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Validating the HIGH-TOOL model: Results of checks and implemented Case Studies

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Glossary

ACEA	European Automobile Manufacturers' Association
BEV	Battery electric vehicles
CARE	European database on road accidents
CEF	Connecting Europe Facility
CNG	Compressed natural gas
CO_2	Carbon dioxide
EC	European Commission
ECR	Economy & Resources module
ETS	Emissions trading scheme
EU	European Union
FCEV	Fuel cell electric vehicle
FRD	Freight Demand module
GDP	Gross Domestic Product
GHG	Greenhouse Gas emissions
GVA	Gross Value Added
HDV	Heavy duty vehicle
HEV	Hybrid electric vehicle
HSR	High-speed rail
LCV	Light commercial vehicles
LPG	Liquefied petroleum gas
M2	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass ("technically permissible maximum laden mass") not exceeding 5 tons
M3	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tons
N2	Vehicles for the carriage of goods and having a maximum mass exceeding 3.5 tonnes, but not exceeding 12 tonnes
N3	Vehicles for the carriage of goods and having a maximum mass exceeding 12 tonnes
No	Number
NO_x	Mono-nitrogen oxides
NO_2	Nitrous oxide
NUTS	Nomenclature of Units for Territorial Statistics
O/D	Origin/Destination
pkm	Passenger-kilometre
PAD	Passenger demand module
PHEV	Electric-hybrid powered vehicle
PM	Particulate matter
SAF	Safety module
SSS	Short sea shipping
TEN-T	Trans-European Transport Network

tkm	Tonne-kilometre
vkm	Vehicle-kilometre
WP	Work Package

Executive Summary

This deliverable presents the results of series of checks of the HIGH-TOOL model, as a part of the validation process. More specifically, the checks were performed by examining the model through eight case studies against the baseline scenario. Each case embraces either a policy scenario, or a specific test case (modules' stability, sensitivity analysis). The scope of changes in model settings and policy levers were documented and the obtained results were compared to the baseline scenario. The case studies were designed such that all the modules of HIGH-TOOL model were concerned in at least one of the conducted case studies. The selected cases addressed in this report are as follows:

- Case 1: Post 2020 introduction of CO_2 standards for cars and vans
- Case 2: Evaluation of corridor improvement for rail passenger transport via the hypernet
- Case 3: Introduction of speed limits for light commercial vehicles
- Case 4: Untapped potential of maritime ports related to liberalisation policies
- Case 5: Cost sensitivity of the HIGH-TOOL model for passenger road mode
- Case 6: Modules' stability in a given time-step
- Case 7: Increase of public and private transport infrastructure investments
- Case 8: Competition between high-speed rail and air.

The obtained results demonstrate that the HIGH-TOOL model is capable of assessing a wide variety of different types of policies at a strategic level. The integrated model – i.e. the composition of the interlinked modules – is well functioning, and the impact chains are correctly covered (e.g. the modification of impedances in the hypernet for passenger transport results in passenger demand changes, which subsequently affect environmental, economic and safety-related indicators). Also the well-functioning and the usefulness of the hypernet model for passenger transport – which represents an add-on to the original scope of the HIGH-TOOL model – has been demonstrated.

The model shows clearly a converging behaviour, and produces stable results at all levels of analysis: at an aggregated level, in different time steps and across different geographical units. For the calculation of the baseline scenario a few iterative calculations (over the previous results) are recommended. Iterative calculations in a policy scenario simulation could produce marginal changes to the results, at the expense of much more computation time. However, an iterative calculation process for policy scenarios to refine the results is not required, since the model produces stable results.

The model outputs are largely in line with expectations. However, as it is usually the case with interpretation of results of any model, features such as modelling methodology, the spatial scope or the underlying assumptions need to be considered when interpreting the results of the HIGH-TOOL model. Furthermore, the case study analyses provided some insights in possible extensions of HIGH-TOOL in the future. Being an open source instrument which does not require any commercial software products to be run, the HIGH-TOOL model provides the basis for an efficient further development in the future.

1 Introduction

1.1 HIGH-TOOL Validation

This deliverable is part of Work Package 8 (WP8), test and validation of results of the HIGH-TOOL model. The validation process implies comparing HIGH-TOOL with other existing model outcomes and specifically the projection by the EU Reference scenario 2013 (EC, 2013), and testing the model's rationality through various policy options. While the first validation objective is documented in Deliverable 8.1 (van Meijeren et al., 2016), the second (model rationality) is examined in this deliverable through a set of case studies.

More specifically, this deliverable sets three distinctive steps which are shown in Figure 1:

- The definition of the case studies, under consultation with the EC, covering a wide range of policies and other technical elements of the model.
- The design, implementation and run of each case study.
- The analysis of the outcomes: each case study results in a new Data Stock with new outputs. These outputs are analysed and compared to the HIGH-TOOL baseline in order to check the validity of the outcomes (how the model reacts to a specific change in input variables).

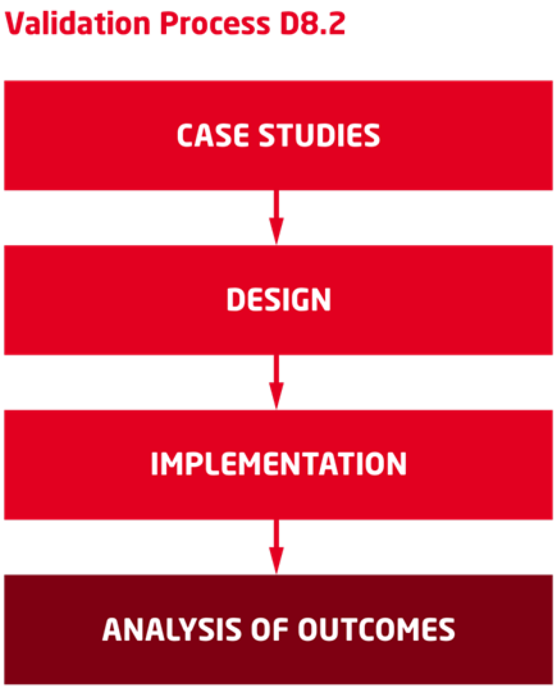

Figure 1: The validation process for D8.2

The HIGH-TOOL case studies were defined and run by different project partners. In this way, the outcomes of the individual runs were assessed by a group of users, ensuring the independent view of the outcomes.

1.2 Test Cases

The case studies were designed such that all the modules of HIGH-TOOL model were concerned in at least one of the conducted case studies. The following eight cases were defined in coordination with the European Commission[1]:

- Case 1: Post 2020 introduction of CO_2 standards for cars and vans
- Case 2: Evaluation of corridor improvement for rail passenger transport via the hypernet
- Case 3: Introduction of speed limits for light commercial vehicles
- Case 4: Untapped potential of maritime ports related to liberalisation policies
- Case 5: Cost sensitivity of the HIGH-TOOL model for passenger road mode
- Case 6: Modules' stability in a given time-step
- Case 7: Increase of public and private transport infrastructure investments
- Case 8: Competition between high-speed rail and air.

1.3 Link to other Deliverables

This deliverable explains the trends when scenarios are applied on the HIGH-TOOL model. For a detailed comparison to the EU Reference scenario, the reader is referred to van Meijeren et al. (2016). Furthermore, the parameters mentioned in the case studies are explained in detail by Kiel et al. (2016). Finally, the description of the equations and elasticities used in the model are described by van Grol et al. (2016), while the model structure is presented by Mandel et al. (2016).

1.4 Structure of the Report

This chapter presents the overall methodology for validating the HIGH-TOOL model and briefly presents the test cases. Chapter 2 describes the main outcomes of the cases. More specifically, Chapter 2 identifies and explains the trends for each case. Chapter 3 presents the conclusions.

[1] The case studies were presented in a memo by Jan Kiel: "Work package 8, Deliverable 8.2 – Case studies" (1 June 2016).

2 Case Studies

In this chapter the eight case studies are described, the policy lever subject to changes are listed, and the expected and actual results are shown and discussed.

2.1 Case 1: Post 2020 Introduction of CO_2 Standards for Cars and Vans

2.1.1 Description of the Case

In the EU, transport CO_2 emissions have risen by 29% since 1990 with 12% of the total EU emissions now arising from the exhaust of cars (Transport & Environment, 2015). As part of its 2030 Climate and Energy Framework[2] the EU has set a target to reduce emissions in the non-ETS sectors by 30% from 2005 levels. In this regard, technology to improve vehicle efficiency, driven through standards, must do much of the heavy-lifting to reduce emissions and help Member States meet their goals (see Transport & Environment, 2015). Setting vehicle CO_2 standards are one of the EU's most successful climate policies. They stimulate innovation and maintain the competitiveness of the EU automotive industry by creating a market for globally important technologies that improve fuel efficiency. At the time being, two regulations are implemented in the European Union, i.e. EC (2009) that sets a fleet-wide average target of 130 g CO_2/km for new passenger cars to be met by 2015 and a target for 2021 of 95 g CO_2/km and EU (2011a) that sets an average target for new light commercial vehicles (LCVs) of 175 g CO_2/km by 2017 and 147 g CO_2/km for 2020.

In this "Post 2020 introduction of CO_2 standards for cars and vans" case we propose to extend the CO_2 standards for the period after 2020. Based on Transport & Environment (2015), this implies to set a target of 70 g CO_2/km for passenger cars and 100 g CO_2/km for vans as of 2025.

2.1.2 Policy Levers

Input parameters to be changed in the Environment module are fuel consumption and CO_2 emission factors of the two conventional vehicle fuel types (g/vehicle-km), i.e. diesel and gasoline, and the purchase costs of those two conventional types as well as two alternative types, namely electric-hybrid powered (PHEV) and battery electric vehicles (BEV).

[2] http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm

McKinsey (2013) estimates that the average manufacturing costs of cars increased by around 3% to 4% between 1998 and 2011 due to regulation on efficiency (CO_2) in that period. Further cost increases should follow stricter regulations following that period but at the same time car manufacturers have to keep their price as competitive as possible. Based on this, we consider then that an increase of 6% and 9% of the average purchase cost of the conventionally diesel and gasoline fuelled vehicles respectively are quite reasonable to be applied in the case study to fully compensate the technological improvement. The difference in purchase cost increase between conventional diesel and gasoline vehicles is caused by the relative efficiency of diesel compared to petrol which means that CO_2 emissions per kilometre are up to 20% less from a diesel car than from a petrol one (ACEA, 2016). For this reason, the increase in the average purchase cost of diesel should be lower than that of gasoline in order to encourage the use of diesel in reaching the CO_2 target.

Second, we assume that powertrain option would accompany the post 2020 CO_2 regulations: there will be a reduction in the purchase prices of PHEV and BEV vehicles in this scenario. which signifies that the government would give slightly more incentives or lift up some taxation on chargeable electric powered vehicles to boost this particular market. Current incentives to boost electric powered vehicles are in place currently in various EU Member States[3]. We consider that an additional 2% reduction in PHEV and BEV average purchase costs assumption would reasonably represent this accompanying measures in the powertrain option side.

Finally we also assume that a limited 5% fuel efficiency improvement will happen at the lowest category of heavy duty vehicles, i.e. rigid trucks below 7.5 tonnes. We can consider this as a spill over effect of fuel efficiency improvements that happen in light commercial vehicles. The purchase price of this truck category is assumed to increase slightly, namely 1% with regards to the baseline scenario.

All the above changes with regard to the baseline scenario are implemented in the model starting in the year 2025.

Table 1 depicts the policy levers for this case.

[3] http://www.acea.be/uploads/publications/Electric_vehicles_overview_2016.pdf

Table 1: Case study 1 – Policy levers

Parameter name	Data stock name	Affected dimension	Type of change
Fuel consumption and CO_2 emission factor for cars	i_ev_emfactor	Year, emission g/km	29.5% reduction of fuel consumption and CO_2 emission factors for all years starting from 2025 for new diesel and gasoline cars on all EU28+2 countries
Fuel consumption and CO_2 emission factor for vans	i_ev_emfactor	Year, emission g/km	28.7% reduction of fuel consumption and CO_2 emission factors for all years starting from 2025 for new diesel and gasoline vans on all EU28+2 countries
Fuel consumption and CO_2 emission factor for rigid trucks ≤7.5 tonnes	i_ev_emfactor	Year, emission g/km	5% reduction of fuel consumption and CO_2 emission factors for all years starting from 2025 for new diesel and gasoline vans on all EU28+2 countries
Vehicle purchase cost	Table: 'i_vs_cap'; Variable 'i_vs_cap_rpsc_mkt'	Year, mode, costs in EUR	Differentiated increase/decrease for new vehicle purchase price in Euro at NUTS-0 level: diesel and gasoline cars and vans: +9%,PHEV and BEV cars and vans: -2%, rigid trucks ≤7.5 tonnes: +1%. This concerns EU28+2 countries

2.1.3 Expected Outcomes

The model inputs were, as described above, higher vehicle purchase costs for conventional vehicles, and decreased emission factors. Therefore the environmental module should show an overall lower emission level, the vehicle module should interact with other modules (Economy, Passenger demand), and result in higher transport costs, and a likely slight mode shift towards public transport and non-motorised modes.

It is expected that the case will change the parameters in the following way:

- Higher transport costs: Due to higher vehicle prices, transport costs will increase, however, this effect will be compensated by the reduced fuel expenses through reduced consumption, up to a certain level.
- Slight mode shift: This effect can be derived from the previous one, higher costs results in a slight mode shift towards public transport and non-motorised modes.
- Reactions at country level will differ: Can also be derived from the increased cost effect, different countries have different population and purchase power.
- Shift in vehicle propulsion types: Due to slightly higher average vehicle purchase costs of the conventional vehicle types and slightly lower average purchase cost of the chargeable electric vehicle types there will be some shifts toward more fuel efficiency in vehicle propulsion types.

- Reduction of emissions: Reduced emissions comes on one hand directly from the reduced emission of the vehicles, and also from the mode shift towards more sustainable modes of transport and propulsion types.

Table 2 shows which parameters are affected by the policy levers.

Table 2: Case study 1 – Affected parameters

Parameter name	Expected type of change
Public transport demand	+
Road externalities: climate change (both for passenger and freight transport)	--
Generalised costs	+

2.1.4 HIGH-TOOL Outcomes

The outcomes are based on the Policy Assessment Report generated by the HIGH-TOOL model on 2 December 2016.

Results of externalities are in line with expectations. Regarding road passenger transport, there is a significant decrease for climate change values after 2025 and a moderate decrease for air pollution. Furthermore, a limited decrease of climate change and air pollution values of the freight sector is forecasted (see Table 3 and Table 4). However, other externality fields show a slight increase, this is due to the higher demand of road transport. This pattern will be explained later.

Table 3: Case study 1 – Summary of externalities, Scenario-Baseline difference

Summary (in € million for EU28+2)

Type	2015	2020	2025	2030	2035	2040	2045	2050	Total
Air pollution	*0,00*	*0,00*	*0,00*	*93,62*	*-82,08*	*-416,32*	*-773,99*	*-857,47*	*-2 036,24*
Climate change	*0,00*	*0,00*	*0,00*	*-1 184,63*	*-2 888,50*	*-5 089,92*	*-7 694,33*	*-8 721,54*	*-25 578,92*
Up-downstream processes	*0,00*	*0,00*	*0,00*	*25,89*	*19,55*	*6,46*	*11,86*	*9,72*	*73,48*
Marginal infrastructure cost	*0,00*	*0,00*	*0,00*	*10,91*	*6,89*	*2,81*	*5,58*	*4,01*	*30,20*
Accidents	*0,00*	*0,00*	*0,00*	*37,23*	*26,91*	*9,39*	*22,80*	*32,97*	*129,30*
Total externalities	***0,00***	***0,00***	***0,00***	***-1 016,98***	***-2 917,23***	***-5 487,58***	***-8 428,08***	***-9 532,31***	***-27 382,18***

Table 4: Case study 1 – Climate change, Scenario-Baseline difference

Climate change (in € million for EU28+2)

Mode		2015	2020	2025	2030	2035	2040	2045	2050	Total
Passenger	**Road**	*0,00*	*0,00*	*0,00*	*-1 083,86*	*-2 654,28*	*-4 690,36*	*-7 053,57*	*-8 003,65*	*-23 485,72*
	Rail	*0,00*	*0,00*	*0,00*	*-0,16*	*0,00*	*0,01*	*-0,12*	*-0,08*	*-0,35*
	Air	*0,00*	*0,00*	*0,00*	*-7,14*	*-4,27*	*-2,72*	*-5,26*	*-6,37*	*-25,76*
Total passenger		***0,00***	***0,00***	***0,00***	***-1 091,16***	***-2 658,55***	***-4 693,07***	***-7 058,95***	***-8 010,10***	***-23 511,83***
Freight	**Road**	*0,00*	*0,00*	*0,00*	*-93,47*	*-230,02*	*-397,33*	*-634,82*	*-710,09*	*-2 065,73*
	Rail	*0,00*	*0,00*	*0,00*	*0,00*	*0,04*	*-0,03*	*-0,05*	*-0,08*	*-0,12*
	Air	*0,00*	*0,00*	*0,00*	*0,00*	*0,02*	*0,05*	*0,08*	*0,08*	*0,23*
	IWW	*0,00*	*0,00*	*0,00*	*0,00*	*0,01*	*-0,04*	*-0,07*	*-0,12*	*-0,22*
	SSS	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,50*	*-0,52*	*-1,23*	*-1,25*
Total freight		***0,00***	***0,00***	***0,00***	***-93,47***	***-229,95***	***-396,85***	***-635,38***	***-711,44***	***-2 067,09***
Total climate change		***0,00***	***0,00***	***0,00***	***-1 184,63***	***-2 888,50***	***-5 089,92***	***-7 694,33***	***-8 721,54***	***-25 578,92***

The explanation of the model behaviour on generalised costs and transport demand, which also affects the externalities, is the following. Car transport demand increases, because the generalised costs of using cars decrease. The generalised costs of cars decrease, because the fuel efficiencies are assumed to improve faster than the purchase price of cars increases. In other words, the decrease of fuel consumption factors outweighs the increase of car purchase price. In this situation, the final generalised costs of car use (EUR/vkm) in the scenario is lower than those in the baseline (see Table 5).

As car generalised costs are lower than in the baseline, the transport demand for cars is expected to increase, while the other road transport modes are decreasing.

Table 5: Case study 1 – Generalised costs, Scenario-Baseline difference

Passenger generalised transport cost (in € million for EU28+2)

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Road	*0,00*	*0,00*	*0,00*	*3 532,68*	*-11 071,04*	*-25 613,76*	*-50 855,40*	*-68 981,30*	*-73 974,67*
Rail	*0,00*	*0,00*	*0,00*	*-62,11*	*-134,72*	*-190,19*	*-372,36*	*-491,14*	*-507,90*
Air	*0,00*	*0,00*	*0,00*	*7,19*	*-309,10*	*-669,80*	*-1 426,15*	*-2 047,03*	*-2 334,31*
Coach	*0,00*	*0,00*	*0,00*	*-40,06*	*-97,36*	*-145,47*	*-282,05*	*-369,19*	*-379,27*
Total passenger cost	***0,00***	***0,00***	***0,00***	***3 437,70***	***-11 612,22***	***-26 619,22***	***-52 935,96***	***-71 888,66***	***-77 196,15***

Freight generalised transport cost (in € million for EU28+2)

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Road	*0,00*	*0,00*	*0,00*	*0,00*	*51,47*	*-61,17*	*-109,13*	*-401,73*	*-834,15*
Rail	*0,00*	*0,00*	*0,00*	*0,00*	*18,93*	*-19,70*	*-17,76*	*-94,26*	*-204,90*
IWW	*0,00*	*0,00*	*0,00*	*0,00*	*1,50*	*-3,31*	*-8,15*	*-18,70*	*-33,85*
Short Sea Shipping	*0,00*	*0,00*	*0,00*	*0,00*	*34,09*	*-88,85*	*-240,47*	*-527,14*	*-764,40*
Maritime	*0,00*	*0,00*	*0,00*	*0,00*	*25,09*	*4,71*	*-8,51*	*-24,91*	*-74,45*
Total freight cost	***0,00***	***0,00***	***0,00***	***0,00***	***131,08***	***-168,32***	***-384,02***	***-1 066,74***	***-1 911,75***

This also appears in the modal split graphs of the passenger demand module; the highest change is the 0.03% increase for car transport in 2025 (see Figure 2).

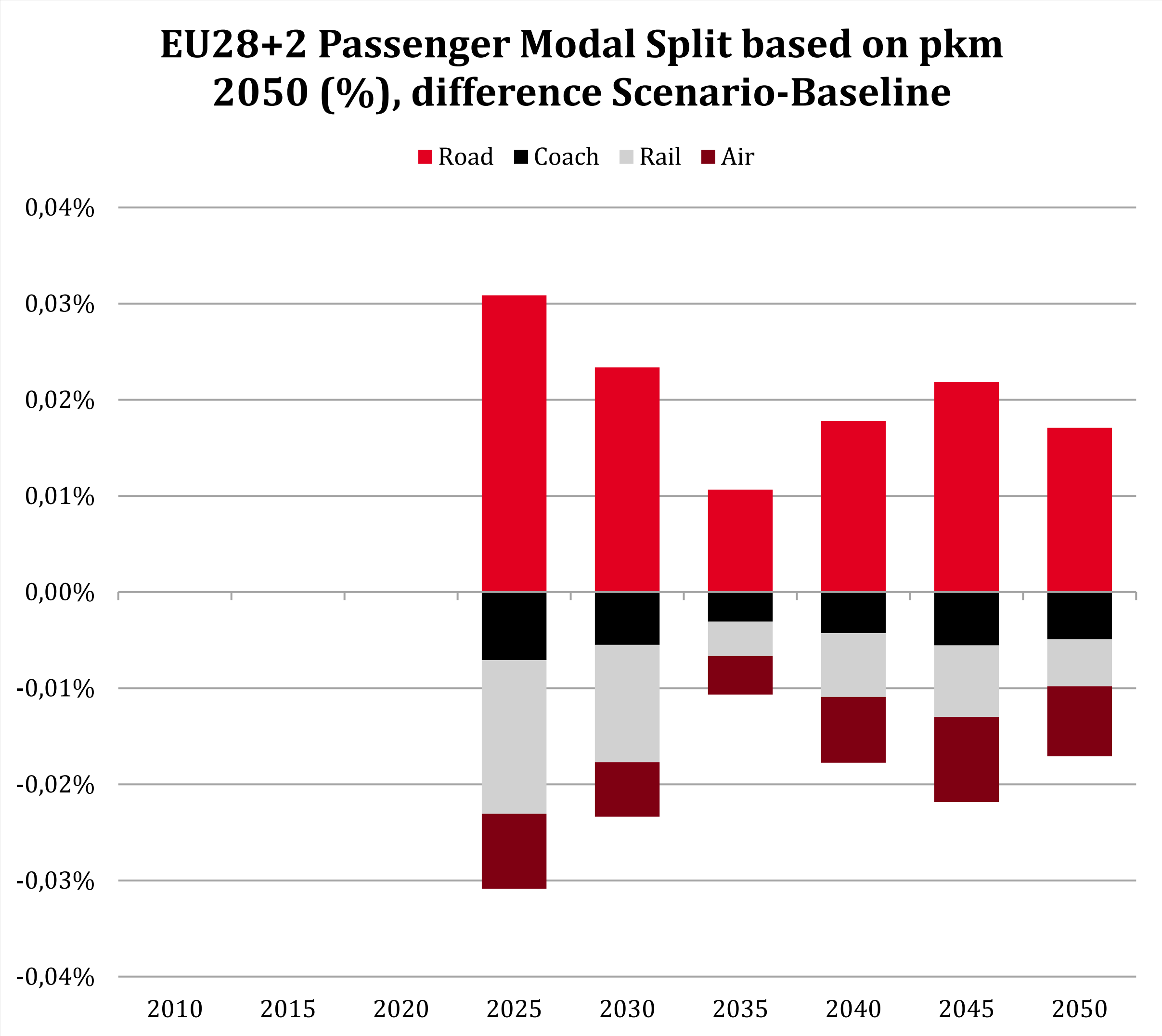

Figure 2: Case study 1 – PAD modal split, 2050

The share of gasoline cars is expected to increase in comparison to other car fuel types. The reason is similar to the generalised cost/transport demand relation: the increase of purchase prices of gasoline cars defined in the scenario is not significant enough to compensate the improvement of gasoline car fuel efficiency. At the end, the generalised costs of gasoline cars are lower with regard to those of other fuel types. Therefore, the vehicle stock share of gasoline cars is expected to increase to the detriment of other fuel type shares. The results are shown in Figure 3.

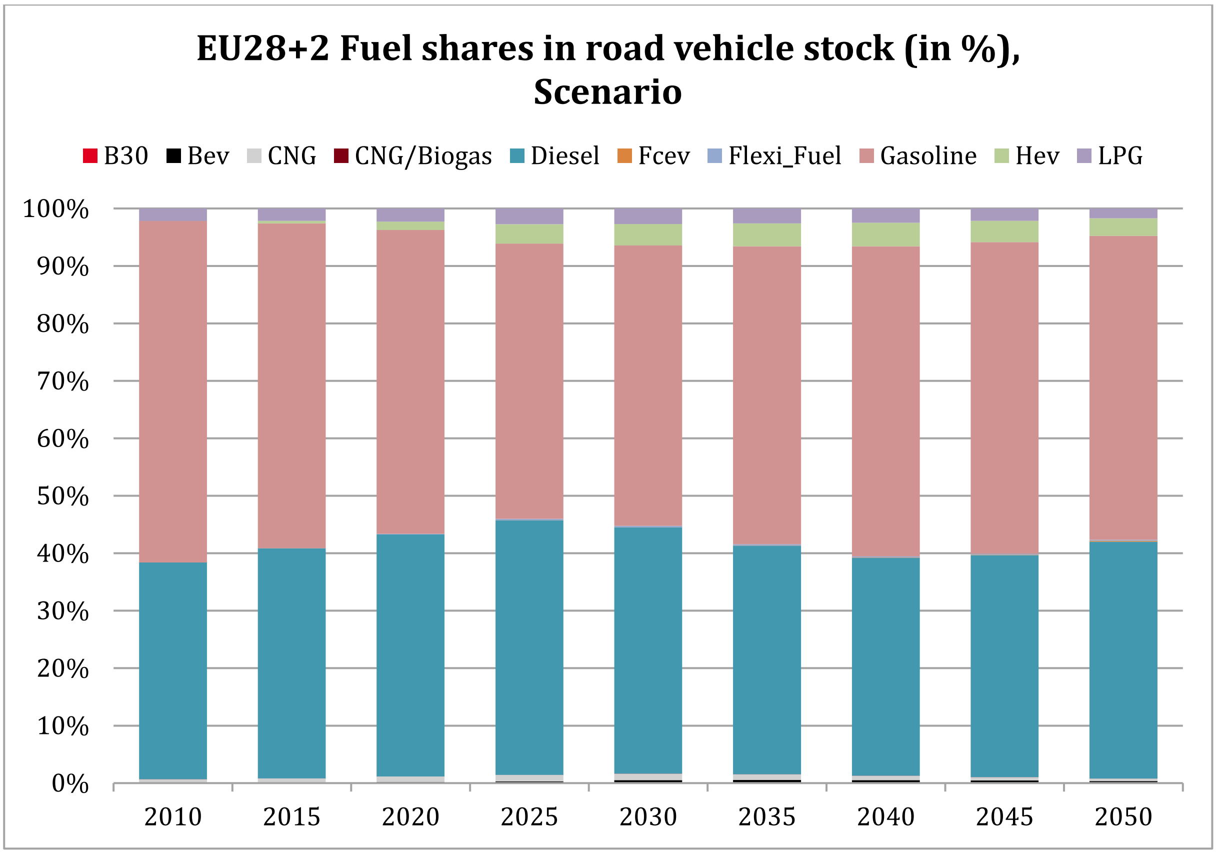

Figure 3: Case study 1 – VES fuel shares, Scenario

Comparison of expected changes and the HIGH-TOOL outcomes is shown in Table 6.

The deviation between the expected change and the outcomes is explained in Chapter 2.1.5 Conclusions, below.

Table 6: Case study 1 – Comparison of results with the outcomes

Parameter name	**Expected type of change**	**HIGH-TOOL outcomes**
Public transport demand	+	-
Car transport demand	-	+
Road externalities: climate change (both for passenger and freight transport)	--	--
Generalised costs	+	-

2.1.5 Conclusions

The scenario has not been balanced enough between the increase of vehicle prices and the decrease of fuel consumption and emission: more detailed, there is an increase of car price which is lower than desirable (in particular that of gasoline cars) or/and the assumption on the reduction of fuel consumption and emission factors were slightly over-estimated. However, all those assumptions included in the case study and the model (regarding the purchase price increase and fuel efficiency improvement) were based on relevant studies[4]. As a final conclusion, the model outcomes differ from the previously expected results, but going into details, it becomes clear, that the answers given by the model are reasonable, plausible and consistent.

2.2 Case 2: Evaluation of Corridor Improvement for Rail Passenger Transport via the Hypernet

2.2.1 Description of the Case

This case study examines the application of the hypernet facility of the HIGH-TOOL model. The assumption is made that rail passenger travel times will further decrease along the "Magistrale" corridor Paris–Strasbourg–Karlsruhe–Munich–Vienna–Bratislava. The travel time decrease is assumed to be on top of the time savings due to TEN-T/CEF policies already in the baseline scenario. Thus, the investment assumptions do not refer to concrete rail infrastructure projects, but are hypothetical.

2.2.2 Policy Levers

A number of hypernet rail links along the Magistrale corridor are assumed to receive a travel time reduction for passenger transport of 10% for 2030 and beyond. Thus the variable "i_pd_core_hyper_net_link.i_pd_link_time_weight" is set to 0.9 for these years, which implies a decrease in travel time by 10% compared to the baseline situation. Table 7 provides a summary of the changes. In Table 8, all hypernet rail links are listed which are modified, while Figure 4 displays these links on a map.

[4] Transport & Environment: 2025 CO_2 regulation, June 2015

Table 7: Case study 2 – Policy levers

Parameter name	**Data stock name**	**Affected dimension**	**Type of change**
Rail passenger travel time	i_pd_core_hyper_net_link.i _pd_link_time_weight	Year, hypernet link	For the selected rail hypernet links, the passenger travel time is reduced by 10% from 2030

Table 8: Case study 2 – Modified hypernet rail links in the Magistrale corridor

HIGH-TOOL IDs	**NUTS-2 IDs**	**NUTS-2 Names**
1120201-1120100	FR21-FR10	Champagne-Ardenne–Ile de France
1120401-1120201	FR41-FR21	Lorraine–Champagne-Ardenne
1120401-1120402	FR41-FR42	Lorraine–Alsace
1070103-1120402	DE13-FR42	Freiburg–Alsace
1070102-1070103	DE12-DE13	Karlsruhe–Freiburg
1070102-1070101	DE12-DE11	Karlsruhe–Stuttgart
1070207-1070101	DE27-DE11	Schwaben–Stuttgart
1070207-1070201	DE27-DE21	Schwaben–Oberbayern
1010302-1070201	AT32-DE21	Salzburg–Oberbayern
1010302-1010301	AT32-AT31	Salzburg–Oberösterreich
1010102-1010301	AT12-AT31	Niederösterreich–Oberösterreich
1010102-1010103	AT12-AT13	Niederösterreich–Wien
1010102-1310001	AT12-SK01	Niederösterreich–Bratislavsky kraj

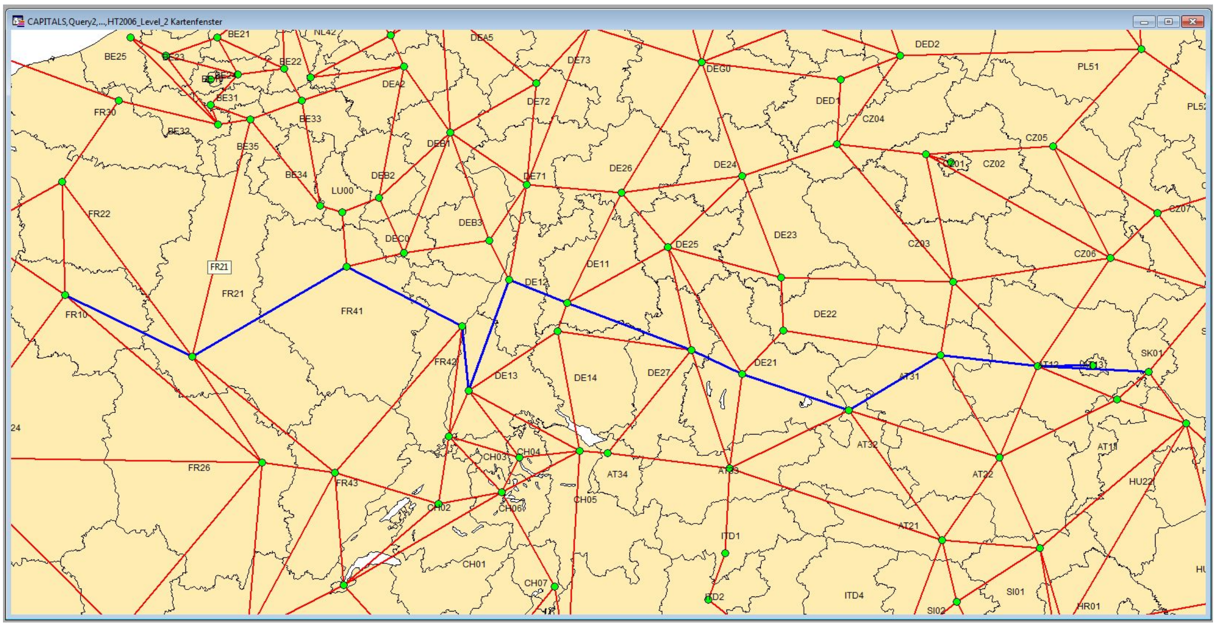

Figure 4: Case study 2 – Map showing the hypernet rail links of the Magistrale corridor (blue), other hypernet rail links (red) and NUTS-2 zone centroids (green)

2.2.3 Expected Outcomes

The assumed decrease of passenger travel time on several rail links results in an improved competitive condition of the rail mode on the concerned O/D relations. Thus the modal share for rail transport is expected to increase, while the market share of competing modes of transport (passenger car, coach, air) is expected to decline. With the modal split changing in favour of rail transport, the emission of GHG and air pollutants, as well as the number of road accidents are expected to decrease. The decrease in travel times and generalised costs of transport is expected to generate positive economic impacts (increase in Gross Domestic Product (GDP) and Gross Value Added (GVA)). Since at the European scale the assumed measures have a relatively limited scope, it is expected that the changes are rather slight. The affected parameters and the expectations in the model are listed in Table 9.

Table 9: Case study 2 – Affected parameters

Parameter name	Expected type of change
Rail passenger demand	+
Road passenger demand	-
Coach passenger demand	-
Air passenger demand	-
GHG emissions	-
Emission of air pollutants	-
Road accidents	-
GDP/ GVA	+

2.2.4 HIGH-TOOL Outcomes

In the following, the HIGH-TOOL results are presented in a more detailed manner.

The infrastructure measures are assumed to become effective in 2030. Thus, any changes with respect to the Baseline occur only for 2030 and beyond. Therefore, the results of the HIGH-TOOL are displayed in this chapter only for 2030 and beyond.

The HIGH-TOOL run reveals impacts on passenger demand by mode of transport (see Figure 5): the model predicts an increase in rail passenger demand while the demand of competing modes (road – i.e. private passenger cars – coach and air) is expected to decrease. The results do not only reveal a mode shift effect, but also reflect induced demand for rail passenger transport: the increase in rail demand exceeds the decrease in demand of the competing modes. Thus for the O/D relations concerned by the assumed infrastructure investments, a slight increase in average length of passenger trips by rail can be recognised.

The percentage changes in relation to the total passenger transport demand are relatively limited (see Table 10), which is explained by the limited geographical scope of the measures, as well as by the pattern that the assumed infrastructure improvements relate to inter-zonal passenger transport flows at the level of NUTS-2, which represent only a small share of the overall market.

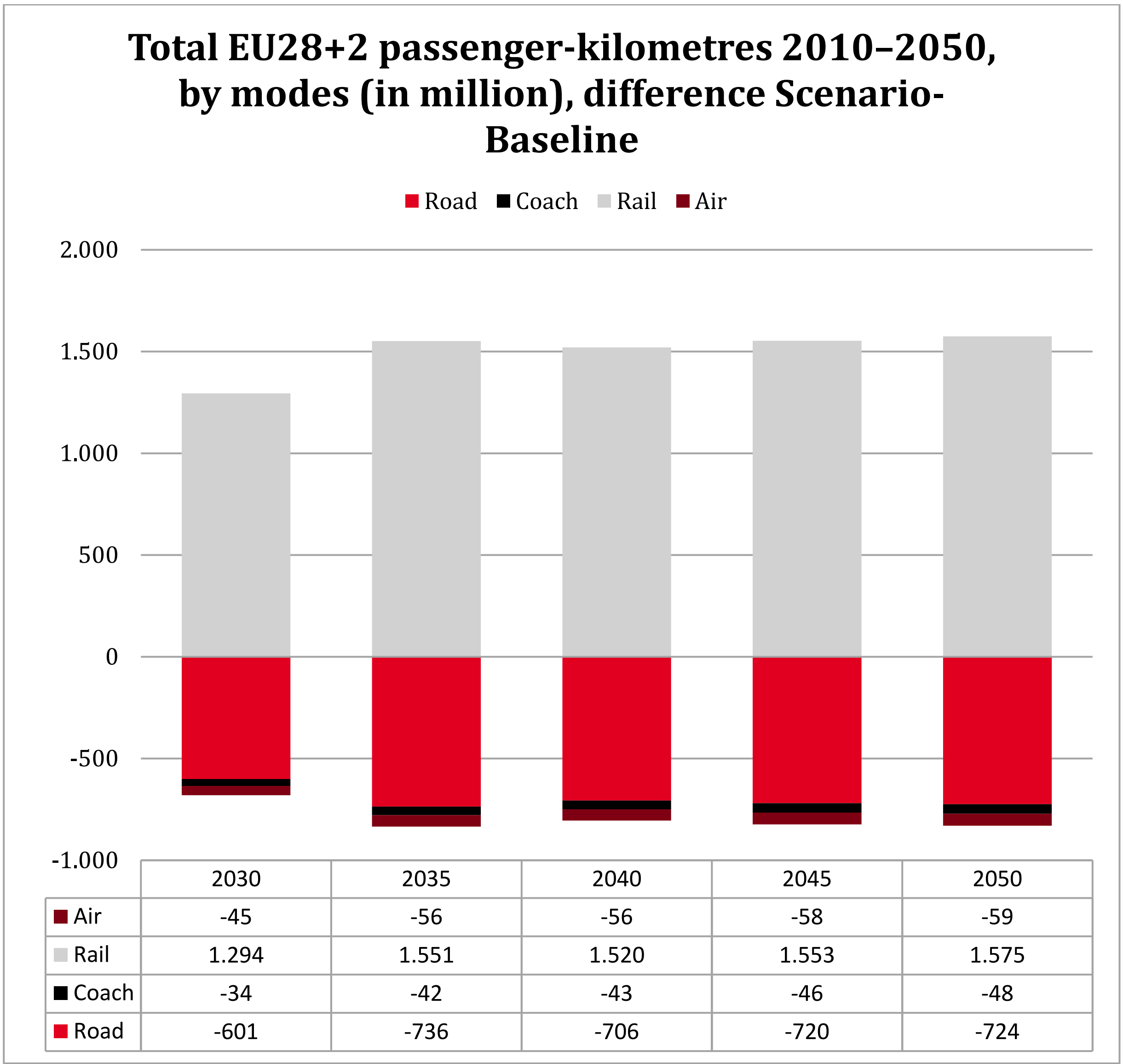

Figure 5: Case study 2 – Impact on passenger demand by mode of transport

Table 10: Case study 2 – Absolute and relative impacts on passenger transport demand by mode of transport

EU28+2 Modal split based on pkm (in millions), Difference

	Air		Coach		Rail		Road	
Year	**pkm**	**%**	**pkm**	**%**	**pkm**	**%**	**pkm**	**%**
2010	0	0,00%	0	0,00%	0	0,00%	0	0,00%
2015	0	0,00%	0	0,00%	0	0,00%	0	0,00%
2020	0	0,00%	0	0,00%	0	0,00%	0	0,00%
2025	0	0,00%	0	0,00%	0	0,00%	0	0,00%
2030	-45	0,00%	-34	0,00%	1.294	0,02%	-601	-0,01%
2035	-56	0,00%	-42	0,00%	1.551	0,02%	-736	-0,02%
2040	-56	0,00%	-43	0,00%	1.520	0,02%	-706	-0,01%
2045	-58	0,00%	-46	0,00%	1.553	0,02%	-720	-0,01%
2050	-59	0,00%	-48	0,00%	1.575	0,02%	-724	-0,01%

Regarding impacts on demand by mode of transport for 2050 at NUTS-0 level, the strongest impacts in absolute terms are expected for Germany and France, followed by Austria (see Table 11). These countries are the key beneficiaries of the assumed infrastructure investments. Due to the network effects, which are covered by the hypernet approach, also the demand structures of other countries, which are not directly concerned by the investments – such as the Netherlands, the Czech Republic, Hungary or Switzerland – reveal impacts in favour of rail.

The modal shift from road and air to rail leads to a decrease in fuel consumption, CO_2 emissions and the emission of air pollutants (see Table 12). Furthermore, the modal shift results in a slight reduction in the number of road accidents (see Table 13). Finally, the HIGH-TOOL model predicts slight economic impacts (see Figure 6): the decrease in rail passenger travel times assumed for the specific links of the hypernet results in savings in generalised costs and, thus, increases economic competitiveness (second order effect).

Table 11: Case study 2 – Impact of passenger demand by mode of transport at NUTS-0 level (year 2050)

EU28+2 Modal split based on pkm by country (in millions), Difference Scenario-Baseline

	Air		Coach		Rail		Road	
Country	**pkm**	%	**pkm**	%	**pkm**	%	**pkm**	%
Austria	-6	-0,01%	-7	-0,01%	186	0,13%	-79	-0,10%
Belgium	-1	0,00%	-1	0,00%	21	0,01%	-11	-0,01%
Bulgaria	0	0,00%	0	0,00%	6	0,01%	-3	-0,01%
Croatia	0	0,00%	0	0,00%	6	0,01%	-3	-0,01%
Cyprus	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Czech Republ	-3	-0,01%	-8	-0,01%	96	0,05%	-43	-0,04%
Denmark	0	0,00%	0	0,00%	4	0,00%	-2	0,00%
Estonia	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Finland	0	0,00%	0	0,00%	2	0,00%	-1	0,00%
France	-11	0,00%	-5	0,00%	251	0,02%	-107	-0,02%
Germany	-13	0,00%	-11	0,00%	442	0,03%	-202	-0,03%
Greece	-1	0,00%	0	0,00%	3	0,00%	-2	0,00%
Hungary	-1	-0,01%	-6	-0,01%	89	0,07%	-37	-0,05%
Ireland	0	0,00%	0	0,00%	1	0,00%	-1	0,00%
Italy	-4	0,00%	-2	0,00%	56	0,01%	-32	0,00%
Latvia	0	0,00%	0	0,00%	1	0,00%	-1	0,00%
Lithuania	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Luxembourg	0	0,00%	0	0,00%	6	0,05%	-4	-0,04%
Malta	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Netherlands	-2	0,00%	-1	0,00%	36	0,01%	-20	-0,01%
Poland	-1	0,00%	0	0,00%	38	0,01%	-24	-0,01%
Portugal	-1	0,00%	0	0,00%	14	0,01%	-6	-0,01%
Romania	2	0,00%	-1	0,00%	80	0,04%	-31	-0,03%
Slovakia	0	0,00%	-3	-0,01%	61	0,09%	-28	-0,08%
Slovenia	0	0,00%	0	0,00%	7	0,02%	-4	-0,02%
Spain	-4	0,00%	0	0,00%	28	0,00%	-14	0,00%
Sweden	0	0,00%	0	0,00%	4	0,00%	-2	0,00%
United Kingd	-3	0,00%	0	0,00%	43	0,00%	-22	0,00%
Norway	0	0,00%	0	0,00%	2	0,00%	-1	0,00%
Switzerland	-6	-0,01%	-2	0,00%	89	0,05%	-47	-0,04%

Table 12: Case study 2 – Impact on emissions and fuel consumption (in tons)

EU28+2 Emissions and fuel consumption, Difference, Baseline-Scenario

Year	Fuel consumption	CO2	NOx	PM	SO2
2030	-7.434	-26.136	-56	-3	-1
2035	-10.634	-35.254	-62	-3	-1
2040	-10.991	-35.718	-58	-3	-1
2045	-11.107	-36.228	-60	-3	-1
2050	-10.866	-35.471	-62	-3	-1

Table 13: Case study 2 – Impact on road accidents

Annual road accidents by type, and related costs 2050, Difference

Year	Fatalities	injuries	injuries	Cost (€)
2030	0	-5	-66	-51.808
2035	0	-7	-78	-60.840
2040	0	-8	-73	-59.728
2045	0	-12	-66	-60.304
2050	0	-10	-78	-60.528

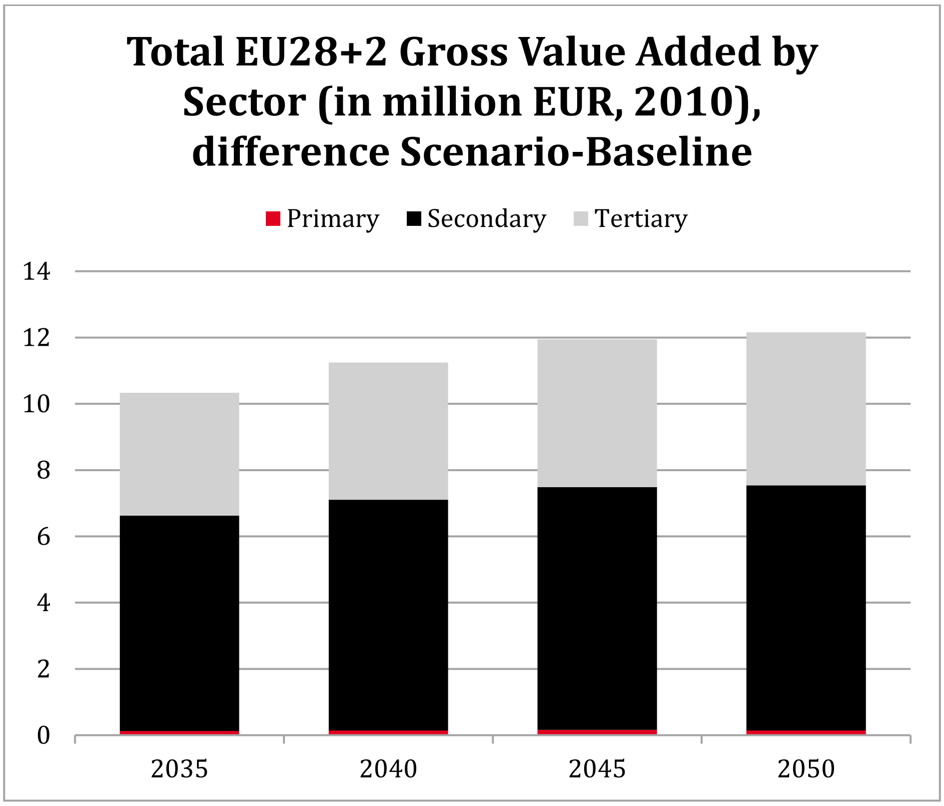

Figure 6: Case study 2 – Impact on Gross Value Added

Overall the results obtained from the HIGH-TOOL run are in line with the expected type of change (see Table 14).

Table 14: Case study 1 – Comparison of results with the outcomes

Parameter name	Expected type of change	HIGH-TOOL outcomes
Rail passenger demand	+	+
Road passenger demand	-	-
Coach passenger demand	-	-
Air passenger demand	-	-
GHG emissions	-	-
Emission of air pollutants	-	-
Road accidents	-	-
GDP/ GVA	+	+

2.2.5 Conclusions

The results of the HIGH-TOOL model reveal a modal shift from private passenger cars, coaches, and air transport to the rail mode, which is in line with the expectations. Furthermore, the decrease in fuel consumption, air transport emissions and road accidents meets the expectations. In relation to the overall passenger transport demand in the EU28+2, the modal shifts from road and air to rail is relatively small.

This pattern is explained by the relatively small geographical scope of the assumed infrastructure improvement, as well as by the comparatively small share of passenger transport demand, which benefits from the assumptions (i.e. inter-regional passenger flows at the level of NUTS-2).

The case study reveals overall plausible results. Furthermore, it demonstrates the functioning and the usefulness of the hypernet approach to cover the spatial scope of infrastructure improvements at a strategic level.

2.3 Case 3: Introduction of Speed Limits for All Road Vehicles

2.3.1 Description of the Case

Limiting the vehicle speed of road vehicles is an important measure to improve road safety and to reduce greenhouse gas emissions, pollutant emissions and traffic noise. The EU has so far implemented legislation on speed limiting devices for all heavy goods vehicles and buses above 10 tonnes (M3 and N3 vehicles) on 1/1/1995 1995 where 100 km/h and 90 km/h speed limits are applied to M3 and N3 vehicles respectively (EC, 1992). This legislation has been extended to the Directive 85/2002 (EC, 2002) where smaller heavy goods vehicles and buses, namely M2 and N2 vehicles: 3.5–10 tonnes are included.

The limits of 100 km/h and 90 km/h are applied to M2 and N2 vehicles respectively starting on 1/1/2006. The EU CARE Database statistics demonstrates that the involvement in fatal road accidents of heavy vans and trucks declined by approximately 50% in the last decade; this is not the case for light commercial vehicles where the involvement in fatal road accidents declined by around 30% (European Road Safety Observatory/Project DACOTA).

This case proposes speed limits for light commercial vehicles (LCVs). We expect to have an overall reduction in external costs, including reduced air pollutants (CO_2 emissions), reduced fuel consumption and improved safety (decrease of number of accidents) but also an increase in transport time and costs. More specifically, the case sets a scenario where a speed limit for LCVs is set at 100 km/h in the whole EU28 region plus Switzerland and Norway (EU28+2).

This case study is in line -among other- with the White Paper on Transport (ECEC, 2011b) that foresees an initiative to "*examine approaches to limit the maximum speed of light commercial road vehicles in order to decrease energy consumption, to enhance road safety and to ensure a level playing field*".

2.3.2 Policy Levers

This case was implemented through two parameters: first the change in the maximum speed and second the change in the fuel consumption and emission factors following the speed reduction.

First, assuming that the costs to set the speed limit of LCVs to 100 km/h, e.g. the costs to purchase and to install on-board speed limiter devices, are negligible, the main parameter to change is the maximum speed. As HIGH-TOOL uses 'average speed' as the only policy lever, for this case the change in the 'average speed' was used as a translation of 100 km/h speed limit applied to LCVs (both for the Freight (FRD) and for the Safety (SAF) modules).

In a study by Transport & Mobility Leuven (2013) the following translation was elaborated: for motorways this speed limitation is translated into a -10 to -15% change in average speed, while on rural roads this means a -2 to -1% change in average speed. However, the effects of the speed limiter on the speed distribution and speed profiles are very different amongst the Member States. This is because the speed reduction depends on the actual speeds driven on the roads in each Member States, influenced by the existing speed regulation or the posted speed limit in each country. The posted speed limits in the Member States are different for each vehicle class, and therefore the extent to which the speed is limited by the speed limiter (see Table 15).

Table 15: Case study 3 – Speed limits in Member States with low and high posted speed limits

Road Type	**Category**	**Vehicle**	**Low Posted Speed Limit**	**High Posted Speed Limit**
Motorway	Light duty	N1	115	130
	Heavy duty	N2/N3	80	90
Rural	Light duty	N1	90	100
	Heavy duty	N2/N3	80	90

As HIGH-TOOL does not differentiate between the different road types (and does not differentiate between LCV and HDV in the sense of speed) it is also assumed that the reduction of 12% is to be applied in the test case for all years from 2015 onwards and for all EU28+2 countries. This 12% value is simply an approximation of the effect of the speed limit regulation on the real speed limit reduction in terms of percentage that we have chosen as a simplification of this case study: as HIGH-TOOL traffic estimates concern in principle mobility at NUTS-2 level, we assume that freight traffic on motorways is of importance in HIGH-TOOL freight road transport demand and it is quite reasonable to take a mid-value suggested by Transport & Mobility Leuven (2013), i.e. between 10 and 15%. This average speed change will be applied to both light commercial vehicles and heavy duty vehicles as the average speed parameter is not differentiated for the two types at road freight level. This 12% speed drop among LCVS means a limited speed at 100 km/h. Assuming that Heavy Duty Vehicles (HDV) speed limit legislations as mentioned previously, namely (EC, 1992) and (EC, 2002) are already implemented in the baseline scenario, the 10% reduction for HDVs implies the setting of a further speed limit from 90 km/h to 80 km/h. Furthermore, the change in average speed should be translated into changes in emission and fuel consumption factors.

To this end, Den Boer et al. (2010) provide information to determine the emission factors for vans on motorways at different speeds. A standard driving pattern with a speed limit of 125 km/h was used to obtain emission factors for the situation without speed limiters. A linear relation was then used to scale the driving pattern to lower speeds, while keeping the driving pattern unchanged. Using this exercise, the study found out that the average CO_2 emission factor will be reduced to 84% (16% of reduction) when the top speed is limited to 100 km/h. It is assumed that that fuel consumption factors will be reduced to the same level as CO_2 emission factors.

Transport & Mobility Leuven (2013) however shows slightly lower reduction rate for LCVs emissions when speed limit is determined at 100 km/h. In this study, the effects of 0% to 14% maximum speed reduction are somewhere between 0% and 14% for CO_2 emissions (and fuel consumption), 2% and 49% for NO_x and 0% and 14% for PM.

Combining both studies, we opt to roughly assume in this study that for LCVs, the maximum speed limitation at 100 km/h will reduce fuel consumption and CO_2 emission factors by 10%, NO_x emission factors by 30% and PM emission factors by 10%.

Finally, the effect of the speed limit measure on HDV is more limited than that on LCVs. According to Transport & Mobility Leuven (2013), the effect is merely 1% when the speed difference between the 'before' and 'after' (speed limit implementation) states is lower or equal to 5 km/h and is close to 4% when the speed difference between the two states is higher than 5 km/h. In this case study a reduction of 2.5% of the fuel consumption and emission factors is assumed.

Table 16 presents the policy levers in this case study.

Table 16: Case study 3 – Policy levers

Parameter name	Data stock name	Affected dimension	Type of change
Average speed for road freight	P_fd_speed_1	Mode	-12% for the average road freight speed for all years from 2015 and on and all EU28+2 countries
Fuel consumption/ emission factors	i_ev_emfactor	An "expert mode" change is necessary to be performed i.e. Mode(=1 which is LCV), Emission type(=0,1,2,4 which are consecutively fuel consumption, NO_x, CO_2, and PM emission factors), Fuel type (=2,4,7, 9 for respectively CNG, diesel, gasoline, and LPG)	-10% for all years from 2015 for fuel consumption factors, CO_2 and PM emission factors, and -30% for NO_x emission factors
		Mode(=2 which is HDV), Emission type(=0,1,2,4 which are consecutively fuel consumption, NO_x, CO_2, and PM emission factors), Fuel type (=4 / diesel)	-2.5% for all years from 2015 for fuel consumption and NO_x, PM and CO_2 emission factors
Policy lever for truck speed (in percentage change) compared to 2010 by country	i_sa_speed_truck	Country	-12% for the average road freight speed in 2015 (compared to previous year) for all EU28+2 countries

2.3.3 Expected Outcomes

A number of studies in the past have shown the following expected results by limiting the LCVs top speed at 100 km/h.

In terms of environmental aspects:

- 5% CO_2 emission reduction, 14% reduction of NO_x emission and 4% reduction of PM emission (Transport & Mobility Leuven, 2013).

In terms of safety aspects:

- Fatal accident reduction of 5% and serious injury accidents reduction of 3% (Transport & Mobility Leuven, 2013).
- Fatalities reduction by about 190 per year (Den Boer et al., 2010).

If calculated in the same way, the environmental indicators outcome of this case study, where speed limit is implemented not only to light duty vehicle, but also in heavy duty vehicles, should give higher results. However, the studies' results are calculated at road link level while the HIGH-TOOL environment module produces results at NUTS-0 (country) level only, where all types of road are combined. Thus the environmental results are expected not to be comparable to those of Transport & Mobility (2013). However, following environmental impacts are expected for the HIGH-TOOL results:

- That there will be reduction in CO_2 emissions as well as in NO_x and PM as the consequence of implementing speed limit measures on road freight transport. For light commercial vehicle (LCV) the order of reduction of PM and CO_2 emission, in percentage term, should be at a similar level, while that of NO_x emission should up to three times higher than that of PM and CO_2.

Table 17 listed the affected parameters by this case study, as well as the expected outcome of HIGH-TOOL compared to earlier studies.

Table 17: Case study 3 – Affected parameters

Parameter name	**Expected type of change**	**HIGH-TOOL outcomes**
Decreasing road freight demand	-	-
Increasing rail freight demand	+	+
Increasing SSS and sea freight demand	+	+
Total CO_2 emission from road freight vehicles	-	-
Total PM emission from road freight vehicles	-	-
Total NO_x emission from road freight vehicles	- -	-
Fatalities	-	-
Serious injuries	-	-
Slight injuries	-	-

2.3.4 HIGH-TOOL Outcomes

The implementation of speed limit regulation on all road freight vehicles from 2015 onwards decreases the EU28+2 road freight demand by around 0.5% to 0.7% in every simulation year (see Figure 7). This demand is shifted to rail freight modes whose demand shares increase by 0.1% to 0.2% and to sea modes whose demand shares increase by around 0.4% to 0.6%. It is interesting to note that speed limit regulation also decreases the share of short-sea shipping (SSS) transport demand share by around 0.1%. This decrease in SSS mode can be understood as the secondary impact of the drop in road freight transport demand which is the closest mode to SSS transport in term of supply chain.

In terms of environmental aspects, the main results are the reduction of fuel consumption and CO_2 emissions of all road freight vehicles. At EU28+2 level, the implementation of the road freight vehicle speed limit scenario decreases the total fuel consumption and CO_2 emission of all transport modes the year 2015 by around -0.4%. In absolute values, this corresponds to around 5.5 million tonnes of CO_2 emissions and 1.8 million tonnes of fuel consumption reduction. The fuel consumption reduction percentage increases to reach the peak of nearly 1% (5 million tonnes of fuel reduction) in 2040 while that of CO_2 emissions also reaches the peak of around 1.3% of emission reduction (16.2 tonnes of CO_2 emission reduction) in the same year of 2040. The decreasing share of road freight modes on their contribution on the CO_2 emissions within the total CO_2 emissions of all transport modes makes that the effect of the speed limit regulation in this scenario gets smaller and smaller as we can see in the reduction potential which is decreasing slightly between 2040 and 2050.

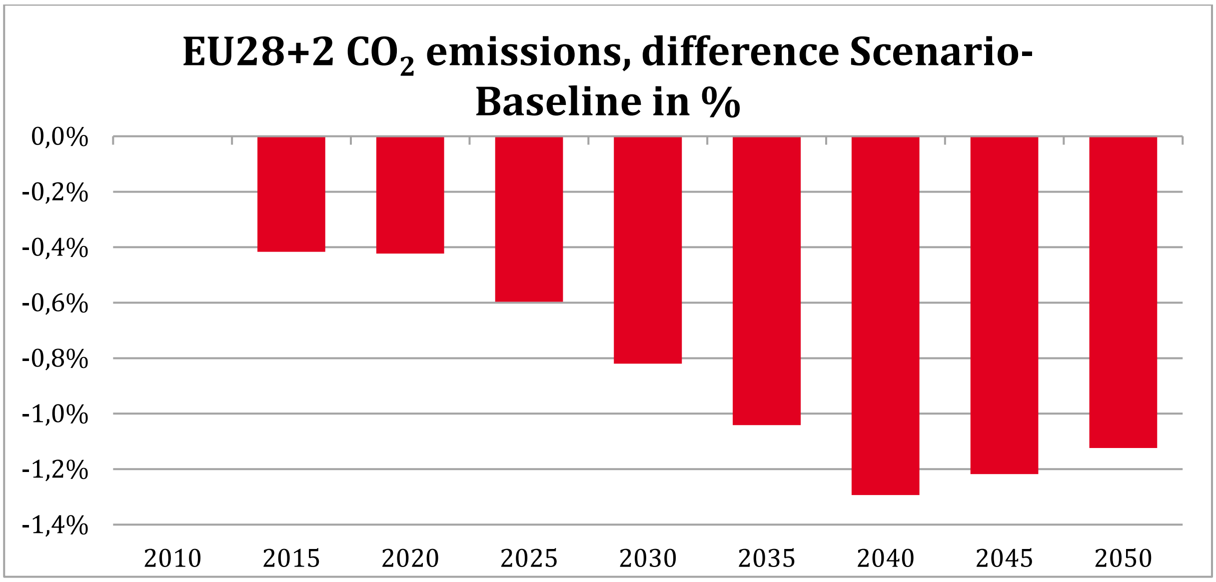

Figure 7: Case study 3 – Impact on EU28+2 CO_2 emissions – all transport modes

Within the road transport modes itself the speed limit measure will reduce the fuel consumption and CO_2 emission by 0.6% in 2015. This reduction percentage will reach its peak of 2% on 2040, and reach 1.8% in 2050.

Finally within the road freight transport, the measure will reduce the fuel consumption and CO_2 emission by 1.6% in 2015 before reaching its peak of nearly 4% in 2040 and then reaching 3.8% in 2050 (see Figure 8).

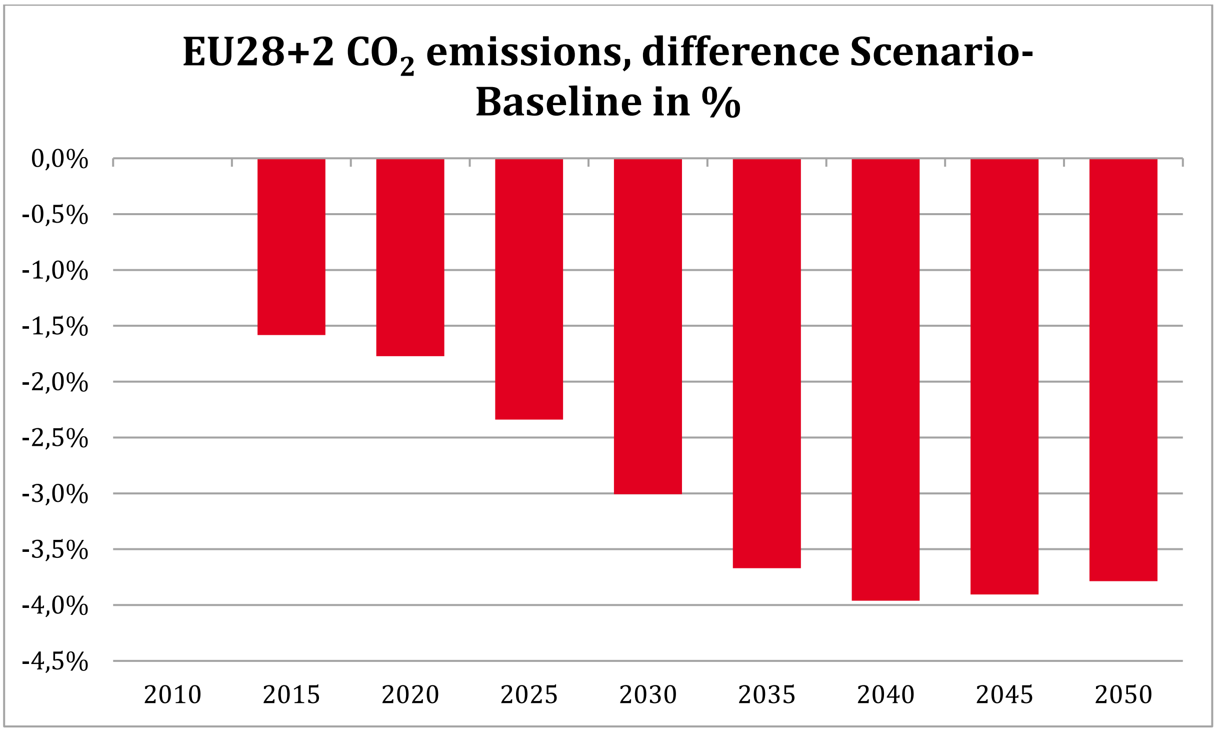

Figure 8: Case study 3 – Impact on EU28+2 CO_2 emissions – all road freight transport modes

In term of air pollution, the speed limit implementation reduces also both the total NO_x and PM emissions in EU28+2 (all transport modes) respectively by around 0.7% and 2% in 2015 compared to the baseline scenario. This reduction rates increase up 2.5% for NO_x and up to 10.5% for PM in the year 2040. The emission reduction rate remains constant between 2040 and 2050 for NO_x and increase slightly, i.e. up to nearly 11% of reduction in 2050 for PM.

Within the road freight transport itself, NO_x pollution will be reduced by around 2.3% in 2015 to reach nearly 8.8% of reduction in 2040 and this rate remains at this level until 2050 (see Figure 9). PM pollution will be reduced by 7% in 2015 which reaches 33.2% of reduction in 2040 and remains at the same level until 2050 (see Figure 10).

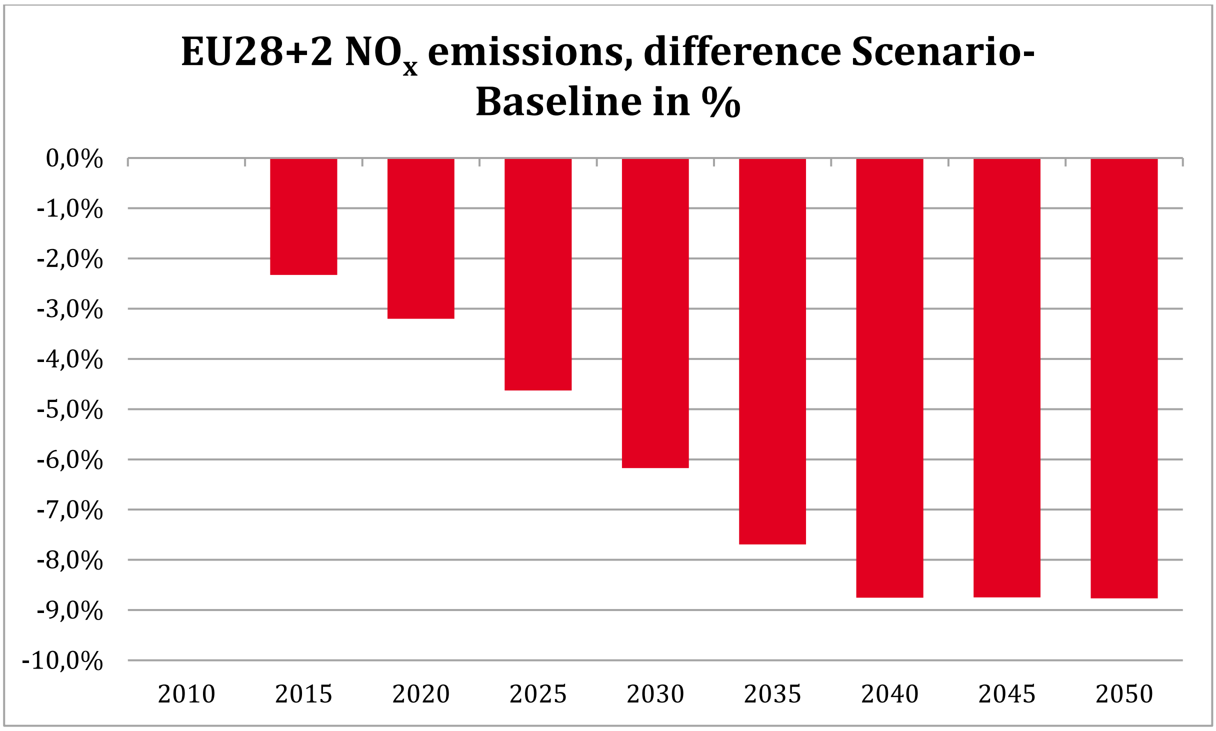

Figure 9: Case study 3 – Impact on EU28+2 NO_x emissions – all road freight transport modes

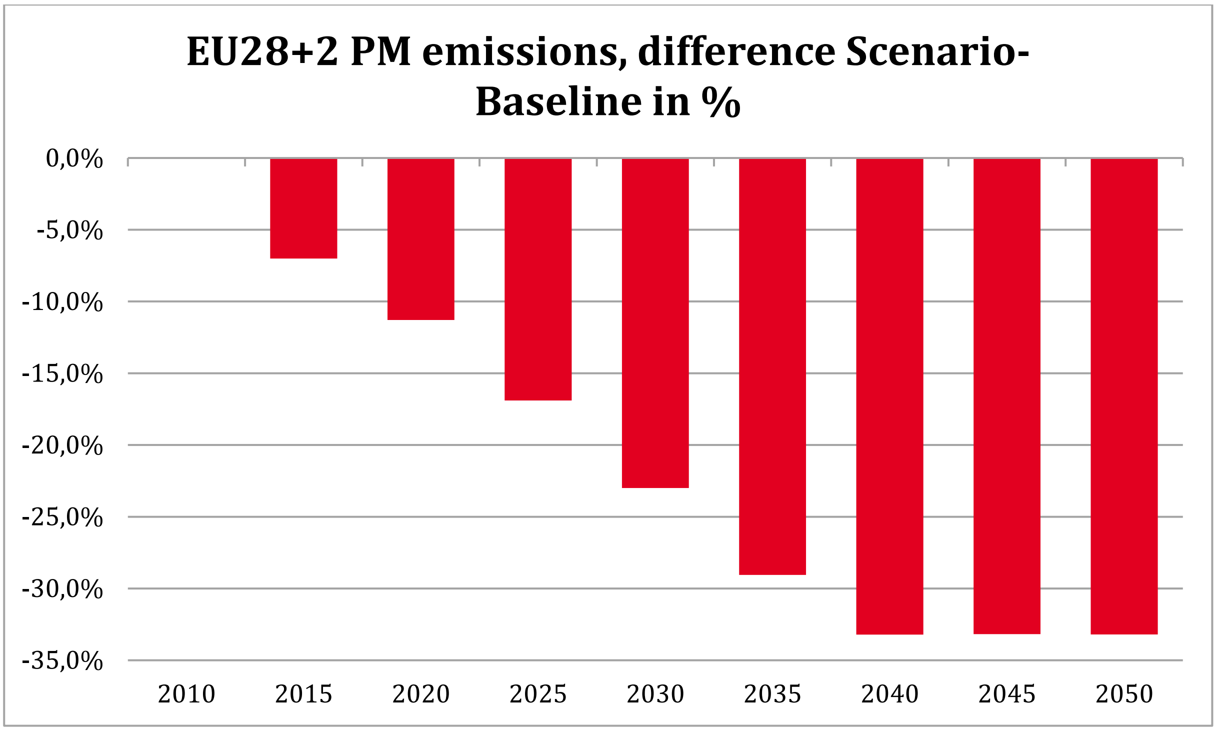

Figure 10: Case study 3 – Impact on EU28+2 PM emissions – all road freight transport modes

The effect of speed limit measures on NO_x and PM emissions are different on LCV and on HDV. On LCV the effects of the measures on NO_x emissions are around 3 times greater than those on PM emissions. This means that the impact of speed limit on NO_x and PM emissions on LCV is comparable to Transport & Mobility Leuven (2013) as mentioned in the section 2.3.3. On HDV, the effects of the measures on PM are around seven times larger than those on NO_x (see Table 18).

Table 18: Case study 3 – Impact in EU28+2 NO_x and PM emissions – Light Commercial (LCV) and Heavy Duty Vehicles (HDV)

Year	**Impact on NO_x**		**Impact on PM**	
	LCV	HDV	LCV	HDV
2010	0.0%	0.0%	0.0%	0.0%
2015	-5.5%	-1.8%	-2.5%	-7.4%
2020	-9.2%	-2.1%	-3.6%	-11.9%
2025	-14.7%	-2.8%	-5.3%	-17.8%
2030	-20.7%	-3.5%	-7.3%	-24.2%
2035	-27.3%	-4.2%	-9.5%	-30.6%
2040	-32.5%	-4.6%	-11.0%	-35.0%
2045	-32.5%	-4.6%	-11.0%	-34.9%
2050	-32.6%	-4.6%	-11.1%	-35.0%

In safety aspects, also at EU28+2 of the year 2015, the speed limit scenario decreases road fatalities by 4% (around 500 reduced accidents), road serious injuries by 2% (slightly more than 2 000 reduced accidents) and road slight injuries by also 2% (nearly 14 000 reduced accidents). In 2050 the fatalities are reduced by 75%, serious injuries by 53% and slight injuries by 50%. The speed limit implementation reduced the road accident costs by around 3% or around EUR 17.2 million in 2015. In 2050 the road accident costs is reduced by 60% (nearly EUR 295 million of reduction) in comparison to the baseline situation (see Figure 11). In 2050, the total costs of accidents decrease by 60% for cars & trucks, by 50% for bicycle and by 38% for motorised 2 wheelers. At the same year, the costs of accidents increase slightly, by almost 1% in rail, inland waterways and short-sea shipping.

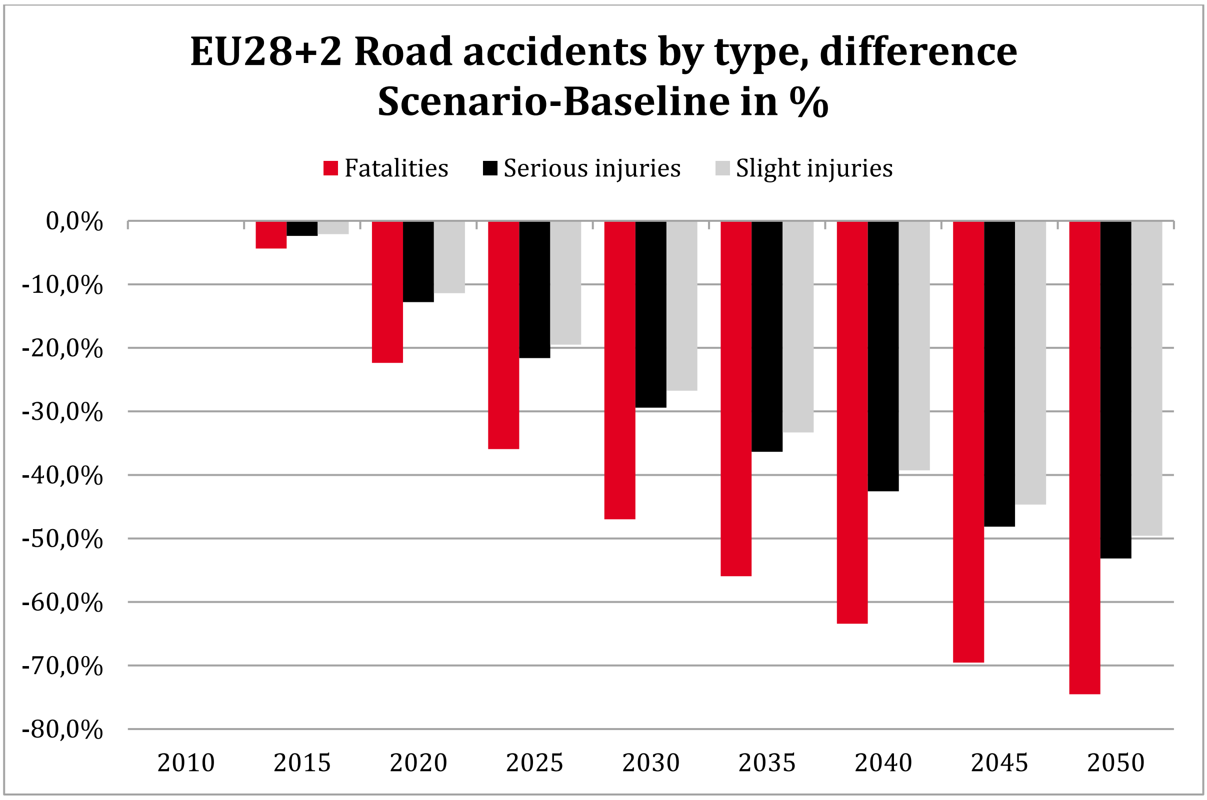

Figure 11: Case study 3 – Impact in EU28+2 road accidents

2.3.5 Conclusions

The results of the HIGH-TOOL model reveal a modal shift from road freight modes to the rail freight and sea freight modes including short sea shipping, which is in line with the expectations. Furthermore, the decrease in fuel consumption, air transport emissions and pollution as well as road accidents meet the expectations.

This case study reveals overall plausible results.

2.4 Case 4: Untapped Potential of Maritime Ports related to Liberalisation Policies

2.4.1 Description of the Case

This case aims at analysing the untapped potential of maritime ports by applying policies related to liberalisation of the market to improve competitiveness of ports outside the northern range.

The idea is to check how HIGH-TOOL can handle such broad policies related to the internal market of the EU. Another feature to be tested is how the freight demand model responds to different inputs in different regions/countries.

Liberalisation policies should in theory be able to improve the costs and times of the ports that are presently being governed to some extent by a central agency and thus do not have the high degree of freedom that ports in the northern range enjoy with respect to business-related decisions such as setting prices or deciding about the contracts with the operators in the port.

For this case study we will suppose that liberalisation has the effect of lowering port costs by -5% in the ports of the Mediterranean (Spain, Italy, Slovenia, Croatia, Greece) and improving even more the time for handling the cargo to reduction by -10%, compared to the baseline.

2.4.2 Policy Levers

The policy levers relevant for the case study are those related to costs and time for the maritime mode, applied with different intensities throughout the EU. They are listed in Table 19.

Table 19: Case study 4 – Policy levers

Parameter name	Data stock name	Affected dimension	Type of change
Average fixed costs for sea freight	p_fd_fixed_cost_5	Year, country, fixed costs	-5% for the fixed costs for all years from 2015 and on for countries in the Mediterranean
Average variable costs for sea freight	p_fd_var_cost_5	Year, country, variable costs	-5% for the variable costs for all years from 2015 and on for countries in the Mediterranean
Average loading time for sea freight	p_fd_load_time_5	Year, country, loading time	-10% for the load time for all years from 2015 and on for countries in the Mediterranean
Average unloading time for sea freight	p_fd_unload_time_5	Year, country, unloading time	-10% for the unload time for all years from 2015 and on for countries in the Mediterranean
Average waiting time for sea freight	p_fd_wait_time_5	Year, country, waiting time	-10% for the wait time for all years from 2015 and on for countries in the Mediterranean

2.4.3 Expected Outcomes

It is expected that the freight flows of the affected countries will increase in all modes compared to the baseline, whereas flows will grow less than the baseline in countries of the northern range (mainly France, Belgium, Netherlands and Germany). This is the effect of outside flows being diverted to southern ports even if the final origin/destination in Europe does not change.

This new transport routes should be a bit shorter than the current ones, and thus it is also expected that environmental indicators will improve with reductions in emissions.

HIGH-TOOL will not be able to simulate the long-term effect this new distribution pattern will have in terms of a new logistic distribution structure and possible re-industrialisation due to agglomeration effects in the south of Europe. Table 20 demonstrates the expected outcomes.

2.4.4 HIGH-TOOL Outcomes

The outcomes shown in Table 20 are logical according to the inputs of the case study, but they are not as expected in terms of the resulting impact intensity nor in the shift patterns between modes and geographical areas.

Table 20: Case study 4 – Results

Parameter name	Expected type of change	HIGH-TOOL outcomes
Total freight demand	No change	No change
Maritime traffic in southern countries	++	+
Maritime traffic in northern countries	-	No change
Inland traffic in southern countries	+	-
Inland traffic in northern countries	-	No change

Total freight demand remains constant and we see an increase in maritime traffic in the southern countries. However, this is matched by an equal decrease of inland traffic in southern countries and almost no change at all in the rest of Europe.

The main impact is the change in mode performance for freight transport as shown in Figure 12. It can be seen that there is a clear increase in the number of ton-km for short-sea and deep sea modes and a decrease in the inland modes, especially road. This means that globally we have more ton-km in the system instead of a global reduction as previously expected.

However, overall the most polluting mode (road) clearly diminishes and this translates into an improvement in environmental indicators (see Figure 13). No clear improvement can be seen with respect to road safety indicators, as the road traffic decrease is not significant enough.

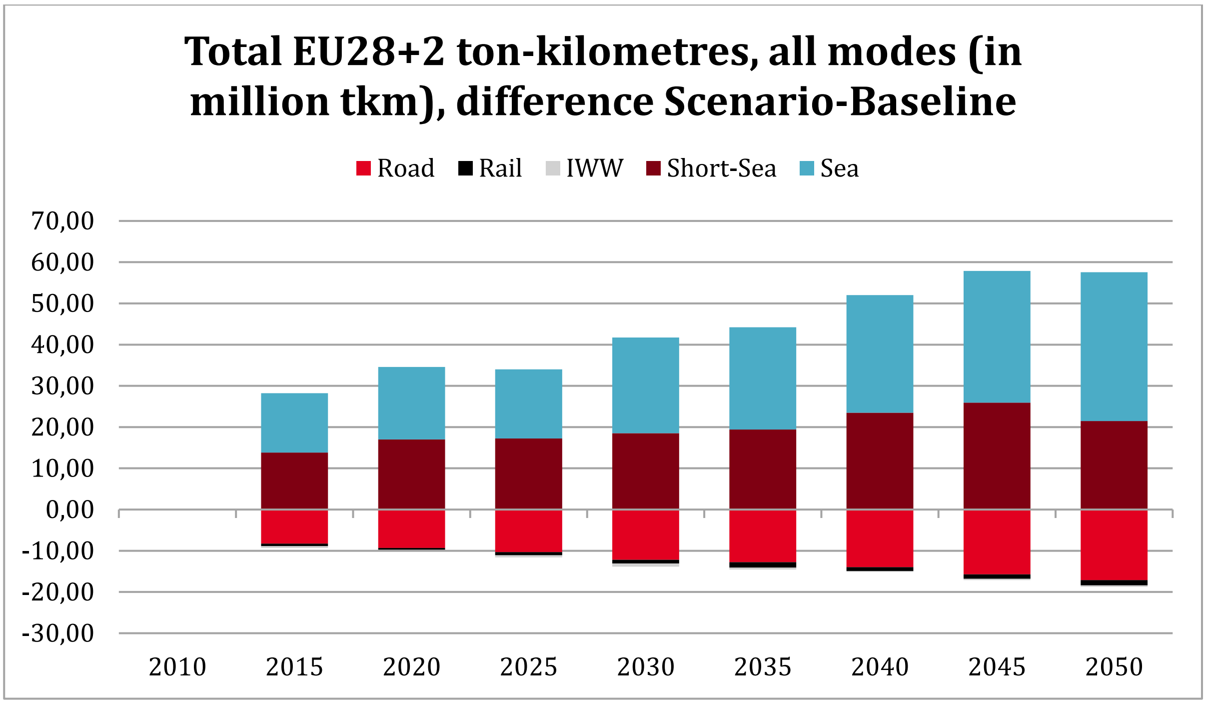

Figure 12: Case study 4 – Impact in mode performance for freight transport

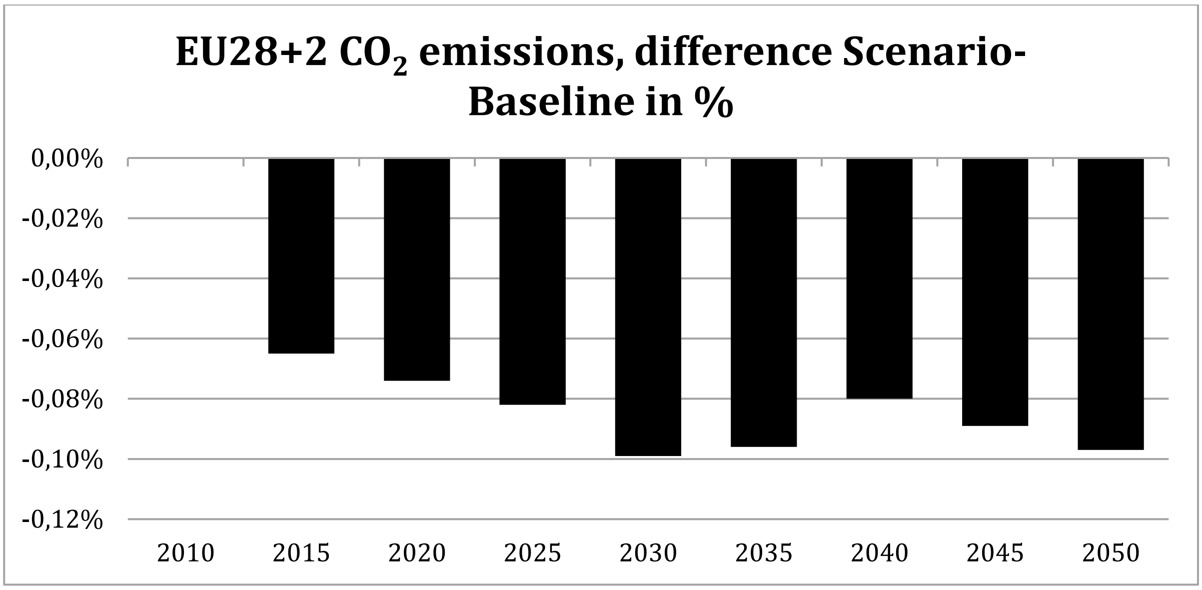

Figure 13: Case study 4 – Impact in CO_2 emissions

Results of freight performance at NUTS-0 level help understand what is happening with the flows. As shown in Figure 14, most modal shift occurs in the countries where policies are applied. However, the shift seems to be happening inside each country individually. This means the expected flow shift pattern is not occurring and changes have a local dimension instead of being at European level.

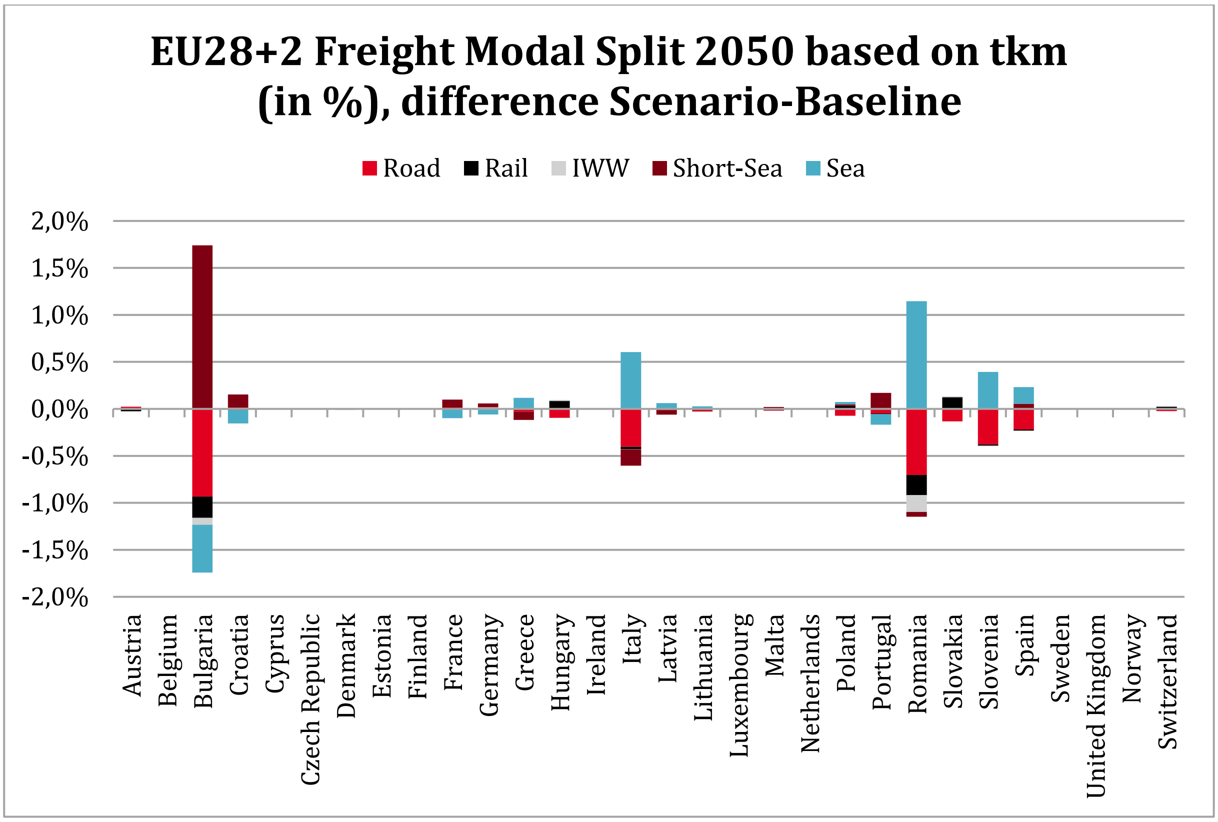

Figure 14: Case study 4 – Impact in mode performance for freight transport at NUTS-0 level

2.4.5 Conclusions

A further analysis of the freight model shows that the maximum shift in flows that could be achieved might be limited by the existence of available routes in the model, given that HIGH-TOOL is not a network model and thus no new routes can be derived from improvements in the transportation costs. So one possible solution to improve the modelling capabilities of HIGH-TOOL in the context of this case study would be adding more logistic chains with new transhipment points, making it possible for instance to get to central Europe via all main Mediterranean ports. This kind of tweaking requires expert user knowledge of the model.

We can therefore conclude that the HIGH-TOOL model needs certain changes in order to be able to do a comprehensive assessment of the current case study. The specific challenge for this case study was the modelling of demand interactions between different European ports, which is beyond the scope of the current version of the HIGH-TOOL model, since the modelling of freight transport demand is not based on a network model.

2.5 Case 5: Cost Sensitivity of the HIGH-TOOL Model for Passenger Road Mode

2.5.1 Description of the Case

The case study investigates the sensitivity of the HIGH-TOOL model upon passenger demand, vehicle stock, environment and safety when cost changes occur. As an example, a policy lever for the road mode is selected for passenger transport. The case study concerns not a specific policy, but rather intends to examine the sensitivity of the HIGH-TOOL model on cost changes to the road mode.

The case study concerns four model runs whereby a linear change of road passenger costs increase over time is assumed. Along the results displayed in the assessment report the model behaviour is shown by displaying the sensitivity curvature of a selection of indicators produced by the HIGH-TOOL model.

2.5.2 Policy Levers

To investigate a user oriented cost increase for the road mode, the toll costs per vehicle-kilometre are used for car and coach. As for some countries toll costs do not exist up to now, the test incorporates four different values increasing toll costs. Thus in some countries toll costs are introduced while for other countries just the existing toll costs is increased. In case no tolls exist, the average toll costs of the ones existing throughout Europe are used as starting point. The implementation has been executed by defining customised scenarios.

Obviously the political discussion about a very selective increase of costs for a single mode while other modes are not affected is critical, as modes must be treated on equal base to maintain a balanced competition, but as the case study just investigates the model behaviour and does not concern a policy measure the selection of the cost parameter and the selective use for one mode is not decisive.

The policy levers in this case study are shown in Table 21.

Table 21: Case study 5 – Policy levers

Parameter name	Data stock name	Affected dimension	Type of change
Average toll costs for passenger mode car and coach by country	i_pd_core_toll_cost_xxx_z	Year, country, mode, user costs (EUR/vkm)	Linear increase of the existing toll costs from 2015 to 2050 Run 1: +10% Run 2: +25% Run 3: +50% Run 4: +100% In case no toll cost exist in a country the average increase was applied

Whereby 'xxx' defines the country and 'z' the mode (car, coach).

It has to be noted that the scope of the scenario covers EU28, whereby 16 of 28 countries have i_pd_core_toll_cost values for passenger cars greater than zero in 2015. For the countries without toll costs we assumed for the year 2020 that toll costs are implemented at the level of the average costs per vkm on all roads, which is equal to 0.66 Cents.

Although the increase by 10%, 25%, 50% and 100% seems quite large, the absolute cost increase per vkm is minor, especially when considering the load factor of vehicles which is taken into account when calculating the costs per traveller. Table 22 and Table 23 show the average road toll costs in the EU28 countries in the year 2015 and the applied change in percentages in the scenario years.

Table 22: Case study 5 – Average road tolls in EU28 countries

EU28 average road tolls per vkm in EUR in the year 2015

Country	Car	Coach
AT	0,0029	0,0158
BE	0,0000	0,0000
BG	0,0026	0,0100
CY	0,0000	0,0000
CZ	0,0032	0,0309
DE	0,0000	0,0000
DK	0,0000	0,0000
EE	0,0000	0,0000
ES	0,0156	0,0211
FI	0,0000	0,0000
FR	0,0110	0,0384
GR	0,0047	0,0138
HR	0,0017	0,0033
HU	0,0061	0,0110
IE	0,0020	0,0050
IT	0,0128	0,0237
LT	0,0000	0,0447
LU	0,0000	0,0000
LV	0,0000	0,0000
MT	0,0000	0,0000
NL	0,0000	0,0000
PL	0,0089	0,0222
PT	0,0102	0,0502
RO	0,0028	0,0174
SE	0,0000	0,0000
SI	0,0037	0,0146
SK	0,0039	0,0248
UK	0,0152	0,0295
Avg	0,0066	0,0221

Table 23: Case study 5 – Implemented series of toll increase over time

Road toll changes applied in EU28 countries

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Toll +10%									
Tolls in 2015	0,00%	0,00%	1,43%	2,86%	4,29%	5,71%	7,14%	8,57%	10,00%
No Tolls in 2015	0,00%	0,00%	0,00%	1,67%	3,33%	5,00%	6,67%	8,33%	10,00%
Tolls +25%									
Tolls in 2015	0,00%	0,00%	3,57%	7,14%	10,71%	14,29%	17,86%	21,43%	25,00%
No Tolls in 2015	0,00%	0,00%	0,00%	4,17%	8,33%	12,50%	16,67%	20,83%	25,00%
Tolls +50%									
Tolls in 2015	0,00%	0,00%	7,14%	14,29%	21,43%	28,57%	35,71%	42,86%	50,00%
No Tolls in 2015	0,00%	0,00%	0,00%	8,33%	16,67%	25,00%	33,33%	41,67%	50,00%
Tolls +100%									
Tolls in 2015	0,00%	0,00%	14,29%	28,57%	42,86%	57,14%	71,43%	85,71%	100,00%
No Tolls in 2015	0,00%	0,00%	0,00%	16,67%	33,33%	50,00%	66,67%	83,33%	100,00%

2.5.3 Expected Outcomes

The cost sensitivity test investigates the behaviour of the HIGH-TOOL model when a cost component, here the toll costs for passenger transport on roads, increases over time. The test is undertaken by four scenario runs whereby the level of cost increase differs between 10% and 100% in the time horizon of 2020 to 2050. It is expected that an increase of costs for road modes will imply a modal shift reaction in favour of the non-road modes. Thus the transport volumes for road transport are expected to decrease while the ones for the non-road modes should increase. In addition, it is expected that less road traffic leads to a decrease in fatalities and injuries for this mode and in consequence the accident costs for road will decrease as well. As the environmental factors are strictly related to the fuel consumption, the lower road fuel usage is expected to be compensated by the non-road modes. Overall economic effects are expected to be minor. In general the results of the case study allow to demonstrate the reliable behaviour of HIGH-TOOL respectively whether the model mirrors the market behaviour in a reasonable and logic way. Table 24 summarises the expected outcomes of this scenario.

Table 24: Case study 5 – Affected parameters

Parameter name	Expected type of change
Passenger kilometre by road	- (--)
Accident costs by road	- (--)

2.5.4 HIGH-TOOL Outcomes

Four assessment reports have been analysed and results of various modules have been extracted. Table 25 shows the overview results of the model runs. The specific results are summarised in tables and graphs which display the sensitivity curvatures based on the applied cost variations.

Table 25: Case study 5 – Results

Parameter name	Expected type of change	HIGH-TOOL outcomes
Passenger performance pkm	+(++) / - (--)	+(++) / - (--)
Annual road accidents cost	- (--)	- (--)

Figure 15 and Table 26 illustrate the relative changes of pkm between the baseline and the test scenarios. The curvature expresses the elasticity of the passenger model to cost changes differentiated by road and non-road modes. The shapes of the curvatures are slightly non-linear picking up thresholds in consumer behaviour and reflect the expectations we see as well in reality. The shift of travellers from road to non-road modes is in relation to each other, but in total there is a decrease in pkm over all modes when increasing tolls. This is due to a higher usage of air and high-speed rail services while coach increases just slightly. Therefore the model works fine as well in relation to modal split effects.

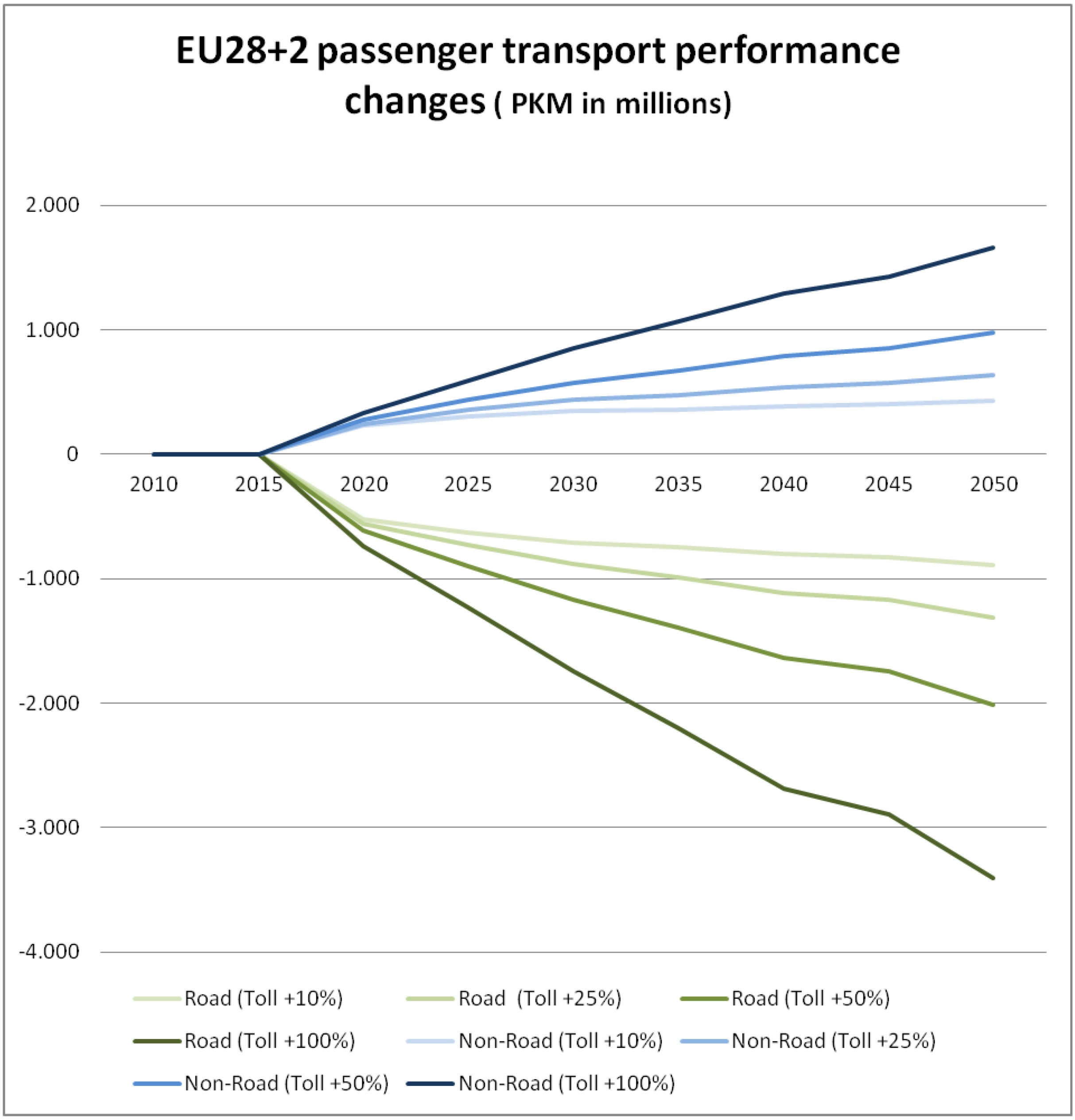

Figure 15: Case study 5 – Elasticity of pkm in toll scenarios

Table 26: Case study 5 – Road pkm changes in toll scenarios

EU28+2 passenger transport performance changes (in millions)

	Road				Non-Road			
Year	**Toll +10%**	**Toll +25%**	**Toll +50%**	**Toll +100%**	**Toll +10%**	**Toll +25%**	**Toll +50%**	**Toll +100%**
2010	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0
2020	-517	-554	-615	-738	229	246	274	331
2025	-629	-729	-895	-1.228	307	355	435	596
2030	-709	-882	-1.171	-1.747	352	436	576	856
2035	-749	-992	-1.397	-2.206	360	478	673	1.065
2040	-803	-1.117	-1.640	-2.684	387	538	789	1.290
2045	-825	-1.171	-1.746	-2.895	399	570	855	1.425
2050	-893	-1.313	-2.012	-3.408	430	635	978	1.662

The results regarding safety and environment are in principle a consequence of passenger demand reactions. For safety the highest impact is with the fatalities. Less pkm result in fewer fatalities for road, but the number of fatalities omitted over all modes is quite small as other modes compensate the gains affected by road. The drop of accident costs for road between 2015 and 2020 is caused by the introduction of tolls at countries which do not have tolls implemented yet. The flat curvature for the test scenario of 50% and 100% toll increase results out of the rounding routine as fatalities have to be integer. In general, the safety model behaves in line with the demand results whereby the curvatures show a slight over proportional reaction of the model (see Figure 16 and Table 27).

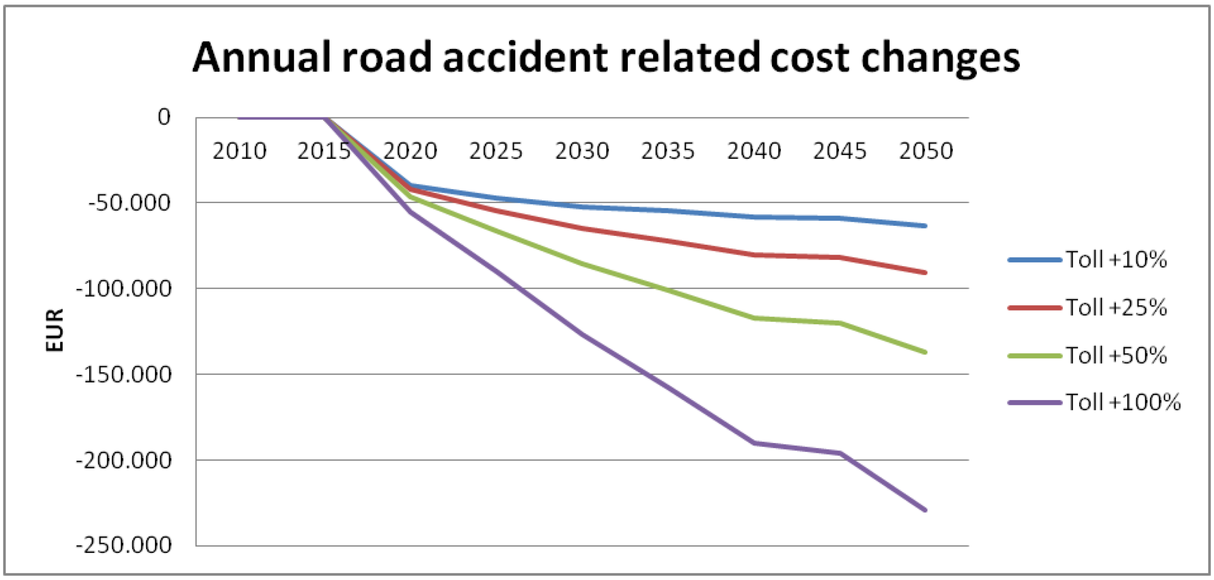

Figure 16: Case study 5 –Elasticity of road accident costs in toll scenarios

Table 27: Case study 5 – Road accident cost changes in toll scenarios

Annual road accident related cost changes in EUR				
Year	**Toll +10%**	**Toll +25%**	**Toll +50%**	**Toll +100%**
2010	0	0	0	0
2015	0	0	0	0
2020	-39.440	-42.080	-46.440	-55.240
2025	-47.096	-54.272	-66.208	-90.056
2030	-52.248	-64.632	-85.232	-126.400
2035	-54.728	-71.976	-100.656	-157.968
2040	-58.240	-80.256	-116.856	-190.008
2045	-58.872	-81.800	-119.928	-196.128
2050	-63.160	-90.848	-136.952	-228.960

2.5.5 Conclusions

The obtained results show a proper reaction of the HIGH-TOOL model for passenger transport. An increase in costs leads to a lower attractiveness of the road mode; thus there is a decline in road transport demand. The changes to the specific modes are in the adequate range of expected sensitivities.

2.6 Case 6: Modules' Stability in a Given Time-Step

2.6.1 Description of the Case

When assessing policy impacts in HIGH-TOOL, the user expects the model to be able to produce stable responses to changes brought on by policies. Given the fact that some of the HIGH-TOOL modules operate in an ordered sequence inside a time step (a feed forward structure) and consume each others' outputs, it is possible that by repeating the same run, the outcomes are different. The lag is twofold. Firstly, Economy & Resources module of 2020, for example, is run by using the outputs of 2015 Vehicle Stock, Passenger Demand, and Freight Demand modules. Secondly, any change in a module from 2011–2015, for example, is only reflected in the year 2015. Intuitively it would seem that this might have an impact on the quality of model outputs.

Besides the feedback loops in a given time step, several modules use stochastic functions to simulate future trends; for example, in the Freight Demand (FRD) module, the modal split function is a multinomial logit model estimating the probabilities of the cargo to be transferred with a specific mode for a given Origin/Destination (O/D).

In this case, the outcomes of HIGH-TOOL were evaluated to analyse this pattern. More specifically, the model was run several times on baseline conditions to compare the outputs for 5-years intervals from different runs and confirm whether the model produces different results and whether it converges.

2.6.2 Policy Levers

Since the convergence of the baseline calibration process is tested in this case study, no policy lever in the model is changed. All modules in HIGH-TOOL are tested in order to see whether they are stable or not. The procedure consists of running HIGH-TOOL with baseline conditions, then taking the resulting data set as input for a next run with baseline conditions and so on, repeating the process four times, so that three comparisons can be made.

2.6.3 Expected Outcomes

There are two potential outcomes of the test: no significant change or significant changes on the final performance indicators of baseline runs. If the test case indicates significant differences among different runs of the baseline, the model might need some adaptions in order to include iterative calculations. If there is no significant change on the final performance indicators, the current feed forward model can be kept. Table 28 indicates the expected outcomes of this case study.

Table 28: Case study 6 – Expected outcomes

Changes in the model	Expected type of change
Nothing, only different runs over the previous results	Significant change/No significant change

2.6.4 HIGH-TOOL Outcomes

Successive runs of the model over the previous results data set, show that results do change in each iteration, but these changes are relatively small and converging to 0, meaning that after several iterations the results do not change. Table 29 shows the results when comparing one run to the previous one per module. All changes are well below 1% in the first iteration and under 0.02% in the second, getting down to almost 0 on the third iteration.

Table 29: Case study 6 – Results at EU28+2 level

Parameter name	**HIGH-TOOL outcomes Run1 vs initial baseline**	**HIGH-TOOL outcomes Run2 vs Run1**	**HIGH-TOOL outcomes Run3 vs Run2**
Vehicle Stock (all modes)	+0,327%	+0,018%	-0,0005%
Passenger demand (pkm all modes)	-0,009%	-0,0002%	+0,0002%
Freight demand (ton-km all modes)	-0,023%	+0,001%	-0,0004%
Environment (tons CO_2 all modes)	-0,101%	+0,002%	+0,001%
Safety (car fatalities)	-0,022%	0,000%	0,000%

When considering the time dimension, results show a similar trend, with more or less amplitude in the variation at each year but overall a decrease in differences that rapidly tend to 0, as shown in Figure 17, Figure 18, and Figure 19.

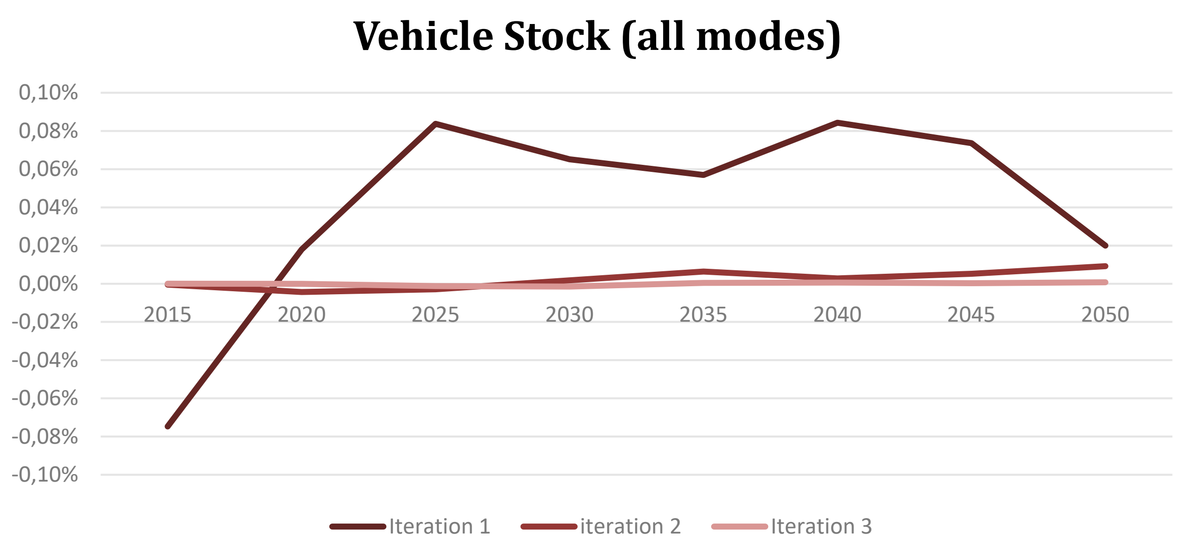

Figure 17: Case Study 6 – Convergence of results for Vehicle Stock module

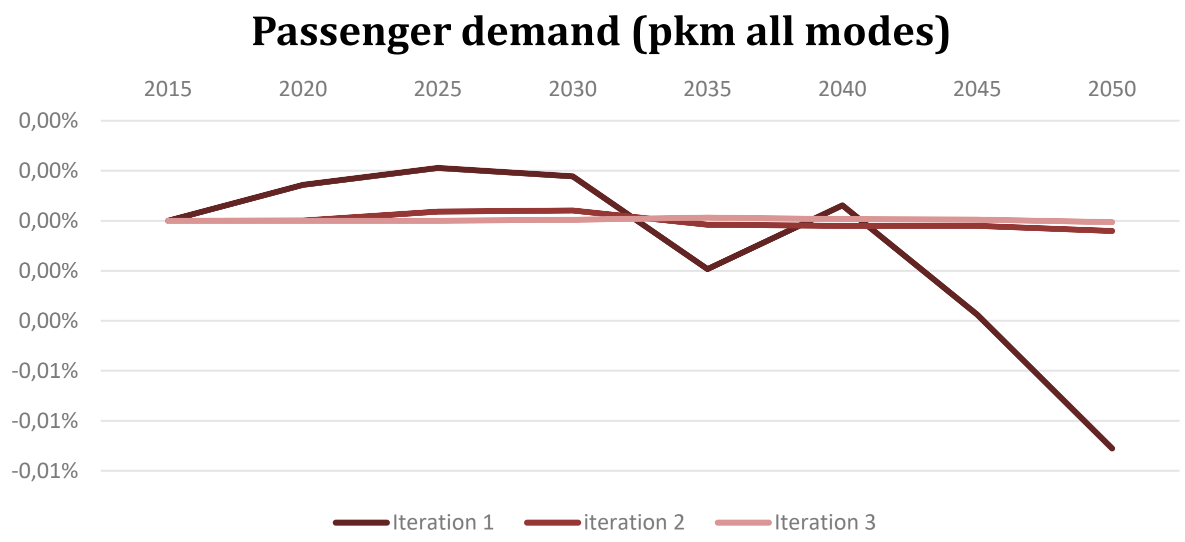

Figure 18: Case Study 6 – Convergence of results for Passenger Demand module

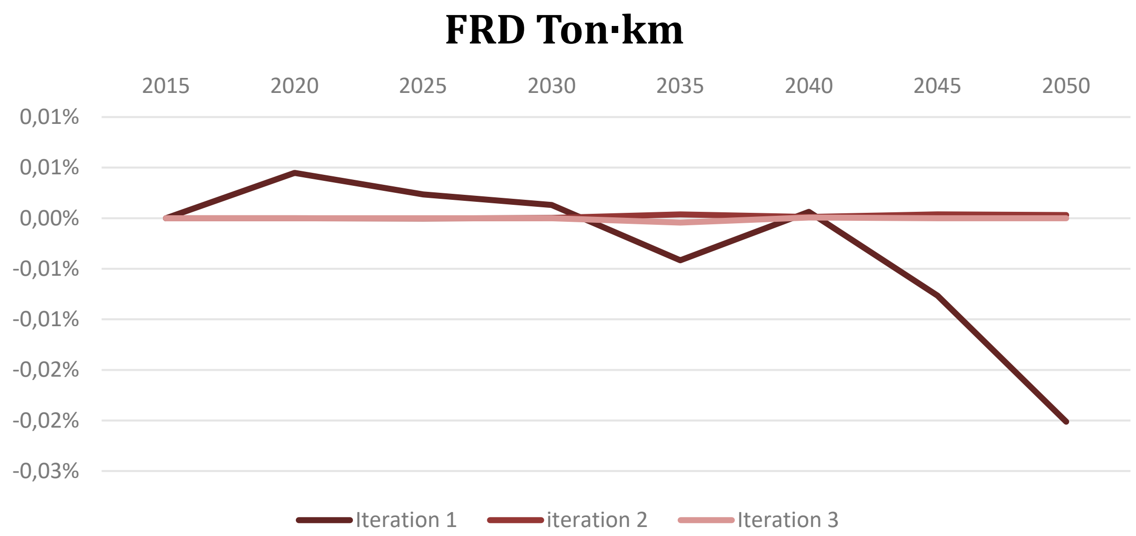

Figure 19: Case Study 6 – Convergence of results for Freight Demand module

Finally, the results of this exercise can be analysed at NUTS-0 level. Again it can be seen that although different variations occur at different countries, the global trend for all of them is a decrease of the variation and a convergence towards 0. Table 30, Table 31, and Table 32 show this trend for results of Passenger Demand module (total passenger-km all modes).

Table 30: Case Study 6 – Results of PAD for the first iteration per NUTS-0 and year

Passenger demand (pkm all modes)
First iteration

Country	2015	2020	2025	2030	2035	2040	2045	2050
AT	0,0000%	0,0011%	0,0017%	0,0010%	-0,0042%	-0,0024%	0,0004%	0,0025%
BE	0,0000%	0,0017%	0,0032%	0,0029%	-0,0018%	-0,0023%	-0,0022%	-0,0043%
BG	0,0000%	0,0000%	0,0069%	0,0038%	-0,0034%	-0,0101%	0,0004%	-0,0068%
CH	0,0000%	0,0029%	-0,0036%	-0,0032%	-0,0054%	-0,0006%	0,0085%	0,0118%
CY	0,0000%	0,0051%	-0,0112%	-0,0179%	-0,0179%	-0,0117%	-0,0097%	-0,0083%
CZ	0,0000%	0,0010%	-0,0002%	0,0013%	-0,0051%	-0,0066%	-0,0060%	-0,0101%
DE	0,0000%	0,0014%	0,0055%	0,0054%	-0,0017%	-0,0013%	-0,0037%	-0,0068%
DK	0,0000%	0,0012%	0,0031%	-0,0005%	-0,0045%	-0,0060%	-0,0060%	-0,0094%
EE	0,0000%	-0,0014%	-0,0063%	-0,0113%	-0,0202%	-0,0223%	-0,0286%	-0,0376%
ES	0,0000%	0,0099%	-0,0022%	-0,0052%	0,0062%	0,0473%	0,0328%	0,0178%
FI	0,0000%	-0,0005%	0,0029%	0,0075%	-0,0005%	-0,0013%	-0,0012%	-0,0037%
FR	0,0000%	0,0018%	0,0035%	0,0010%	-0,0067%	-0,0052%	-0,0066%	-0,0117%
GR	0,0000%	-0,0011%	0,0039%	0,0169%	0,0031%	-0,0115%	-0,0194%	-0,0345%
HR	0,0000%	0,0014%	0,0062%	-0,0061%	-0,0101%	-0,0063%	-0,0126%	-0,0152%
HU	0,0000%	-0,0002%	0,0020%	0,0028%	-0,0024%	-0,0043%	-0,0040%	-0,0115%
IE	0,0000%	-0,0003%	-0,0012%	-0,0052%	-0,0079%	-0,0079%	-0,0088%	-0,0084%
IT	0,0000%	-0,0004%	0,0049%	0,0049%	-0,0025%	-0,0026%	-0,0040%	-0,0111%
LT	0,0000%	-0,0010%	0,0066%	0,0085%	0,0006%	-0,0038%	-0,0027%	-0,0136%
LU	0,0000%	0,0016%	0,0031%	0,0046%	0,0035%	0,0104%	0,0149%	0,0200%
LV	0,0000%	-0,0014%	0,0098%	0,0112%	0,0090%	0,0062%	0,0049%	-0,0041%
MT	0,0000%	0,0070%	-0,0090%	-0,0128%	-0,0321%	-0,0223%	-0,0093%	0,0116%
NL	0,0000%	0,0028%	0,0061%	0,0057%	-0,0007%	-0,0091%	-0,0100%	-0,0163%
NO	0,0000%	0,0017%	-0,0052%	-0,0078%	-0,0079%	-0,0047%	-0,0017%	0,0087%
PL	0,0000%	-0,0006%	-0,0020%	0,0008%	-0,0032%	-0,0020%	-0,0078%	-0,0203%
PT	0,0000%	0,0059%	-0,0093%	-0,0163%	-0,0299%	-0,0291%	-0,0352%	-0,0594%
RO	0,0000%	-0,0018%	-0,0095%	-0,0024%	0,0126%	0,0173%	-0,0196%	-0,0196%
SE	0,0000%	0,0000%	0,0028%	0,0033%	-0,0018%	-0,0039%	-0,0056%	-0,0107%
SI	0,0000%	-0,0029%	-0,0004%	0,0025%	-0,0031%	-0,0036%	-0,0036%	-0,0083%
SK	0,0000%	-0,0035%	-0,0031%	-0,0016%	-0,0043%	-0,0019%	0,0007%	0,0111%
UK	0,0000%	0,0000%	0,0018%	0,0021%	0,0027%	-0,0060%	-0,0152%	-0,0139%
EU28+2	0,0000%	0,0014%	0,0021%	0,0018%	-0,0019%	0,0006%	-0,0038%	-0,0091%

Table 31: Case Study 6 – Results of PAD for the second iteration per NUTS-0 and year

Passenger demand (pkm all modes)
Second iteration

Country	2015	2020	2025	2030	2035	2040	2045	2050
AT	0,0000%	0,0000%	0,0005%	0,0008%	-0,0002%	-0,0003%	-0,0002%	-0,0004%
BE	0,0000%	0,0000%	0,0012%	0,0010%	-0,0001%	-0,0001%	-0,0002%	-0,0002%
BG	0,0000%	0,0000%	-0,0001%	0,0002%	0,0000%	0,0001%	0,0001%	0,0002%
CH	0,0000%	0,0000%	0,0015%	0,0025%	0,0011%	-0,0003%	0,0001%	0,0002%
CY	0,0000%	0,0000%	0,0001%	-0,0003%	-0,0004%	-0,0003%	-0,0002%	-0,0001%
CZ	0,0000%	0,0000%	-0,0003%	0,0001%	0,0001%	0,0000%	-0,0001%	-0,0001%
DE	0,0000%	0,0000%	-0,0001%	0,0001%	0,0002%	-0,0002%	-0,0004%	-0,0003%
DK	0,0000%	0,0000%	0,0003%	0,0004%	-0,0003%	-0,0006%	0,0001%	-0,0001%
EE	0,0000%	0,0000%	0,0001%	-0,0002%	-0,0001%	-0,0001%	-0,0002%	-0,0004%
ES	0,0000%	0,0000%	0,0001%	-0,0001%	-0,0001%	0,0000%	0,0005%	0,0002%
FI	0,0000%	0,0000%	-0,0001%	-0,0003%	0,0001%	0,0000%	-0,0002%	-0,0001%
FR	0,0000%	0,0000%	0,0009%	0,0008%	-0,0004%	-0,0002%	-0,0002%	-0,0002%
GR	0,0000%	0,0000%	0,0000%	0,0002%	0,0004%	-0,0006%	-0,0008%	-0,0011%
HR	0,0000%	0,0000%	-0,0002%	-0,0002%	-0,0007%	-0,0002%	-0,0007%	-0,0007%
HU	0,0000%	0,0000%	-0,0001%	0,0003%	0,0000%	-0,0001%	-0,0002%	-0,0004%
IE	0,0000%	0,0000%	0,0001%	0,0000%	-0,0001%	-0,0001%	-0,0001%	0,0000%
IT	0,0000%	0,0000%	0,0004%	0,0005%	0,0000%	-0,0001%	-0,0001%	-0,0002%
LT	0,0000%	0,0000%	0,0000%	0,0001%	0,0002%	0,0000%	0,0001%	0,0000%
LU	0,0000%	0,0000%	0,0016%	0,0037%	0,0029%	0,0000%	-0,0001%	0,0000%
LV	0,0000%	0,0000%	-0,0002%	0,0002%	0,0001%	0,0001%	0,0001%	-0,0002%
MT	0,0000%	0,0000%	0,0004%	0,0000%	-0,0002%	-0,0006%	0,0001%	0,0003%
NL	0,0000%	0,0000%	0,0019%	0,0018%	-0,0001%	0,0004%	0,0004%	0,0004%
NO	0,0000%	0,0000%	-0,0001%	-0,0006%	-0,0010%	0,0000%	0,0000%	0,0000%
PL	0,0000%	0,0000%	0,0002%	0,0001%	0,0001%	0,0000%	0,0002%	0,0002%
PT	0,0000%	0,0000%	0,0002%	-0,0002%	-0,0003%	-0,0012%	-0,0014%	-0,0018%
RO	0,0000%	0,0000%	-0,0002%	-0,0001%	0,0003%	0,0007%	0,0002%	0,0000%
SE	0,0000%	0,0000%	0,0001%	0,0001%	-0,0001%	-0,0001%	-0,0001%	-0,0001%
SI	0,0000%	0,0000%	-0,0001%	-0,0001%	-0,0001%	0,0000%	0,0000%	0,0000%
SK	0,0000%	0,0000%	0,0002%	-0,0002%	-0,0003%	-0,0002%	0,0000%	0,0001%
UK	0,0000%	0,0000%	0,0004%	0,0005%	-0,0010%	-0,0009%	-0,0009%	-0,0022%
EU28+2	0,0000%	0,0000%	0,0004%	0,0004%	-0,0002%	-0,0002%	-0,0002%	-0,0004%

Table 32: Case Study 6 – Results of PAD for the third iteration per NUTS-0 and year

Passenger demand (pkm all modes)
Third iteration

Country	2015	2020	2025	2030	2035	2040	2045	2050
AT	0,0000%	0,0000%	0,0000%	0,0003%	0,0000%	0,0000%	-0,0002%	-0,0002%
BE	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	-0,0001%	-0,0001%
BG	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
CH	0,0000%	0,0000%	0,0000%	0,0006%	0,0013%	0,0001%	0,0000%	-0,0001%
CY	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
CZ	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
DE	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
DK	0,0000%	0,0000%	0,0000%	0,0001%	0,0000%	0,0001%	-0,0001%	-0,0001%
EE	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0001%
ES	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
FI	0,0000%	0,0000%	0,0000%	-0,0001%	0,0000%	0,0000%	0,0000%	0,0000%
FR	0,0000%	0,0000%	0,0000%	0,0000%	0,0002%	0,0000%	0,0000%	0,0000%
GR	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	-0,0001%	-0,0001%	-0,0001%
HR	0,0000%	0,0000%	0,0000%	0,0002%	0,0003%	-0,0001%	0,0000%	0,0000%
HU	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	-0,0001%	-0,0001%
IE	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
IT	0,0000%	0,0000%	0,0000%	0,0000%	0,0002%	0,0000%	0,0000%	0,0000%
LT	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
LU	0,0000%	0,0000%	0,0000%	0,0009%	0,0026%	0,0000%	0,0000%	0,0000%
LV	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
MT	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
NL	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0007%	0,0006%	0,0006%
NO	0,0000%	0,0000%	0,0000%	-0,0001%	-0,0004%	0,0000%	0,0000%	0,0000%
PL	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
PT	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	-0,0001%	-0,0001%
RO	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	-0,0001%
SE	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
SI	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
SK	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%	0,0000%
UK	0,0000%	0,0000%	0,0000%	0,0002%	0,0003%	0,0003%	0,0003%	-0,0005%
EU28+2	0,0000%	0,0000%	0,0000%	0,0000%	0,0001%	0,0001%	0,0000%	-0,0001%

2.6.5 Conclusions

The results show that the model produces stable results at all levels of analysis: at an aggregated level, in different time steps and across different geographical units. This exercise shows the need to calibrate the baseline scenario using iterative calculations (over the previous results) in order to have a fixed starting point that serves as the basis for the policy scenario simulations.

It can also be derived that iterative calculations in a policy scenario simulation could produce marginal changes to the results, at the expense of much more computation time. Thus we conclude that it is not worth it to include an iterative calculation process to refine the results and that the current keep forward model produces correct and stable results.

2.7 Case 7: Increase of Public and Private Transport Infrastructure Investments

2.7.1 Description of the Case

In this case the impact of an increase in public and private transport infrastructure investments is investigated. It is proposed to increase the investments in transport infrastructure in the EU 28+2 with 0.5% per year. This increase starts in 2020. Since we run the model in 5-year steps we increase the infrastructure investments by 2.5% in the years 2020, 2025, 2030, 2035, 2040, 2045 and 2050.

2.7.2 Policy Levers

In this case study only one policy lever is relevant. We do not distinguish between public and private infrastructure investments, because in the HIGH-TOOL Economy and Resource Module only one optimising economic agent is considered. Table 33 presents the policy lever subject to change.

Table 33: Case study 7 – Policy levers

Parameter name	**Data stock name**	**Affected dimension**	**Type of change**
Infrastructure investments	I_er_delta_inv	Year, country, investment	increase the investments in transport infrastructure in EU28 with 0.5% per year starting in 2020

2.7.3 Expected Outcomes

The increase in investments in infrastructure will have an expected impact on several indicators from other modules within HIGH-TOOL. First of all, we expect that this will directly increase intermediate consumption for the construction and related sectors. This increases total demand and effects production and trade-flows. Indicators with highest impact will be identified and plausibility of these results will be checked. Table 34 presents the affected parameters.

Table 34: Case study 7 – Affected parameters

Parameter name	Expected type of change
GDP	+
Output (GVA)	+

2.7.4 HIGH-TOOL Outcomes

In this section we present the HIGH-TOOL outcomes after running case study 7. The outcomes are more or less as expected. The changes caused by the increase in private and public infrastructure investments are small and are mainly observed in the ECR module. Table 34 gives an overview of the expected outcomes and the HIGH-TOOL outcomes. Figure 20 and Figure 21 show the difference between the baseline scenario and the case study scenario for GDP and GVA, respectively.

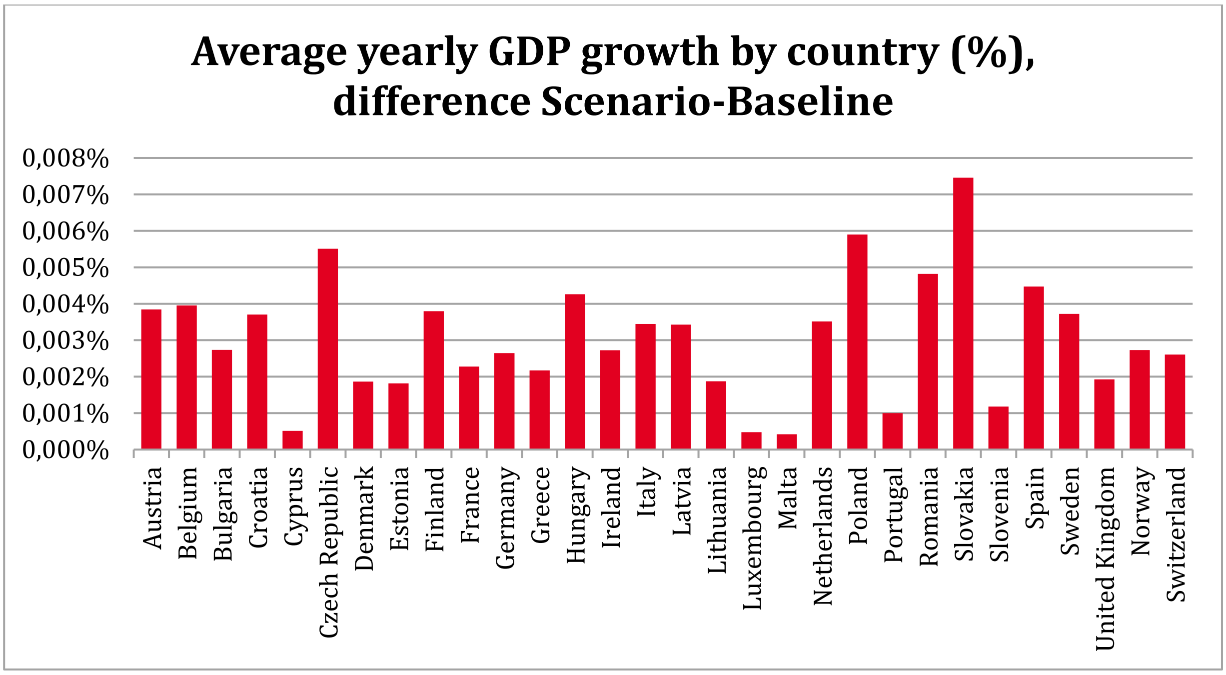

Figure 20: Case Study 7 – Difference in average yearly GDP growth between baseline and scenario

We can see that mostly the secondary sector is effected by the increase in infrastructure investments, followed by the tertiary sector and then the primary sector although the size of these effects is already negligible (the change for both sectors starts in 2030 and amount to EUR 3.2 million for the tertiary sector, which increases to EUR 29.4 million in 2050, and EUR 0.4 million for the primary sector in 2030 which increases to EUR 1.6 million in 2050).

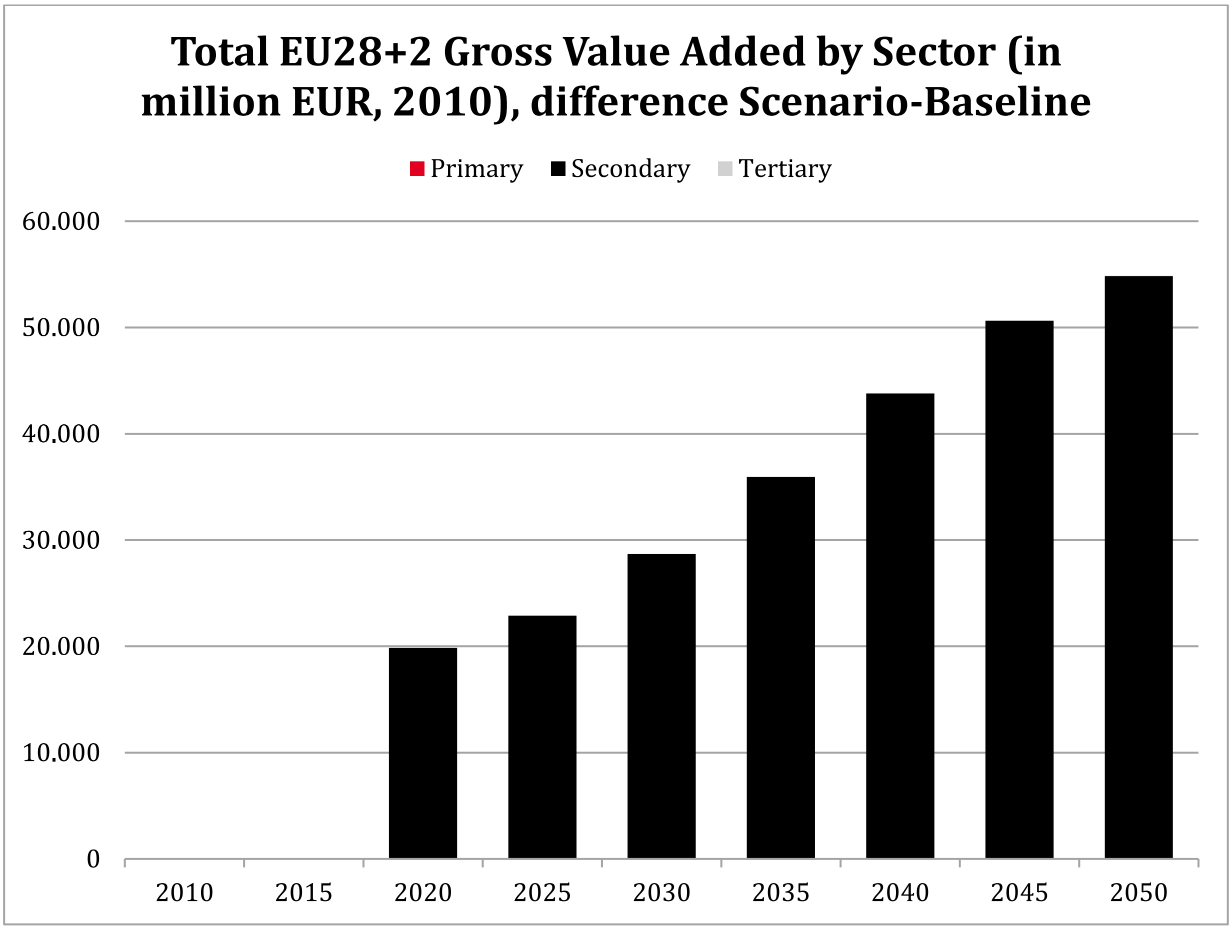

Figure 21: Case Study 7 – Difference in GVA between scenario and baseline

In Table 35 we see the change in private and public infrastructure investments causing a slight decrease in freight and passenger demand. This is mainly caused by an increase in prices (both for freight and passenger transport) due to the (small) increase in GDP, thus representing a second order effect.

Table 35: Case study 7 – Results

Parameter name	Expected type of change	HIGH-TOOL outcomes
Freight demand	No change	Negligible change (-)
Economy	+	+
Passenger demand	No change	Negligible change (-)
Safety	-	Negligible (-)
Environment	No change	Negligible change (-)

The current HIGH-TOOL model is not a network model, and hence first order effects caused by an increase in infrastructure investments, such as decrease in travelling time and costs are not measured. There is no interlinkage between the demand modules and the ECR module from a network perspective. The small change in freight and transport demand causes the small change in both the Safety and the Environmental module. Basically, less transport demand decreases the number of accidents and causes less pollution.

2.7.5 Conclusions

We see that changes in private and public infrastructure investments effect GDP and GVA directly (small increase). As expected, mostly the secondary sector is affected. Transport demand is expected to decrease marginally, which is caused by an increase in costs due to the change in GDP (second order effect). Since the current version of the HIGH-TOOL model is not a network-based model first order effects caused by an increase in infrastructure investments, such as decrease in travelling time and hence costs are not measured. There is no interlinkage between the two demand modules and the ECR module from a network perspective. This case shows that the HIGH-TOOL model is, for now, only suitable to measure second order effects of economic measures on transport. Impacts of infrastructure investments can be implemented in the HIGH-TOOL model by generically altering impedances through the setting of travel impedance-related policy levers at EU28, national or NUTS-2 level, or – additionally for passenger transport – by changing impedance values in the hypernet (see Case 2).

2.8 Case 8: Competition between High-Speed Rail and Air

Passenger transport by airplane is fast and comfortable. Furthermore, with the arrival of low-cost airlines and the increased fare competition between airlines, air ticket prices have become rather attractive in many markets. For long journeys to intercontinental destinations there are no real alternative modes. For continental journeys over medium long distances (say 300–1 000 km) the private car can be a competitor, but also high-speed rail (HSR) can be competitive. Private transport by car is particularly attractive for small groups of travellers, particularly when they carry luggage with them and when they want to visit multiple destinations. Public transport such as HSR can be attractive as an alternative to travel by air, particularly for origins and destinations within major cities where access and egress times to railway stations can be substantially shorter than those for air travel. However, HSR's attractiveness critically depends on its key characteristics: short origin-destination travel times, competitive ticket costs, sufficiently high service frequency and hours of operation, and a reasonable standard of comfort and ease of booking.

From societal perspective transport by rail including HSR is less polluting than transport by air, which is directly linked to its lower (and different form of) energy consumption. So substituting part of the passenger air travel to travel by HSR is therefore likely to have a positive greenhouse effect. This benefit might justify some cost or incentives to stimulate such substitution, by making the HSR mode more competitive relative to the air mode for instance by subsidising HSR ticket prices for distances between 300 and 1 000 kilometres, or by changing the rather advantageous taxation rules for air travel.

This case study will identify some high-level policy measures that could improve the competitive position of (high-speed) rail relative to travel by air. The measures will be linked to their corresponding policy levers, and specific changes in their values shall be defined. Then the HIGH-TOOL model will be used to simulate the effects of the different possible policies. Analysis of the outcomes shall clarify what the potential is for changing the market shares of air and HSR, and what the predicted impact is on car travel. This should enable us to identify what benefits can be achieved in terms of energy consumption and emissions.

2.8.1 Policy Levers

The case study will consist of two sub-cases: subsidising HSR ticket prices for distances between 300 and 1 000 kilometres, and changing the rather advantageous taxation rules for air travel. Both cases will be investigated. The cases will be tested with the two separate policy levers shown in Table 36 and Table 37.

Table 36: Case study 8 – Policy levers (decreasing HSR costs)

Parameter name	**Data stock name**	**Affected dimension**	**Type of change**
Electricity (resource) cost of electricity trains in eur_toe	i_vs_fu_fuel_resource_toe	time, fuel type	Reduction by 20%
Crew cost for high speed train in eur_h	i_vs_nf_rail_crec	time	Reduction by 20%
Damage load cost for high speed train in eur_veh_day	i_vs_nf_rail_damc	time	Reduction by 20%
Other costs for high speed train in eur_tkm	i_vs_nf_rail_othc	time	Reduction by 20%
Repair and maintenance costs for high speed train in eur_vkm	i_vs_nf_rail_repmaintc	time	Reduction by 20%

Table 37: Case study 8 – Policy levers (increasing air costs)

Parameter name	**Data stock name**	**Affected dimension**	**Type of change**
Resource cost of jetfuel in eur_toe	i_vs_fu_fuel_resource_toe	time, fuel type	Increase by 10%
Variable air passenger costs in eur_pkm	i_vs_nf_air_neoe_pas	time, vehicle type	Increase by 10%

2.8.2 Expected Outcomes

Essentially the outcomes of the HIGH-TOOL simulations will be a series of modified market shares of HSR, air and car. Obviously a 20% reduction of HSR ticket costs is expected to lead to a significant increase in the HSR market share, a significant decrease in the air market share and a limited decrease in the car market share. A 10% increase in the air ticket cost is expected to lead to broadly similar effects. Table 38 shows the expected changes.

Table 38: Case study 8 – Affected parameters

Parameter name	**Expected type of change**
Air passenger demand	--
Rail passenger demand	++
Road passenger (decrease in rail costs)	-
Road passenger (*increase in air costs*)	+
Emission of pollutants	-
Fuel consumption	-

2.8.3 HIGH-TOOL Outcomes

Both implementations of the case study have been tested. In neither case it was possible to limit the cost increase (or decrease) to travel in the distance-range of 300–1 000 kilometres. This limits the applicability of the case study. In case of the increase of air costs the level of realism is somewhat higher, because air travel by itself takes mainly place in de 300+ distance range.

The results of both implementations, decrease in rail costs and increase in air costs, will be discussed separately. The results of the sub-case on decrease in rail costs are shown in Table 39.

Table 39: Case study 8 – Results for the sub-case on rail cost decrease

Parameter name	Expected type of change	HIGH-TOOL outcomes
Air passenger demand	--	-
Rail passenger demand	++	++
Road passenger	-	--
Emissions of air pollutants	-	-
Fuel consumption	-	-

Decreasing the cost of rail has the expected effect in terms of the direction of change. The expected level of change on air travel is however not realised. The effect on road passenger demand is much bigger than on air passenger demand. This is mainly due to the fact that in HIGH-TOOL we do not explicitly model High Speed Rail (HSR). So to model a cost reduction for HSR we can only decrease the cost for rail in general (all distance ranges). As there is much more short distance travel than long distance travel, the reaction of the model is understandable and correct in principle.

Whereas the direction of the effect is correct and the size of the effect is understandable, the shape of the effect over time is not entirely logical. The case study prescribes a decrease in cost for rail from 2015 onwards. In the results the effect disappears after 2035.

The environmental impacts (pollution and fuel consumption) are logical and follow the effect on mode choice.

The results of the scenario in which the air costs are assumed to increase, are shown in Table 40. To discuss the results we distinguish between the modal split effects and the environmental effects.

Table 40: Case study 8 – Results for the sub-case on air cost increase

Parameter name	Expected type of change	HIGH-TOOL outcomes
Air passenger demand	--	--
Rail passenger demand	++	+
Road passenger	+	++
Emissions of air pollutants	-	-
Fuel consumption	-	-

As for the modal split effects; increasing the cost of air travel has the expected effect in terms of the direction of change. The expected level of changes, however, is not realised. The effect on road passenger demand is much bigger than on rail passenger demand. Like the other case where we decreased the cost of rail travel, this is mainly due to the fact that in HIGH-TOOL high-speed rail is not modelled separately and therefore cannot limit these changes to the distance range above 300 km. The increase in air tariffs also shows impacts on destination choice: some air trips are substituted by shorter rail and road trips. Such reaction is in principle realistic, while the scope of the reaction on change in destination choice requires further analysis.

Whereas the modal split effects are correct in terms of the direction, and the size of the effect is understandable, at a more detailed level there are some results that would require a more in-depth analysis. The case study prescribes an increase in cost for air from 2015 onwards. In the results the effect almost disappears in 2035 after which it returns again.

The environmental impacts (pollution and fuel consumption) are logical and follow the effect on mode choice.

2.8.4 Conclusions

A case study where the attempt is to only influence travel in a specific distance range, is not suitable for HIGH-TOOL until it is possible to limit the effects to specific a distance range. Furthermore, in order to analyse certain market segments in a more detailed manner, the rail market could be split into high-speed rail and conventional rail (the latter may further distinguish between long-distance and regional services). This will allow for a significantly more detailed analysis of competition between high-speed rail and air.

3 Conclusions

This deliverable presents the results of series of checks of the HIGH-TOOL model, as a part of the validation process. More specifically, the checks were performed by examining the model through eight case studies against the baseline scenario. For each case study, either a policy scenario, or a specific test case (modules' stability, sensitivity analysis) were defined. The scope of changes in model settings and policy levers were documented and the obtained results were compared to the baseline scenario. The case studies were designed such that all the modules of the HIGH-TOOL model were concerned in at least one of the conducted case studies.

The obtained results demonstrate that the HIGH-TOOL model is capable of assessing a wide variety of different types of policies at a strategic level. The integrated model – i.e. the composition of the interlinked modules – is well functioning, and the impact chains are correctly covered (e.g. the modification of impedances in the hypernet for passenger transport results in passenger demand changes, which subsequently affect environmental, economic and safety-related indicators). Also the well-functioning and the usefulness of the hypernet model for passenger transport – which represents an add-on to the original scope of the HIGH-TOOL model – has been demonstrated.

The model shows clearly a converging behaviour, and produces stable results at all levels of analysis: at an aggregated level, in different time steps and across different geographical units. For the calculation of the baseline scenario a few iterative calculations (over the previous results) are recommended. Iterative calculations in a policy scenario simulation could produce marginal changes to the results, at the expense of much more computation time. However, an iterative calculation process for policy scenarios to refine the results is not required, since the model produces stable results.

The model outputs are largely in line with expectations. However, as it is usually the case with interpretation of results of any model, features such as modelling methodology, the spatial scope or the underlying assumptions need to be considered when interpreting the results of the HIGH-TOOL model. An example: for the first judgement of the results of Case 2 (hypernet application), the model reactions may appear relatively slight. However, when considering the modelling context – i.e. the pattern that the underlying modelling approach implies the modification of impedances and flows at inter-regional level at NUTS-2, thus regarding only a small share of the overall passenger transport demand – the results are plausible.

Finally, the case study analyses provided some insights in possible extensions of HIGH-TOOL in the future: the linkages between the Economy & Resources module and the demand modules can be extended to allow also the modelling of first order effects of some selected economic policies. Furthermore, in order to allow for the definition of more focused transport policies, the rail market could be split for passenger demand modelling into high-speed rail and conventional rail (the latter may further distinguish between long-distance and regional services). This will allow for a more detailed analysis of competition between high-speed rail and air, as well as between rail and long-distance coach and passenger car. In general, in HIGH-TOOL impedance matrices are used for the modelling of the supply side, rather than network models. However, the hypernet approach for passenger transport has proven a useful add-on to capture the spatial scope of infrastructure investment policies. Extending the approach to freight transport will also enable the freight demand modelling to consider network effects at a strategic level. Furthermore, the hypernet approach may be extended to the non-road modes, allowing for a rough modelling of spatial interdependencies between European terminals (ports, airports).

The HIGH-TOOL model is an open source instrument, and does not require any commercial software products to be run. This pattern – which distinguishes the HIGH-TOOL model from other European transport policy assessment instruments – ensures thorough transparency of computations, allows the experienced user to modify calculation methodologies, and provides the basis for an efficient further development of the model.

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