and completion of the TEN-T core network until 2030. Implementing the core network increases the European capital stock of transport networks, transport terminals and stations as well as innovative technologies in the transport sector like IT-systems to manage and improve the efficiency of the transport system and facilities to increase the use of alternative energies in transport. Investments of about 620 billion € between 2015 and 2030 will be generating between 10 and 12 million person-years of employment and increase the European GDP by between 2.9 and 3.4 trillion €. This is roughly a macro-economic GDP multiplier of 5 for the investment into the TEN-T core network.

Of course, an investment in any infrastructure sector of the economy will generate macro-economic impacts, as Figure 61 shows. These impacts will be different for each sector. Most common across sectors will be the direct impact of investments (left hand side of Figure 61), where the investment will have to be split onto the sectors generating the different investment goods. In case of transport always the construction sector will produce a large share of the investment, while for instance in case of wind turbines it will be rather the machinery and metal product sectors. In ASTRA like in most other economic models the investments then are split onto the economic sectors used by the model applying a so-called split vector. The split investments then generate further wider economic effects altering GDP, income and employment.

Each sector will then have its specific way how infrastructure investments cause direct effects in the sector (in the middle of Figure 61). Of course, a transport infrastructure investment will cause changes in travel times, travel costs and accessibility, while an investment into energy infrastructure like for renewable energies will cause changes of energy cost, energy tax revenues and imports of fossil energy and possibly some further changes not depicted in the schematic figure. Thus each infrastructure investment will cause further wider economic effects via their specific ways direct effects are generated and how they are then forwarded to other sectors of the economy.

Finally, sectors may also differ by the way how their infrastructure investment is funded. While in the transport sector most of network investments are sourced from government funds the energy sector is largely investing in their infrastructures from private funds. For the transport sector also the other options to combine public and private funds by means of PPPs or to fund infrastructure via loans from banks or nowadays also insurances and pension funds would be potential sources of funding. An alternative funding approach is also to raise the user cost by introducing new infrastructure charges or by increasing existing ones. Again the different funding approaches will also cause differences in the wider economic effects. This was for instance analysed in 2002 for the TEN-T planned at the level of EU15 with a time horizon until 2020. Funding alternatives included via increased fuel taxes, via social marginal cost pricing increasing the transport user costs and considering different ways of refunding the SMCP revenues not required for the TEN-T investment. The resulting GDP and employment changes differed significantly with SMCP based funding generating better results, in particular when it was combined with reduction of direct taxes (Schade 2005). In this study, it was assumed that largely the investment comes from government funds due to the fact that detailed funding plans were not developed for the CNC and the full core network, yet.



Source: own representation after Schade/Krail 2015

Figure 61: Comparing similarities and differences of infrastructure investments in different sectors

A few references in the literature enable to compare our results with previous findings. The European Commission has undertaken an assessment of the economic impact of the 14 Essen projects defined as the first concept of TEN-T in 1994. The investment required to implement them was estimated to be 90 billion ECU (where 1 ECU was set 1 EURO when the Euro was introduced). The macroeconomic impact in terms of increase of GDP was estimated to reach 560 billion ECU until 2030. This results into a macro-economic GDP multiplier of about 6, which would be slightly higher than what we found. However, the period for which the impacts are aggregated was about a decade longer than in our calculation. Additional employment was estimated to amount to 700,000 person years until 2030. Thus the employment effect is much smaller than our estimate as well as it is observed in the literature. In fact, only 7,770 job-years per billion € of investment would have been created with the Essen TEN-T. The result of our estimation was that 19,600 job-years per billion € of investment will be created with the nine CNCs. This fits also with literature vales that are reported to be between 13,000 and 37,000 job-years per billion € of investment (Table 2).

11 Conclusions on cost of non-completion of TEN-T

In this study we looked at the economic impact of the non-completion of the TEN-T core network until 2030. The focus of our analysis was on the nine core network corridors (CNC). For these CNC the EC had commissioned in 2013/2014 so-called corridor studies. One of their outputs were the work plans of each corridor, which basically constitute a list of projects with descriptions, schedules, investment cost and in some cases also funding approaches. These nine project lists were the major input to this study as they provided investment and an indication on the transport improvement to be expected from a project.

EC analysis revealed that the nine CNC account for 75% of the length of network infrastructure of the full core network. Therefore we extrapolated our analysis to cover also the remaining infrastructure and to provide results on the full core TEN-T network. The European transport policy and the ASTRA-EC model applied for our analysis include in their *Reference Scenario* the full implementation of the core TEN-T network by 2030. In contrary our scenario analysis assumed that from 2015 onwards planned investments and improvements to the TEN-T core network corridors (CNC) would be stopped. In other words: the work plans of each of the CNC that have been identified by the nine corridor studies would not be implemented. With this setting in mind we defined two test cases and three scenarios:

- Non completion of the nine CNC stopping their implementation at the end of 2014 (*No CNC* scenario). This scenario was extrapolated to the full TEN-T core network.
- Non completion of the Rhine-Alpine corridor stopping its implementation at the end of 2014 (*No CNC RhAlp* test case/scenario).
- Non completion of the Scandinavian-Mediterranean corridor (*No CNC ScanMed* test case/scenario).
- Non completion of the (large) cross-border projects along the CNC (*No CNC Cross-Border* scenario).
- Non completion of the innovative technologies along the CNC (*No CNC Innovation* scenario).

The objective of our analyses was to identify the economic impacts of non-completion of the five TEN-T implementation scenarios. Therefore we looked in particular at economic indicators that would also provide statements on growth and economic development, i.e. change of GDP and employment. Our analysis focuses on the year 2030 and the comparison of the *Reference Scenario* with TEN-T implementation to the non-completion scenarios and on the accumulated changes over the period 2015 until 2030.

The main results from the analysis are as follows:

- Not implementing the CNC would cause a loss of growth. In 2030 EU27 GDP would be € 294 billion lower without the CNC compared to the *Reference Scenario* (REF).

- The number of jobs not created in EU27 by the CNC implementation compared with the REF would reach about 733,000, or 655,000 in terms of full-time-equivalent jobs in 2030.
- Accumulating the losses of GDP and employment over the period 2015 until 2030 reaches a total loss of € 2,570 billion and 8.9 million job-years of full-time-equivalent employment not generated.
- The decomposition analysis reveals that in the first decade the reduced investments play the most important role, while over time the changes of travel times and costs start to grow and around 2030 would be of similar importance to generate macro-economic impacts as the investment.

The results have been obtained by considering mainly two impulses in the ASTRA-EC model: the investment impulse and the impact of travel time changes. Both impulses cause direct and indirect economic impacts (or second round impacts). The difference of these can be easily identified at the investments: in 2020 the reduction of transport infrastructure investment by not implementing the CNC amounts to € 45 billion. These are the **direct impacts** of the scenario related to investment. However, the total investment represented by the investment variable in ASTRA-EC is changing by € 84 billion. This means the **indirect impacts** of the policy causes another loss of € 39 billion of investments. These indirect effects usually accumulate over time: in 2030 the direct impact accounts for a mere loss of € 15 billion of investment not made for the CNC. The total loss of investment amounts to € 77 billion such that the indirect impact reaches € 62 billion, which is more than half higher than observed in 2020.

Due to the lack of detailed network input data for 2030 it was not possible to estimate time savings for the CNCs applying a network modelling approach as it was planned. Thus we used the project list of the CNC studies to develop own estimates of the time savings at NUTS-I level. Uncertainties about the validity of our expert estimates of time savings could be mitigated by findings of the CNC study on the Baltic-Adriatic corridor. This study applied a network model to their corridor and provided their results on time savings at the NUTS-I aggregation level that is required by the ASTRA-EC model as input. These corridor results show that time savings of long distance transport by the CNC can reach two-digit levels, i.e. 20 to 30 % were achievable in some of the NUTS-I zones of this corridor. This is consistent with our estimates of time savings applied for the non-completion scenarios. Of course, in the future using a network model fed by the proper network attributes for 2030 for all corridors would mean an improvement of the inputs and of our results. Nevertheless, we deem our approach sufficiently robust to present our findings.

We have presented the results by two approaches: first as pure macro-economic indicators like GDP and employment that describe the economic losses if the nine CNC and the core network would not be implemented. The second option is to use them as input to calculate GDP multipliers, which would relate the cost (in this case the investment) to the benefits (in this case the accumulated GDP increase until 2030). With about a total investment of € 457 billion for EU28 and a total GDP increase of € 2,570 billion we would obtain a GDP multiplier of about 5.7, which is high compared with classical transport CBA results. Comparing this figure with earlier results of the Essen TEN-T they are in a similar order of magnitude.

In the regional analysis at country level we observe that the size of annual investment into the CNC in the Member States lies between below 0.1 % and 1.7 % in relation to their GDP. The higher numbers fall upon the new Member States, in particular in Eastern Europe, which shows their efforts to catch-up with their infrastructure endowment to the EU15 countries.

On the other hand the new Member States have lower labour productivities and in the first corridor scenarios that were covering two north-south oriented corridors these countries were excluded. Therefore the jobs multiplier to investments in the *No CNC* scenario is higher in relation to its GDP multiplier when comparing the same relation between the two multipliers of the two north-south corridor test cases. In other words employment is more sensitive to investments than GDP in the New Member States.

Support for innovative technologies by the TEN-T policy would be expected in particular for rail and to some extent for shipping. Infrastructure innovations would benefit from ICT innovations. This finding results from our combined analysis of the innovation systems of modes looking at patents, market structures etc. and the structure of the planned investments along CNCs. The most relevant technology would likely be ERTMS and their single technological components, though we would propose to promote only the most recent developments of ERTMS technologies. For these technologies also the existence of lead market effects by TEN-T policy would be arguable. The results obtained by ASTRA-EC so far, are not containing any benefits from lead markets.

Finally, we can conclude that the investment into the core TEN-T would generate substantial benefits for the EU economy. The single elements of TEN-T provide their specific share of the benefits. The absolute level of benefit generated by each of the nine CNC varies depending on transport flows and European regions affected by a specific CNC. The implementation of the cross-border projects as well as of the innovative technologies generates the highest benefit in terms of GDP multiplier, which is about triple the GDP multiplier of the nine CNC. They seem to be important building blocks of the whole TEN-T concept. Of course, they will generate these benefits in particular as part of the overall core TEN-T network and of a single European transport area.

12 Annex I

12.1 Discussion of methods to assess economic impacts

There are various ways of judging on the economic impacts of infrastructure projects, depending on the standpoint one looks at the possible effects. One could look at the profitability of the project as such, which is often done via Cost-Benefit Analysis. This view is quite micro, as it restricts the view on a certain area and tries to calculate all relevant quantities, which are directly or, to a certain degree, indirectly affected by the project.

While this approach has its distinct advantages, mainly found in the clear boundary of the examination and the endeavour to correct for market failures, a broad range of indirect effects are usually not considered, like impacts on trade flows and the effects resulting from the construction, like labour market effects or increased investments due to intermediate deliveries. Further, those could also trigger productivity gains and enhance consumption due to income effects. While this macro view may be less suited for single projects, it may be quite beneficial to apply it on large-scale projects or projects that spread over wider areas (Tsolakis and Preski, 2005).

12.1.1 CBA analysis

A classic assessment tool of investment decisions is Cost-Benefit Analysis (CBA). It tries to monetise relevant quantities of the project. On the cost side there are standard costs including investment and program costs like planning and steering, which are by far the easiest least controversial quantities. However, there are also costs concerning environmental impacts like land use change or noise, which depend on a much more critical choice of parameters.

CBA relies partly on the methodology of intertemporal welfare effects, so the choice of weighting utility of future generation against those of the current generation is quite critical. This weighting is usually done in the form of employing a discount rate (Harrison, 2010). While it may be tempting to use such a rate as it is standard in cash-flow analysis to calculate the net present value (and CBA could also be seen as a kind of extension of it), this bears a lot of problems, especially regarding the quantification of externalities. The costs are often small in a single year, but accumulate over time. However, the bigger the discount rate, the smaller the impact of future values, including a “cut-off” where any future value does not have any effect on the results, no matter how big this future value might be. This also applies to the choice of the discount period (Rockliffe et al., 2005).

The consideration of the environmental impacts, however arbitrary the choice of parameters sometimes might appear, is at least beneficial in the sense that it accounts for those externalities and the fact that damage to public goods is in most cases a market failure (Perman et al., 2003). The same applies to landscape and cultural heritage, which might be affected by the project.

While there is obviously some arbitrariness in the calculation of costs, the quantification of benefits are even less certain. In the microeconomic view of transport infrastructural cost-benefit project appraisal, benefits are usually assumed time gains for both the users of the new facility, but also for the non-users who profit from a network whose capacity is expanded as there is less congestion (Rockliffe et al., 2005).

Further benefits may also include a change in the operating costs (which could apply to both sides), accidents (improved security induced by the project) and accessibility (and the competitiveness of a region).

However, side effects that counteract the assumed benefits from infrastructural projects like induced demand are often neglected (Naess et al., 2012). Additionally, since CBA value a project only positively if benefits outweigh costs, there could also be ethical reasons for still evaluating a project positive. It should be noted that there often is no single choice of parameter values, especially concerning the measurement of the project externalities.

12.1.2 CGE and SCGE models

Computable General Equilibrium (CGE) models are currently probably the most utilized tool for macro policy analysis (Mitra-Kahn, 2008) and are also increasingly used in Sustainable Impact Assessment studies, notably at the Energy-Environment-Economy (E3) interface. The basic idea to develop this kind of models was the dissatisfaction with some of the features of static Input-Output models, such as the lack of demand and supply equations and capacity constraints (Perman et al., 2003).

CGE models are used for a wide array of different purposes: evaluating the effects of international trade changes, national policy planning efficiency and sectoral demand shifts in the analysis of tax reforms, welfare distribution, and more recently global warming (Mitra-Kahn, 2008). However, since there have been developed many different CGE models, not every model is suited for every analysis and for this reason no overall survey article exists.

The main kind of policies that is assessed with the help of CGE models are price measures. These may arise e.g. in the form of a decided tax, raising the prices for capital and labour, which then triggers sectoral or supranational (affecting ex- and imports) substitution effects. This substitution then alters the distribution of income attached to the different sectors.

Reasons to use CGE or other economy-wide models include projects that have a major regional impact, trade impact, development facilitation, benefitting geographical connections and/or where the inputs for construction are sourced locally (Tsolakis and Preski, 2005). Employing national modelling may seem conceptually attractive, but it is often a difficult and relatively expensive endeavour. Nevertheless, it can be very useful to supplement or complement CBA assessments.

CGE models are based on the theory of general equilibrium (Athreya, 2013) and thus neoclassical concepts are inherently part of this modelling class. So deriving an optimal policy is one of the stated claims that this modelling approach seek to deliver (Scrieciu, 2007).

General equilibrium theory is quite distinct in their basic set-up: utility is derived from the consumption of a good, neglecting interference with other products, and the first derivative of the utility function is generally positive and concave (McKenzie, 2008). Equilibrium is given by Pareto optimality, which means that, given the choices of the other market participants, no single participant is better off by another decision. In equilibrium, the production or consumption plans of the market participants as well as goods prices do not change any more.

CGE models usually employ four sorts of assumptions (Perman et al., 2003):

(1) market clearing -> no unused resources and equilibrium is reached
(2) Walras' law -> no overuse of resources and interconnectedness of markets
(3) utility maximisation by households
(4) profit maximisation by firms

The general critique on neoclassical economics with their utility-maximising assumption also applies to CGE models.

There are some issues with the theory not being easily falsifiable (Scrieciu, 2007), since in the calibration it is quite common to borrow parameter values from other sources, but that is fairly common with all simulated macroeconomic methods. The more concerning part for CGE models is that their calibration is based solely upon one year, thus disregarding time series altogether (as long as they are not inherently present in an econometrics estimate of a parameter). This base year is regarded as being a true representation of the current and also of future states of the economy. Selecting the base year is also not straightforward, since it is desirable to exclude years with a strong impact of business cycles.

Another problem with CGE models is their inability to model true transition paths of a policy. The dynamic representation is a mere snapshot of equilibrium states, which are strung together (Scrieciu, 2007).

Since the underlying paradigm of CGE models is the general equilibrium theory, they are equally susceptible to the implications of the Sonnenschein-Mantel-Debreu theorem (Ackerman, 2002). This theorem states that a single solution point for excess demand needs not to be given, so this lack of uniqueness opens up for several equilibrium solutions. Or, otherwise put: for deriving an aggregate demand function it is essential that all consumers have the same preference map and that preferences do not change with income.

The market mechanism in CGE models is generated via price changes; money neutrality implies that only relative prices are relevant. However, in oligopolistic markets firms treat rather the production quantity as a decision variable, since the price signal also reaches their competitors. Experimental studies show that in such game theoretical constructs, tit-for-tat strategies could backfire on the price setter. As a result, supply does not adjust quite according to demand. This is only one example of market imperfection, which is very hard to implement into CGE models.

Spatial Computable General Equilibrium (SCGE) models are typically, like their non-spatial counterpart, comparative static equilibrium models, with the addition of interregional trade (Tavasszy et al., 2002). The interface between transport and the economy is done via the costs of transport services and policy measures results in cost changes for transport.

Explicit modelling of location differences is not the main feature of SCGE models; moreover, they include factor mobility, economies of scale and transport costs (Bröcker and Korzhenevych, 2011).

It is not uncommon to use a variation of the so-called "Iceberg"-approach in SCGE modelling: a certain percentage of the transport commodity itself is used up during transport, accounting for the costs of transport (Bröcker, 1998). The distance is covered using an exponential decay function as multiplier for the resulting quantity of the commodity.

In CGE models, and especially their spatial sub-types, interfacing between the macroeconomic model and the model representing transport proves to be a rather challenging endeavour (Tavasszy et al., 2002). The concept of shadow pricing implies a behavioural relationship between the minimiser and the maximiser, where in reality a market price establishes a structural relationship between both agents. It is important to avoid double counting which could happen if one includes benefits from both the transport cost savings and the increases in income or asset values induced by those cost savings (Tsolakis and Preski, 2005).

12.1.3 Other assessment methods

Methods for impact assessment of infrastructure projects include the following (Tavasszy et al., 2002):

- micro surveys with firms
- estimations of production functions
- partial equilibrium potential models
- macro and regional economic models
- land use/transportation interaction models and
- spatial computable general equilibrium models.

While CGE and SCGE models as specific examples of macroeconomic models have been discussed above, the first three methods are briefly characterized, following the description of Oosterhaven and Knaap (2003):

The first one tries to either assess the importance of infrastructure accessibility for firms or the historical or future impacts of specific infrastructure investments via questionnaires.

Production function estimation extends a production function with an explicit modelling of the infrastructure stock and runs econometric tests on these. The economic potential concept tries to approximate the changes in accessibility for the economy of a region at hand, which is derived from total traffic flow changes.

The discussion on the production potential effects of infrastructure arose from a debate on public expenditures (Aschauer, 1989), stating that especially “core” infrastructural projects are a main driver of productivity enhancement. There has been a debate around the issues of identifying infrastructure gaps. This assessment is carried out by econometric test, regardless of the efficiency of this method for this kind of problem (Gramlich, 1994).

Land use/transportation interaction models are often highly disaggregated models of urban conglomeration, aiming at some growth forecasts. Since various interaction effects including relocation are modelled, consumer benefits are not easily estimated.

A side remark on Dynamic Stochastic General Equilibrium (DSGE) models:

DSGE models are usually of the following form, respective have the following properties:

- In their basic form they consists only of households and firms, government and trade do not play any role
- They focus primary on consumption; basic DSGE models even omit investments altogether
- Households decide according to their utility function how much of their resources they put into labour (which is a disutility in this case)
- Firms are possessed by households and have only labour as a production input, generating revenues according to prices
- Price setting can be stochastic, notably on the length by which prices are valid
- Since the firms are possessed by the households and price setting is dependent on the wage rate (since labour is the only production factor), the important conflict incorporated in this model is the question whether the revenues of the firm exceed the disutility for working, so parameter choice on the exponents becomes crucial and the Achilles heel of these kind of models

DSGE models incorporate price uncertainty and are therefore in line with the equilibrium of plans, prices, and price expectations under uncertainty, which were originally incorporated in the classic Arrow-Debreu- model of general equilibrium in the form of information incompleteness for all agents (Majumdar and Radner, 2008). Besides the fact that uncertainty is more than just probabilistic risk, DSGE models do currently not offer any extension for dealing with non-monetary questions, so that they are quite inadequate for any policy assessment not coming from a central bank.

12.1.4 Outlook

The introduced assessment methods may have their unique advantages and disadvantages, but they most often suffer from a common problem: it is quite hard to introduce a proper accounting of uncertainty in those methods. This problem cannot be easily addressed, since it draws on some philosophical issues (Fjelland, 2002). Not only are some impacts just unknown, but also the probability of some events (or its distribution) to happen usually cannot be derived simply from statistics. It is therefore not only of utmost importance that the result of an assessment procedure is more than a single number, but also that the underlying assumptions and choice of parameters are transparent. It therefore requires the policymaker not to solely rely on the pundit delivering the analysis but also to understand the method(s) used and the critical points of it.

Another critical point that all these methodologies share is the question of defining a base case option or scenario, since it is meaningless to ask the value of an option without first defining a reference point (Rockliffe et al., 2005). The choice of the reference itself may implicitly or explicitly favour some of the alternatives. One example is selecting a more pessimistic base scenario in contrast to a more favourable dampens the positive macroeconomic effects of the same infrastructural investments (Frey et al., 2014).

Finally, defining the boundaries of the project appraisal requires a thorough understanding of the problem or project to be evaluated. While it might appear at first glance attempting to include as many variables or parameters as possible, this strategy often fires back later in the appraisal. A conscious choice is generally more promising than the attempt to cover all aspects. This will lead to a worse understanding, since an increase in the aspects makes it harder to keep track and both the sensitivity analysis of the parameter choice will suffer. It bears the danger that there will be a disagreement on some minor points and a blurring of the relevant facts.

13 Annex II

13.1 Peer review meeting

Peer Review Meeting (PRM) Cost of non-completion of TEN-T

Author Wolfgang Schade

Time March 26rd 2015, 09:30 to 16:00

Venue Permanent representation of North Rhine-Westphalia to the EU, Brussels

13.1.1 Agenda

0.	Registration and welcome coffee	All	09:30 – 10:00
1.	Welcome by the study coordinator	ISI	10:00 – 10:05
2.	Stage of TEN-T development, framework of study	EC	10:05 – 10:20
3.	Objective and introduction to the study (Q&D)	ISI	10:20 – 10:40
4.	Presentation of findings on 5 TEN-T scenarios (Q&D)	ISI	10:40 – 11:40
	Coffee break		11:40 – 12:00
5.	Peer reviewers feedback on study (1st round)	Experts	12:00 – 13:00
	Lunch break		13:00 – 13:45
	Presentations on specific findings		
7.	Regional impacts of TEN-T non completion (Q&D)	Infras	13:45 – 14:05
8.	Employment impacts (Q&D)	ISI	14:05 – 14:25
9.	Innovations and European added value (Q&D)	ISI/PTV	14:25 – 14:45
10.	Peer reviewers feedback on study (2nd round)	Experts	14:45 - 15:45
11.	Coordinators impressions and wrap-up of meeting	ISI	15:45 – 16:00

13.1.2 List of participants

Name	Organisation	Country/Region
	Invited external experts	
Enrico Bernardis	LeighFisher	IT
Yves Crozet	Université de Lyon (IEP, LET)	FR
Carlo de Grandis	European Commission	EC
Roland Haller	Bundesministerium für Verkehr, Innovation und Technologie (BMVIT)	AT
Andreas Kopp	Worldbank	US/INT
Dejan Makovsek	International Transport Forum (ITF)	FR/INT
Meryn Martens	European Investment Bank (EIB)	LU/EU
Monika Nogaj	European Parliament	EU
Jan Oosterhaven	University of Groningen	NL
Jörg Stangl	Bundesministerium für Verkehr und digitale Infra-strukturen (BMVI)	DE
Therese Steenberghen	KU Leuven	BE
Jose Manuel Vassallo	Universidad Politécnica de Madrid	ES
	EC Steering Group and Project Team	
Andreas Boschen	European Commission, INEA	EC
Martijn Brons	European Commission, DG ECFIN	EC
Menno van der Kamp	European Commission, DG MOVE	EC
Michael Krail	Fraunhofer ISI	DE
Herald Ruijters	European Commission, DG MOVE	EC
Wolfgang Schade	Fraunhofer ISI	DE
Gudrun Schulze	European Commission, DG MOVE	EC
Jakub Siwinski	European Commission, DG MOVE	EC
Daniel Sutter	Infras	CH
Filip Tanay	European Commission, DG EMPL	EC
Bernardo Urrutia	European Commission, DG MOVE	EC
Christoph Walther	PTV	DE
Martin Zeitler	European Commission, DG MOVE	EC

13.1.3 Minutes

The objective and concept of the Peer Review Meeting (PRM) was to present the methodology and draft findings of the study and to discuss both with the invited experts. The experts had been sent the Draft Final Report in advance to the PRM on Monday March 23rd. They were also given the opportunity to comment the report in writing before or up to three weeks after the PRM. The PRM was chaired by Dr. Wolfgang Schade from Fraunhofer ISI. Half of the invited experts have been proposed by the project team in their proposal, the other half was proposed by the European Commission.

As an introduction to the meeting the chairman and the European Commission set the scene by explaining the framework of TEN-T policy and funding as well as the objective of the study and the meeting. Then the project team presented their methodology and findings.

Basically the group of experts endorsed the methodology and findings of the study. Specific comments/criticism and suggestions for improvements or further research concerned:

- The study applied the European Reference Scenario that includes the implementation of core TEN-T network by 2030. Mainly government and European funds are considered as sources in the Reference Scenario i.e. also in the ASTRA model. Some experts questioned the consistency of this Reference Scenario in times of austerity and budget consolidation and suggested to have a counterfactual without TEN-T implementation against which any project or corridor of TEN-T should be estimated. However, the project team argued that this Reference Scenario was agreed by the Member States and provides the common base for analyses at EU level. And a counterfactual without TEN-T would not enable to measure the network effects between different and connected areas of the network.
- It was questioned by some experts if crowding out of other investment is considered. Though the ASTRA model does not include a financial market a mechanism is modeled that dampens investment when government debt is above a threshold of 60% of GDP of a country.
- Some experts expected that the (large) projects contributing to the completion of the core TEN-T network include a few whose Cost-Benefit-Ratio (CBR) could be questioned. They proposed to perform separate analyses of that type of the study for these projects to test their hypothesis. The EC underlined that all projects of the TEN-T core network are based on EU legislation (Regulation N° 1316/2013 of the European Parliament and the Council of 11 December 2013 on Union Guidelines for the development of the trans-European transport network), and that they are furthermore backed by an analytical process undertaken in the framework of the core network corridor approach. The study team explained that in the course of the study on the cost of non-completion of the TEN-T, such a separate analysis is not foreseen.

- Other experts pointed out that it is very valuable and important to look at the whole network and expected that the implementation of whole TEN-T could generate higher wider economic benefits than estimated by the study due to creating larger markets, leading to cost reductions and stronger specialization fostering higher productivity growth and thus improving the European competitiveness. They argue that the full spectrum of such impacts seems not to be covered by the ASTRA model. The project team argued that the model estimates impacts on trade by transport improvements, though other experts argued that the resulting trade impacts seem to be at the lower end. In particular the cross-border cases should generate stronger trade impacts i.e. stronger growth of exports.
- Further some experts highlighted that economic impacts of improved reliability by TEN-T implementation might not be captured in full. The project team agrees that only part of these impacts would be captured by the ASTRA capacity-flow models. However, theory on measuring the full benefits on roads is just developing and it will require the use of a network model.
- It was suggested to carry out further sensitivity tests. Two examples were given: (1) GDP shock and (2) traffic forecast overestimation. It was argued that probability for future GDP shocks is significant and that in case of GDP shocks the wider economic benefits would not occur or at least would be less substantial then estimated by the study.
- It was pointed out that the results should be path dependent (i.e. time profiles of implementation(s) of projects matter) and questioned if a slower implementation would generate the same benefits. The project team agreed to the fact of path dependency and would expect that slower implementation by 2030 would lead to a lower level of benefits of TEN-T by 2030.
- It was also suggested that the same level of investment made into other sectors might generate higher multipliers. The project team argued that the wider economic effects come from both (1) the implementation of infrastructure, which might be comparable to other sectors and (2) the improvements of time and cost efficiency of transport, which will not be generated by other sectors. Therefore it could not be decided ex-ante which sector generates the higher multipliers. The findings were in the range of other multipliers found in literature.
- An intense debate focused on the role that different approaches of Cost-Benefit-Analysis (CBA) should play and if the assessment of wider economic effects is recommended. Some experts favored the classical project based assessment using a transport network model and taking its results as input for the CBA. The new EC DG Regio Guide to Cost-benefit Analysis of Investment Projects was proposed as a blueprint to carry out such analyses. Other experts proposed to improve Spatial Computable General Equilibrium Models (SCGE) and to use their results for the CBA as they would provide the relevant indicators. The project team argues that given the size of the investment into TEN-T both in terms of invested money and in terms of impacts for long distance transport a mere project level

based assessment is insufficient. With this size we must expect wider economic effects not captured by the transport network model based approaches. And SCGE could be another option as for a methodology but still would require further developments.

- Other experts recommended, if feasible to provide results at the project level or at least to explain if and how the approach of the study could be useful for assessments at the project level. In the view of these experts, this would be the important level for decisions of the funding Institutions. The Commission points out that a more in-depth analysis, also allowing conclusions at project level, might be undertaken along with the continuing analysis of the core network corridors in the years ahead.
- It was recommended to use the term "multiplier" for the aggregate result of the macro-economic analysis and not to use the term (quasi) CBA, when calculating an indicator relating investment with impact on economic output. Additionally it was recommended to use income instead of GDP as output indicator. Also it was pointed out that the values were not discounted to present values. This is confirmed by the project team, but they also argued that the infrastructures provide for long term benefits also after 2030, which were also not included in the estimation of benefits.
- Another expert recommendation concerned to use the internal rate of return and not the net present value for the assessment of projects. Also to use accessibility as an indicator for assessment was recommended.
- Other experts highlighted the link between TEN-T policy implementation (especially rail projects) and improved performance of the railway system which will also contribute to increasing the benefits. This refers to issues such as interoperability, improved efficiency by breaking the link between rail network managers and rail operators or to collect railway performance data that enables to identify weaknesses and potentials. This data should then be public. These experts also argued that the competition between maritime and rail transport for freight should be considered in more detail as the results reveal that the focus on railways also may dampen demand for maritime transport.
- The innovation analysis was deemed to be a very informative and innovative approach. The conclusions that TEN-T policy would contribute to foster innovations in particular in the rail sector, and to some extent in the shipping sector, were convincing to the experts. TEN-T funding decisions of railway technologies should take this aspect into account.
- The experts argued that the regional analysis on NUTS-II level lacks the input from a proper network model. Connecting the results of the national economic structure with the regional economic structure covers only one part of the influencing factors of regional impacts. Presenting these results could cause misleading conclusions. It was therefore agreed that the analysis should not be reported and should be

repeated when the fully specified network data of TEN-T networks for 2030 becomes available.

- However, it was emphasized by some experts that an analysis of impacts at the regional level (NUTS-II and lower), and in particular the impacts on peripheral regions, will also be relevant to gather the full spectrum of results. It was understood that this level of detail was not the purpose of the study.

Finally, the EC concluded that this type of study has been undertaken for the very first time. The very valuable comments and suggestions of the experts greatly help to comprehend and judge the results. The draft final report would be revised taking into account the comments.

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