Optimal Regulation and Infrastructure for Ground, Air and Maritime Interfaces

DELIVERABLE D7.1

SCENARIOS FOR FUTURE CO- AND INTERMODALITY IN LONG-DISTANCE PASSENGER TRANSPORT

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EXECUTIVE SUMMARY

General objectives

ORIGAMI is concerned with improvements in long-distance door-to-door passenger transport chains through both improved co-modality and inter-modality.

ORIGAMI develops in Workpackage 7 medium and long-term scenarios through modelling, forecasting and analysing factors influencing transport and travel behaviour. These scenarios are conceived to support the discussion about the level to which the passenger long-distance transport sector can contribute to the objectives set by the 2011 transport White Paper and the EU2020 strategy.

Therefore, the ORIGAMI scenarios are based on those presented by the Impact Assessment report of the transport White Paper, but are adapted to specifically analyse passenger long-distance transport, whereas the White Paper scenarios consider passenger transport of all ranges as well as freight transport.

Since the 2006 mid-term review of the transport White Paper, the EU policy has focussed on co-modality (i.e. the efficient use of modes on their own and in combination, that will result in an optimal and sustainable utilisation of resources). Shifts to more environmentally friendly modes are needed, especially on long-distance journeys and in urban areas and congested corridors, but at the same time each transport mode needs to be optimised on its own.

ORIGAMI starts from the premise that, with the continuing increase in trip length in interregional travel, effective use of the available transport modes as well as the interconnection between trip legs will become increasingly important for a growing proportion of passenger journeys.

The general focus of ORIGAMI is on those long-distance journeys which might benefit from more effective co-operation and/or interconnection between different modes and services, and on those situations where this is currently hampered by institutional barriers, lack of investment, or failure to innovate and which could benefit from a more enlightened approach.

By reviewing potential solutions and assessing their applicability and usefulness in a range of scenarios for the medium- and long-term future, ORIGAMI will be able to make a substantial contribution towards the formulation of new transport policies aimed at promoting co- and inter-modality.

Development of the scenarios

The main objective of ORIGAMI WP7 is the definition of scenarios at European level where the specific evolution of different types of transport segments is studied for multiple dimensions. Task 7.1 provides specifically the framework for the scenarios by defining the dimensions that they will have and the most relevant aspects that will be taken into account. Task 7.2 models and implements the scenarios. Task 7.3 evaluates their relative performance.

Scenarios are developed for 2030 and 2050 time horizons and cover the main issues analysed in ORIGAMI.

Four explorative scenarios for Europe in 2030 are defined, with qualitative narratives and quantitative characterisation. These scenarios are inspired from those proposed in the Impact Assessment report of the 2011 transport White Paper, but focussing only on long-distance passenger transport.

Explorative scenarios considered alternative visions to promote co-modality through more or less strict market regulations, at national and European level, by applying alternative planning and public investment strategies, and public-private partnerships. These scenarios investigated the impact of four different strategies without imposing explicit a priori constraints (e.g. CO_2 targets). They tried to cover all possible futures, so hypotheses for these four scenarios were alternative, if always realistic.

The four scenarios are linked to four alternative policy packages operating on the supply side of the transport system. Each policy package contains diverse policy actions linked to all transport modes which work together towards a specific transport option. Each scenario tests how demand responds to alternative hypotheses of infrastructure availability and transport management, mostly in terms of variations in the cost of transport, modal shares, or the levels of emissions released in the atmosphere.

The four exploratory policy packages are as follows:

- OR1. Better public regulation and infrastructure investment, mostly financed by public funds with some regulation.
- OR2. Better public regulation, especially on vehicle technological standards and little emphasis on infrastructure.
- OR3. More liberalisation and more emphasis on infrastructure management. Technology applied to improve efficiency of transport infrastructure.
- OR4. More liberalisation and more investment in efficient infrastructure co-financed by the private sector.

A Normative scenario has been defined by incorporating transport, energy and environment targets currently in place in the EU, mostly by the White Paper and the EU2020 strategy. The task of ORIGAMI has been to identify the combination of alternative policies required to achieve these predefined goals.

Scenarios are contrasted to a Baseline. This Baseline scenario is defined as a future without further policy implementation, a continuation of current socioeconomic trends as forecast in EU strategy documents (Energy & Transport outlook 2030, Ageing report...) and no additional transport policies applied besides those already in place.

Scenarios for 2050 compare a Prospering Europe (PE) and a Lagging Europe (LE), where trends in demographics and economic growth assumptions are varied, against a Baseline that continues current trends (Business As Usual, or BAU). A variant of the 2030 Normative scenario is then tested within these three alternative base scenarios.

The transport dimension of scenarios focuses on the co-modal optimisation of transport system for seamless travelling (which includes all intermodality options as well). For 2030, the analysis was based on a network analysis model (MOSAIC) and focused on the economic and environmental costs of European passenger travel resulting from different management criteria (e.g. more or less strict market regulations, legal / technological speeds of different modes, costs of interconnection…) and availability of infrastructure (alternative definitions of TEN-T). For 2050, the analysis has been carried out at a more strategic level using a new system dynamics model (LUNA).

Scenarios 2030

The main findings from the scenarios 2030, as modelled by MOSAIC, are as follows:

- Total mobility measured in passenger kilometres changes slightly across different future scenarios, with some stronger local variations.
- Road will remain the main mode for passenger transport in Europe, but some degree of modal shift can be achieved depending on the policies applied. Rail has the highest growth potential, multiplying by 3 its share on scenario OR1.
- The most effective policy for lowering the number of cars on the roads is to increase the average vehicle occupation.
- New routing options appear when new infrastructure is developed. For new rail this usually causes trips to get a little shorter in distance to get to the rail station, although in some cases the distance can become longer when rail is used as part of an intermodal chain; but even then trips generally become shorter in total travel time.

- Global travelling time tends to decrease in all the scenarios as changes in transport costs and infrastructure lead to better routes. However, the most effective measure to improve it is increasing the speed on the road as in scenario OR4.
- In most scenarios with a higher share of rail, trips tend to be more multimodal, mixing rail with road but also with air on the same trip. Mobility becomes more complex with lots of interchanges between modes. However in scenario OR4, the increase of rail does not result in an increase of multimodality, as the growth of air trips and the high increase in road speed compensates it.
- On the other hand, in some cases scenarios with a higher share of air mode tend to be more unimodal with long-distance flights, making mobility simpler (access/egress to airports from a very close location is not considered another mode), although scenarios OR4 and the Baseline are exceptions, as here the air trips are not so long, and road as a feeder mode becomes relatively more relevant.
- Fuel efficiency improves in all scenarios, but the most effective policy is the technological one. In scenario OR2, the vehicles are forced to consume less, resulting in a reduction of up to 40% compared to the Baseline.
- CO_2 emissions also decrease in all the scenarios, with the technological scenario again being the one with the highest reduction. The Normative scenario achieves the White Paper target of reducing emissions by 20% by 2030.
- Accessibility measured as the accessible population weighted by the time of reaching this population tends to improve when new infrastructure appears, allowing for better transport chains. However, the pricing policy in some scenarios causes transport to get more expensive, thus lowering the accessibility in certain regions.

Scenarios 2050

The main findings from the scenarios 2050, as modelled by LUNA, are:

- Car ownership will be rising in the future, but least in a Prospering Europe scenario due to a combination of population growth, an increase in older population, rising household sizes and a decrease in GDP per person. The Normative Transport Policy curbs car ownership to a limited extent.
- The total number of cars will also rise, but here the population growth is the key factor, so that the number of cars rises highest in a Prospering and least in a Lagging Europe.
- The number of passenger kilometres grows in all scenarios from 2010 to 2050, by up to 52% in PE, mainly due to the increase in the number of trips and to a lesser extent due to a lengthening of air trips, and with the policy also rail trips. The number of trips is not affected by the application of the Transport Policy.
- The strongest growth in passenger mileage comes in all scenarios from the growth in air travel, while growth in car travel depends much more on the socio-demographic and economic development. Neither is much affected by the Transport Policy, but the Policy does lead to an increase in rail travel, in the combination of the Policy with the assumptions of a Prospering Europe by up to 66%. Coach and maritime travel are both expected to grow continuously, slightly less with than without the Policy, but in terms of overall pax km, they will still remain less important than the other modes.
- The development of vehicle kilometres is, unsurprisingly, dominated by the car whose mileage is in 2010 27 times that of all collective modes together, and this relationship does not change much until 2050 in the Baseline scenario. But it is susceptible to both the socio-demographic and economic development and the assumptions about car occupancy in the Policy, and therefore its growth ranges from -6% in LE with the Policy to 39% in PE without the Policy. The fastest growth of all modes with 21% in LE to 41% in PE is that in the air travel mileage and the Policy only reduces that by less than 5% in all cases, while at the same time increasing the use of rail.
- The time spent on long-distance travel per person per year increases from 16.8 hours in 2010 to 21.0 hours in LE, 21.9 in the Baseline and 22.4 in PE, but the Transport Policy reduces this in all three again by one hour, mainly due to less time spent on air travel.

- User expenditure increases from €248 per person per year in 2010 to €410 to €440, depending on the scenario. The main factors are a doubling of the cost of car travel and a 60% increase in the cost of air travel, but differences between scenarios with or without Transport Policy are with a maximum of €25 per person per year between the lowest and highest value too small to make a factual difference for the users. Differences between richer and poorer countries increase, however, from €1,200 in 2010 to €1,900 in 2050.
- In all scenarios there is an initial decline in fuel consumption but then it is rising again and, except for LE with the Transport Policy, ends up in 2050 well above 2010 levels. This is largely driven by the large increase in air fuels, and the decrease in car consumption through the increase in car occupancy, while the impact of any changes in the other three modes is totally marginal.
- Greenhouse Gas emissions decrease with the Transport Policy in place by between 22% and 28% and without the Policy decline even much less. This is all well below the EU's GHG reduction target for 2050 of 60 %, and even a much more stringent Transport Policy than the one chosen in these scenarios could not possibly lead to results that come anywhere near that. Only a step change in propulsion technology would have any chance of producing a result that is approaching the EU target.
- The biggest absolute and relative decrease in particulate emissions in the three BAU scenarios from 2010 to 2050 comes from rail, based on the assumptions made about the electrification of rail. However, the biggest absolute decrease overall comes from the Transport Policy, and therein for the cars due to the change in the car fleet: the reduction in particulates for cars in the Baseline scenarios in 2050 from BAU to With Policy is significantly higher than the particulates for the entire rail sector contributed in 2010.
- The indicator for social welfare available from LUNA is the holiday trip rate per country and age group. The number of holiday trips per year increases in all scenarios, though more in PE than in LE. The trip rate for young people is catching up with that of the middle-aged, but people of 65+ years fall further back as their level of car ownership does not increase at the same pace as their longevity. There are stark differences between holiday trips in different parts of Europe with that of Central Europe being – and remaining in the future – twice that of Eastern Europe, and Western Europe being another 10% ahead, even though there are strong differences within each of these three groups, in particular a very strong north/south divide. Moreover, the disparities between social welfare in the different European countries, as measured by the holiday trip rate, increase over time.

Overall conclusions

The two sets of scenarios for 2030 and 2050 start in many aspects from different premises, and it is therefore not straightforward to compare them and come to common conclusions. The key difference is that the 2030 scenarios are dealing with any travel between NUTS3 zones (or where no NUTS structure is available similar, if often somewhat larger, regions) within Europe plus Turkey, while the 2050 scenarios only look at travel that involves at least one overnight stay and, furthermore, also includes intercontinental journeys. One key resulting difference is that one of the core findings in the 2030 scenarios is that road is, and will remain, the dominant mode for long-distance travel in Europe, while the 2050 scenarios already start with air journeys entailing the largest share of passenger kilometres in Europe in 2010, and air even enlarging its lead in every scenario for 2050. Nevertheless the two sets of scenarios come to some common findings:

- The most effective way to decrease the number of cars, or at least the growth in the number of cars, is to increase vehicle occupancy with policy incentives.
- Investment in rail, in particular in High Speed Rail, and policies to reduce the cost of rail travel can significantly increase rail usage.
- Air travel will rise in all scenarios well above 2010 levels with the lowest assumption for 2030 being +36% to the highest of +66% by 2050 for a Prospering Europe.
- Both sets of scenarios foresee a decrease in fuel consumption for the nearer future, but in the 2050 scenarios consumption is rising again in later years, largely driven by the increase in air travel, and in most scenarios end up well above 2010 level. The most important factors in limiting fuel consumption are the assumptions for future propulsion technology.

Some further general conclusions can be drawn from the 2050 scenarios only, with the main one being that socio-demographic and economic changes can significantly influence the future of transport. The difference between a Prospering and Lagging Europe, based even on very reasonable rather than extreme assumptions, can be more 400 million trips per year. This equates to more than 200 billion passenger kilometres per year, or a difference of more than 25%. In contrast, the Transport Policy applied in these scenarios has a significant influence on mode choice, but very little on total mileage travelled.

What can be regarded as the key message from both sets of scenarios concerns the Greenhouse Gas emissions. They decrease in all scenarios, but while the Normative Transport Policy for the 2030 scenarios manages to meet the EU target of reducing GHG emission by 20% by 2030, the 2050 scenarios are much less optimistic and, even in the best case, only reduce emissions by 28% by 2050, far away from the EU target of a 60% reduction by that year. As for fuel consumption, the key factor is the future of propulsion technologies, but the assumptions made for 2050, that were assumed to be realistic, are still clearly not sufficient, and a real step change in technology is necessary to make transport and mobility sustainable in the future.

1 INTRODUCTION

1.1 AIMS OF ORIGAMI

ORIGAMI is concerned with improvements in long-distance door-to-door passenger transport chains through both improved co-modality and inter-modality.

ORIGAMI develops in WP7 medium and long-term scenarios thorugh modelling, forecasting and analysing factors influencing transport and travel behaviour. These scenarios are conceived to support the discussion about the level to which the passenger long-distance transport sector can contribute to the objectives set by the 2011 transport White Paper and the EU2020 strategy.

Therefore, the ORIGAMI scenarios are based on those presented by the Impact Assessment report of the transport White Paper, but are adapted to specifically analyse passenger long-distance transport, whereas the White Paper scenarios consider passenger transport of all ranges as well as freight transport.

Since the 2006 mid-term review of the transport 2001 White Paper, the EU policy has focussed on co-modality (i.e. the efficient use of modes on their own and in combination, that will result in an optimal and sustainable utilisation of resources). Shifts to more environmentally friendly modes are needed, especially on long-distance and in urban areas and congested corridors, but at the same time each transport mode needs to be optimised on its own.

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By reviewing potential solutions and assessing their applicability and usefulness in a range of scenarios for the medium- and long-term future, ORIGAMI will be able to make a substantial contribution towards the formulation of new transport policies aimed at promoting co- and inter-modality.

1.2 OBJECTIVES OF WP7

The main objective of ORIGAMI WP7 is the definition of scenarios at European level where the specific evolution of different types of transport segments is studied for multiple dimensions. Task 7.1 provides specifically the framework for the scenarios by defining the dimensions that they will have and the most relevant aspects that will be taken into account. Task 7.2 models and implements the scenarios. Task 7.3 evaluates their relative performance.

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The expert work of ORIGAMI in designing the scenarios has been complemented with inputs from the European transport sector to make sure that the most relevant factors influencing the transport market in the next decades are considered. To do so:

- An expert web-based consultation was run in November 2011 among a number of academic experts, industry stakeholders, civil servants and transport consultants. The consultation was based on 10 transport policies, and associated transport solutions to these policies. 265 people participated in this survey and their contributions can be consulted in www.origami-project.eu.
- An expert workshop on upcoming transport solutions, policies and transport scenarios for Europe and the World was held in Barcelona in May 2012. This workshop gathered 100 participants from the transport sector, research institutes and public administrations from all over Europe. Conclusions of the workshop can be consulted in www.origami-project.eu.

2 MOSAIC MODEL DESCRIPTION

2.1 BACKGROUND

State-of-the-practice forecast models are based on a conventional modular structure with trip generation, distribution, modal split and network assignment, having two major draw-backs:

- The separation between mode choice and traffic assignment means that intermodal chains cannot be properly included and analysed in these kinds of model.
- Interconnections between local and regional networks are neglected.

The MOSAIC model was developed in the framework of the INTERCONNECT EC 7FP project (2011), and has been refined for ORIGAMI.

MOSAIC is a modal choice and assignment module originally programmed to investigate how interconnection facilities and services influence the costs of transport, and therefore, how the upgrading of interconnections in Europe may impact on the European transport system.

MOSAIC is intended to overcome the weaknesses of state-of-the-practice forecast models at continental level in relation to the integration of interconnections into their modal choice and assignment procedures.

MOSAIC is fed with trip matrices originated by TRANS-TOOLS, and works as stand-alone software to perform multi-modal network assignments. A meta-model approach is later adopted to process the large data outputs of MOSAIC and produce sets of indicators.

The MOSAIC network graph is based on the so-called *supernetwork approach*. In this approach, the different modal sub-networks (uni-modal networks) are completely integrated, and the combined modes and the interactions among the vehicular modes on the roads might be explicitly taken into account. The multi-modal graph was constructed using the road, rail and air graphs from TRANS-TOOLS, identifying intermodal terminals and establishing connectors between networks at these points.

MOSAIC assigns TRANS-TOOLS matrices, rearranged to be assigned all together onto the multi-modal graph. Traffic on the networks - travel behaviour - depends on the topology of the integrated multi-modal graph and the impedance of its different elements. Interconnections are an additional element equivalent to other transport links, having a direct impact in the route choice processes. The variation of multi-modal parameters at connectors and transport terminals allow for analysis of the influence of interconnections in the behaviour of travellers.

The EC TRANS-TOOLS model is calibrated with Eurostat transport statistics. This implies that internal parameters in TRANS-TOOLS are set so that results from its modelling process sufficiently fit reality. The internal parameters of MOSAIC – transport costs, interconnectivity costs, VOT - were adjusted in a process of validation using TRANS-TOOLS outputs. In doing so, MOSAIC gets in line with TRANS-TOOLS.

2.2 MODEL DESCRIPTION

2.2.1 Overview

The next table presents the structure of the MOSAIC model, specifying the data (or samples), the formulation (or postulates), the queries the model can address, and the results it can produce. The inputs and outputs of the model are detailed thereafter.

Table 2-1 MOSAIC specification

NAME	MOSAIC
BACKGROUND	
Last update	2011
Developer	MCRIT based on TRANS-TOOLS (TT) previous developments.
Developed in the project	7th EU Framework Programme (INTERCONNECT)
Ownership	MCRIT co-financed by EC. No commercialised.
Main applications	TT is the best state-of-the-practice transport-oriented forecast model available at EU level. DGMOVE has required the application of TT model in all studies carried out during the last years in the process to redefine the Transeuropean transport networks and the new Transport White Book 2010-2020. TT model is being continuously improved in different projects of the 7th European Framework Programme. In INTERCONNECT (2010) MCRIT developed the MOSAIC model, based on TT trip generation and distribution results, being also applied in ORIGAMI (2011-2012) to assess four different transport policy-scenarios for 2030.
Documents of reference	INTERCONNECT Final Report (www.interconnect-project.eu)
Scientific papers	TRA2012 "*Impacts of improving interconnectivity between local and long-distance transport networks in Europe: Conclusions from the modelling activities in the INTERCONNECT 7th EU Framework Programme project*"
Running time	12 hours
Size of total results	16 Gb
Data exchange format	Results can be provided in MDB format
Software platform	BridgesNIS (proprietary software programmed in C++ by MCRIT) linked to most GIS packages, especially Geomedia Intergraph. Tutorial and guide under development.
S A M P L E S	
Reference data from	2005
Data for calibration	MOSAIC internal parameters are calibrated with TT 2005 results.
Data inputs	Multimodal Transport Networks (50.000 links) including detailed intermodal exchanges and proxy to long-distance passenger services. Information restricted.
	TRANSVISIONS socio-economic, trip generation and distribution databases 2005-2020-2030 produced by TRANSTOOLS for Baseline scenarios at NUTS3 level. Publicly available information.
P O S T U L A T E S	
Forecast reliable up to	2030
Geographic coverage	EU27 and neighbouring countries
Adm. desegregation	NUTS3
Thematic scope	Passengers (freight not included)
Theory of TT-MSAIC	Integrated modal split and assignment for passengers applied to TT trip distribution matrices
Theory of TRANSTOOLS (TT)	4-steps passenger and freight transport model see: http://energy.jrc.ec.europa.eu/transtools/
Q U E R I E S	
Transport supply-oriented policies	How *infrastructure provision policies* (new infrastructure) may change traffics in the networks?, induce modal shifts?, change energy consumptions and emissions?, accidents?, increase accessibility?
Transport market regulatory	How *pricing and subsidy policies* may change traffics in the networks?, induce

policies	modal shifts?, change energy consumptions and emissions?
Technologic innovation	How changes on *vehicle technologies* may change traffics in the networks?,, induce modal shifts?, change energy consumptions and emissions?, accidents?
R E S U L T S (Main families of indicators)	
Transport endowment	Aggregated, by NUTS3, by mode
Infrastructure investment	Aggregated, by NUTS3, by mode
Costs of travelling	Between NUTS3 by trip purpose using optimal transport chains
Time of travelling	Between NUTS3 by trip purpose (business, visit, inter-NUTS3 commuting, holydays)
Accessibility	Surface, people or activities (GDP) at a given distance or time or cost from a given place
Trips	Between NUTS3 by trip purpose (business, visit, inter-NUTS3 commuting, holydays)
Modal shares	% trips between NUTS3 by trip purpose (business, visit, inter-NUTS3 commuting, holydays)
Modal chains	% length or time or cost between NUTS3 by trip purpose (business, visit, inter-NUTS3 commuting, holydays)
Emissions	CO2, PMx, NOx by network link, aggregated at NUTS3 or NUTS0
Typical graphic output (maps, diagrams)	Maps with traffics on transport links Accessibility maps displayed by 5x5 km2 cells Maps with patterns for NUTS3 Time lines for key indicators aggregated at different scales
DATA MANAGEMENT IN NON EU27 COUNTRIES	
ESPON space countries (Iceland, Norway, Switzerland and Lichtenstein)	Networks and travel data available, at a lower resolution than in EU27 countries. Data available for all ESPON partner countries
Accession countries (Western Balkans and Turkey)	Networks and travel data available, at a lower resolution than in EU27 countries. Data available for Western Balkans and Turkey
Neighbouring countries	Networks and travel data available, at a lower resolution than in EU27 countries. Data available for Ukraine, Belarus, Russia. No data available for Northern Africa nor Middle East.

2.2.2 Infrastructure Graph

Next table provides a summary of most elements in the MOSAIC Transport Networks, which can be varied to simulate different Infrastructure Scenarios with the model, before assigning trips.

Table 2-2 MOSAIC Infrastructure Input

TOPIC	INPUT	Baseline reference source and/or conditions for 2030
Cities	NUTS3 capitals	NUTS3 and capitals remain the same as nowadays
Transport terminals	Rail stations	EIB IGIS Database. No more rail stations planned
	Airports	TT airports. No more airports planned, but capacity extensions following demand needs.
	Ports	TT ports. No more airports planned, but capacity extensions following demand needs.
Infrastructure links	Road	TT road network with **4,850 km** of new motorways according to Core Network outline as defined by EC in 2011 (the criteria to select the new motorways and upgrades are

TOPIC	INPUT	Baseline reference source and/or conditions for 2030
		equality based on investing in busiest corridors and less developed countries)
	Rail	TT rail network with **6,300 km** of new HSR and 6.500 km of conventional rail according to Core Network outline as defined by EC in 2011 (the criteria to select the new motorways and upgrades are equality based on investing in busiest corridors and less developed countries)
	Air	TT air network. No new connections envisaged.
	Sea	TT road/rail network. No new connections envisaged.
Interconnections between transport networks	Road – Rail interconnection	One connector per rail station to closest road. No new connections envisaged.
	Air – Road interconnection	One connector per airport to closest road if < 5km. No new connections envisaged.
	Air – Rail interconnection	One connector per airport to closest railways if < 10km. No new connections envisaged.
Access/Egress to Capital Cities	Road access to cities	One connector per NUTS3 centroid to closest road. No new connections envisaged.
	Rail access to cities	One connector per NUTS3 centroid to closest rail if < 15 km. No new connections envisaged.

2.2.3 Input Parameters

Data used in transport models has to be attached to specific objects, from administrative levels (NUTS3, NUTS2, NUTS0), to users or commodities, by trip purposes or type of products, and to different type of vehicles or fleet. The next table provides a summary of most relevant parameters by topics.

Table 2-3 MOSAIC Input Parametres

TOPIC	INDICATOR	Type / Unit	Baseline values 2030
TRANSPORT SERVICES	Road free-flow speed	Km/h	The same in TRANSVISION Baseline
	Rail commercial speed	Km/h	The same in TRANSVISION Baseline
	Air commercial speed	Km/h	The same in TRANSVISION Baseline
	Ferry commercial speed	Km/h	The same in TRANSVISION Baseline
	Speed in road access to cities	Km/h	40 km/h
	Speed in rail access to cities (PT)	Km/h	15 km/h
	Speed in transfers in intermodal terminals	Km/h	4 km/h

TOPIC	INDICATOR	Type / Unit	Baseline values 2030
	Time penalty between two consecutive air trips	Minutes	90min
	Time penalty between two consecutive ferry trips	Minutes	Defined as 1/2 of ferry frequency in TT
OPERATION COSTS[1]	Road travel cost *(cost allocated to a road link)*	Euros/km	0.15 €/km
	Rail travel cost *(cost allocated to a rail link)*	Euros/km	Between 0.09 and 0.20 €/km
	Ferry travel cost *(cost allocated to a ferry link)*	Euros/km	0.15 €/km
	Air travel cost *(cost allocated to an air link)*	Euros/km	Function of (trip length, airport, user class)[2]
	Cost of accessing a city from road network *(cost allocated to connector between road network and NUTS3 centroid)*	Euros/km	0.25 €/km
	Cost of accessing a city from rail network *(cost allocated to connector between rail network and NUTS3 centroid)*	Euros/km	0.10 €/km
	Cost of accessing an airport from road network *(cost allocated to connector between road network and airport)*	Euros/km	0,15 €/km
	Cost of accessing an airport from rail network *(cost allocated to connector between rail network and airport)*	Euros/km	0.15 €/km
	Cost of accessing a rail station from road network *(cost allocated to connector between road and rail networks)*	Euros/km	0.25 €/km
	Variation of travel cost in infrastructure around EU	Constant (0 to 1)	0.75
	Variation of travel cost in interconnections around EU	Constant (0 to 1)	0,75

[1] Average cost for a vehicle to use a link in the graph. Average costs are later adjusted in each link based on the level of income of the NUTS3 where link is located. This adjustment is intended to simulate the inpact of different levels of regional wealth on the cost of travelling along infrastructure located in different areas of Europe. The adjustment factor is specified through the "*Dispersion of travel cost in infrastructure around EU*" and "*Dispersion of travel cost in interconnections around EU*" parameters under SOCIETY topic.

[2] The cost function of air travel (euros per kilometre) is a decaying function of distance, adjusted in relation to the level of congestion of airports at origin and destination of trip (busiest airports result on increased costs), and passenger classes (traveller classes with higher Value of Time VOT (e.g. business) pay more than those with lower VOT (e.g. holydays)).

TOPIC	INDICATOR	Type / Unit	Baseline values 2030
VOT: USERS VALUE OF TIME[3]	Business travellers	Euros/hour	25 €/h
	Private purpose travellers	Euros/hour	10 €/h
	Commuters inter-NUTS3	Euros/hour	10 €/h
	Holyday travellers	Euros/hour	8 €/h
	Variation of value of travel time among EU citizens	Constant (0 to 1)	0,75
VEHICLE EMISSIONS	Road emissions	CO2 tons/pax km	135 gr/veh km
	Rail emissions	CO2 tons/pax km	13 gr/pax km
	Air emissions	CO2 tons/pax km	70 gr/pax km
	Ferry emissions	CO2 tons/pax km	100 gr/pax km

2.2.4 Outputs

The next table provides a summary of the most relevant parameters by topics.

Table 2-4 MOSAIC Output Parametres

TOPIC	OUTPUT	Type / Unit	Levels of desegregation
TRANSPORT COST	Euros spent travelling along the transport networks (links)	euros	- At EU level, NUTS0, NUTS3 - By trip purpose: business, private, commuter and holyday trip purposes
	Euros spent in interconnections (connectors)	euros	- At EU level, NUTS0, NUTS3 - By trip purpose: business, private, commuter and holyday trip purposes
INTENSITY OF USE OF NETWORKS	Total kilometres travelled	km	- At EU level, NUTS0, NUTS3 - By trip purpose: business, private, commuter and holyday trip purposes
	Average trip length	km	- At EU level, NUTS0, NUTS3 - By trip purpose: business, private, commuter and holyday trip purposes
	Travel time *(time spent in networks)*	hours	- At EU level, NUTS0, NUTS3 - By trip purpose: business, private, commuter and holyday trip purposes

[3] Average values of travel time (VOT) for different types of users (business, private, commuter, and holidays). For each type of user, average VOT are later adjusted based on the income level of the NUTS3 where trip is originated (GDP per capita). This adjustment is intended to simulate the effect of different levels of regional wealth on the VOT of its inhabitants. The adjustment factor is specified in the "*Dispersion of value of travel time among EU citizens*" parameter under SOCIETY topic.

TOPIC	OUTPUT	Type / Unit	Levels of desegregation
MODAL SPLIT	Modal share *(based on itineraries, trips or trip·kilometres)*	%road // %rail // %air	- At EU level, NUTS0 - By trip purpose: business, private, commuter and holyday trip purposes
	Multimodality share *(based on itineraries, trips or trip·kilometres)*	%uni-modal trips // %multi-modal trips[4]	- At EU level, NUTS0 - By trip purpose: business, private, commuter and holyday trip purposes
	Modal chain share *(based on itineraries, trips or trip·kilometres)*	%road uni-modal %rail uni-modal %air uni-modal %road-rail multi-modal %road-air multi-modal %rail-air multi-modal %road-rail-air multi-modal	- At EU level, NUTS0 - By trip purpose: business, private, commuter and holyday trip purposes
INTER-CONNECTIVITY	Shifts between modes	Number of changes between different transport networks[5]	- At EU level, NUTS0, NUTS3 - By trip purpose: business, private, commuter and holyday trip purposes
	Breaks between modes	Number of changes between different transport networks or transport services[6]	- At EU level, NUTS0, NUTS3 - By trip purpose: business, private, commuter and holyday trip purposes
	Number of modes used	1, 2 or 3	- At EU level, NUTS0, NUTS3 - By trip purpose: business, private, commuter and holyday trip purposes
ENVIRONMENT	CO2 emissions	Tons of CO2	- At EU level - By trip purpose: business, private, commuter and holyday trip purposes
	Particle emissions	Tons of NOx and PMx	- At EU level - By trip purpose: business, private, commuter and holyday trip purposes
	Fuel consumption	Tons of fuel (per fuel type)	- At EU level - By trip purpose: business, private, commuter and holyday trip purposes
SPACE	Accessibility	Surface, population or activities within certain distance from NUTS3 capitals	- At NUTS3 level (spatially distributed)

2.3 Implementation of Transport Policies in MOSAIC

MOSAIC allows simulating policies by modifying the following parameters.

Table 2-5 MOSAIC Parameters allowing to implement transport policies

POLICY INSTRUMENTS	MOSAIC- RELATED PARAMETRES

[4] Uni-modal trips only use one mode, whereas multi-modal trips use two or more modes
[5] i.e. road to rail, road to air, rail to road, rail to air, air to road and air to rail.
[6] i.e. all shifts between modes plus changes between consecutive air-air services and rail-rail services

POLICY INSTRUMENTS	MOSAIC- RELATED PARAMETRES
Market liberalisation - Market opening (free competition) - Privatisation (PPPs)	Average Road travel cost (€/km) Average Rail travel cost (€/km) Average Air travel cost (€/km) Average Ferry travel cost (€/km)
Bans and regulation - Efficiency standards - Speed limitations - Accompanying measures (behavioural incentives)	Average Car vehicle emissions (grams/veh km) Electric vehicles (% of non-ICE vehicles) Car occupation (people/vehicle) Average Rail emission factors (grams/pax km) Average Air emission factors (grams/pax km) Average Ferry emission factors (grams/pax km) Road speed (km/h)
Pricing and Taxation - Road pricing - Vehicle taxation - Rail subsidies - Fuel taxation - Air taxation	Road travel cost (€/km) Rail travel cost (€/km) Air travel cost (€/km) Ferry travel cost (€/km) Cost of accessing a city from road network (€/km) Cost of accessing an airport from road network (€/km)
Infrastructure management - New technological solutions - Organisational issues - Optimisation of procedures	Road speed (km/h) Rail speed (km/h) Air speed (km/h) Ferry speed (km/h) Speed of accessing a city from the road network (km/h) Speed of accessing a city from the rail network (km/h) Cost of accessing an airport from the road network (€/km) Cost of accessing an airport from the rail network (€/km) Cost of accessing a rail station from the road network (€/km) Time penalty between consecutive air trips (transit) Time penalty before starting an air trip (check-in / security / boarding)
Infrastructure provision - Missing links - Bottlenecks - Interconnections between networks	More road links (km) in core network More HSR links (km) in core network More conventional rail links (km) in core network More air links (km) More ferry links Airport - rail interconnections
Soft Measures - Increased comfort - Better traveller information	VOT for business travellers VOT for private travellers VOT for commuter travellers VOT for holiday travellers

3 DESCRIPTION OF SCENARIOS FOR 2030

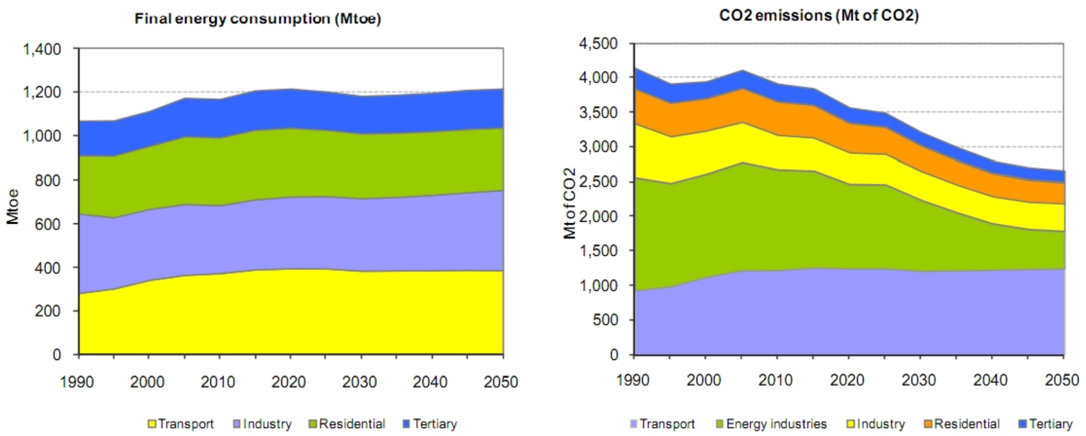
3.1 DEFINITION OF THE ORIGAMI BASELINE

3.1.1 Approach

The Baseline represents the future without any additional policy intervention to change current trends. This scenario is the same as Policy Option 1 defined in the White Paper, and is the same one used in the Impact Assessment of the *Low-carbon economy 2050 roadmap* and in the *2050 Energy Roadmap*, more focussed in long-distance passenger transport. It is a projection, not a forecast, of developments in absence of new policies.

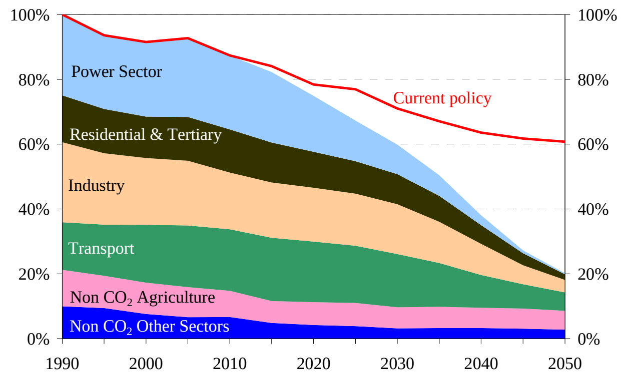
The Baseline scenario has been built based on official strategy and prospective reports by EU institutions (mostly ECFIN's 2009 *Ageing Report*, DGTREN's *Transport and Energy Outlook 2030*, DGMove's 2011 *Transport White Paper* accompanying working papers, and EEA and Eurostat statistics and forecasts) and complemented with additional inputs from EU research projects and works by other international reference institutions and corporations (various EC 7FP projects, BP's 2011 *Energy Outlook 2030*, UNWTO's 2011 *Tourism Towards 2030*).

The Baseline considers a stabilisation of population growth towards 2040, population decreases in some areas of Europe, internal migration, moderate economic growth, transport growth coupled to the economy, increased energy consumption (especially from the transport sector). Even if a substantial reduction of CO2 emissions is foreseen with respect to the 1990s, reductions are insufficient to accomplish set targets for 2050 (80% of 1990s levels), and in particular, emissions from the transport sector increase by some 30%.



(Source: Impact Assessment report of 2011 transport White Paper)

Figure 3-1 Evolution of total final energy consumption and CO2 emissions between 1990 and 2050 according to EC official Baselines



(Source: A Roadmap for moving to a competitive low carbon economy in 2050 // COM(2011) 112 final)

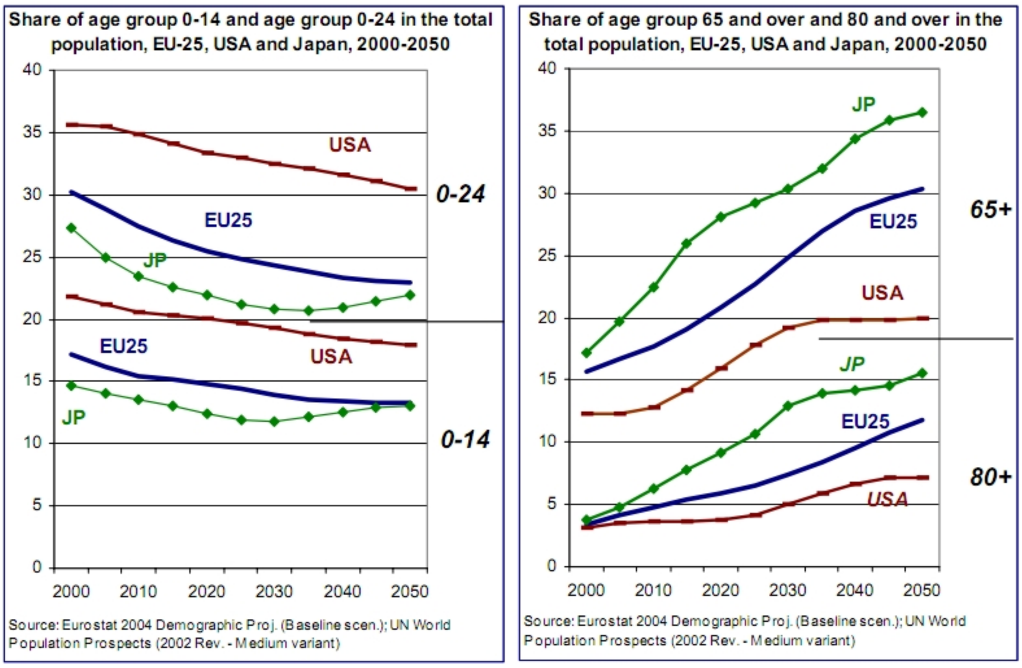
Figure 3-2 Difference between EU GHG emissions targets for 2050 and anticipated trends according to EC Baselines (100% =1990)

3.1.2 Qualitative Storyline

Demographics and society

Stable in demographic terms, within the EU27. Population most likely to stabilise between 2030 and 2050 mainly thanks to migration. According to EU projections, native population could start declining in about 30 to 40 years. Even if public policies aimed at mitigating population ageing and decline have been successful in some Scandinavian countries, the effects of these policies are likely to be felt only in the very long term globally in Europe, and immigrants will still be required to fulfil European labour needs. With almost twice as much people aged 65 or more in 2050 as today, most regions will have reached a median age of 45 years already in 2030, and some regions even before. A major consequence of the ageing of the population is that the working age population will decline with downward effects on economic growth and competitiveness of many European regions. The consequences may be different for different regions and may affect migration flows across regions in different ways[7]. Peripheral and rural regions may have fewer and older residents. The aging of European population will create new challenges which will require specific policies, bringing additional pressure on national budgets and the welfare systems (25% increase in social expenditure by 2050)[8]. Transport policy will also require meeting new needs of the elderly, who will travel more than today. North-South migration will increasingly substitute East-West migration and South-North migration. The Mediterranean shore, the European Sun Belt, is expected to receive significant migration flows.

GRAPH 3: SHARE OF THE YOUNGEST AND THE OLDEST IN THE EUROPEAN POPULATION



Graph 3 presents the shares of the two youngest and the two oldest age groups between 2000-2050 for Japan, USA and EU-25. In all three cases an important decline in the share of younger cohorts is observed while the share of the older cohorts has increased. The main implication of these trends is that the overall demand for care will increasingly have to shift from the young to the elderly. The only way to cope with this potentially huge increase in demand from old age groups is to develop *active ageing* policies.

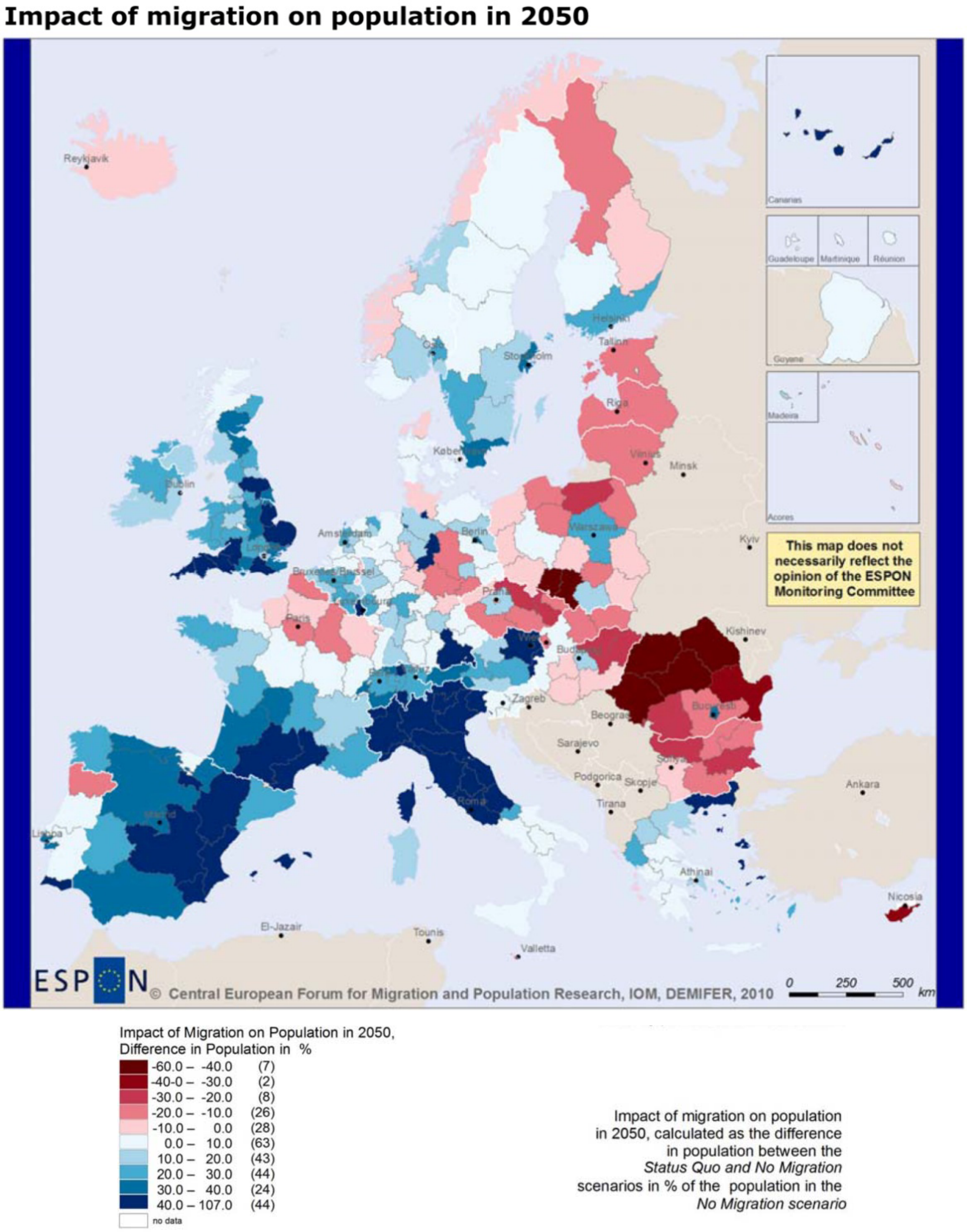
(Source: EC 2005[9])

Figure 3-3 Share of youngest and oldest in the European population

[7] *Demographic and Migratory Flows Affecting European Regions and Cities (DEMIFER)*, Applied Research Project conducted in the framework of ESPON 2013 Programme, partly financed by the ERDF, 2010. http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/demifer.html

[8] *2009 Ageing Report*, ECFIN 2009.

[9] *Green Paper "Confronting demographic change: a new solidarity between the generations"* EC COM(2005)94

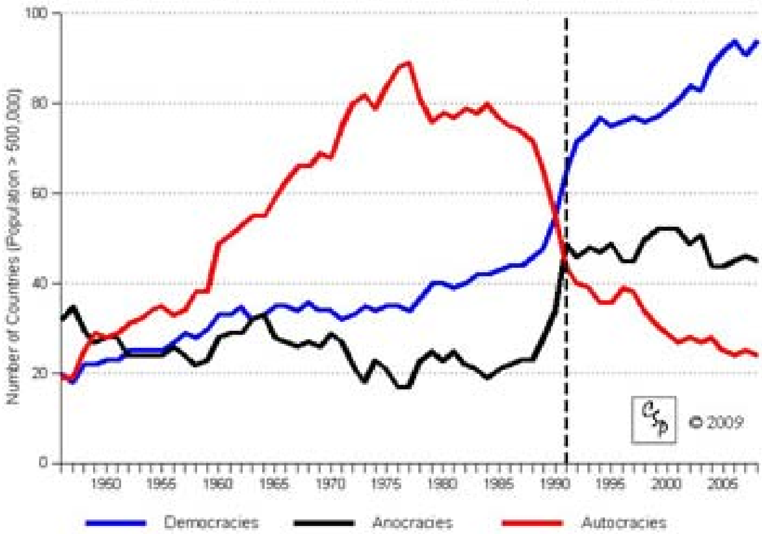


(Source: ESPON DEMIFER 2010)

Figure 3-4 Impact of migration on population 2050

More public - private collaboration

Peaceful and democratic Europe enlarged to integrate a few neighbouring countries in the Balkans and in the East by 2030.



(Source: Center for Systemic Peace (CPS) and George Manson University, 2009 (sponsored by PITF, CIA))

Figure 3-5 World trends in Governance 1946-2008

Return to moderate economic growth in the mid term

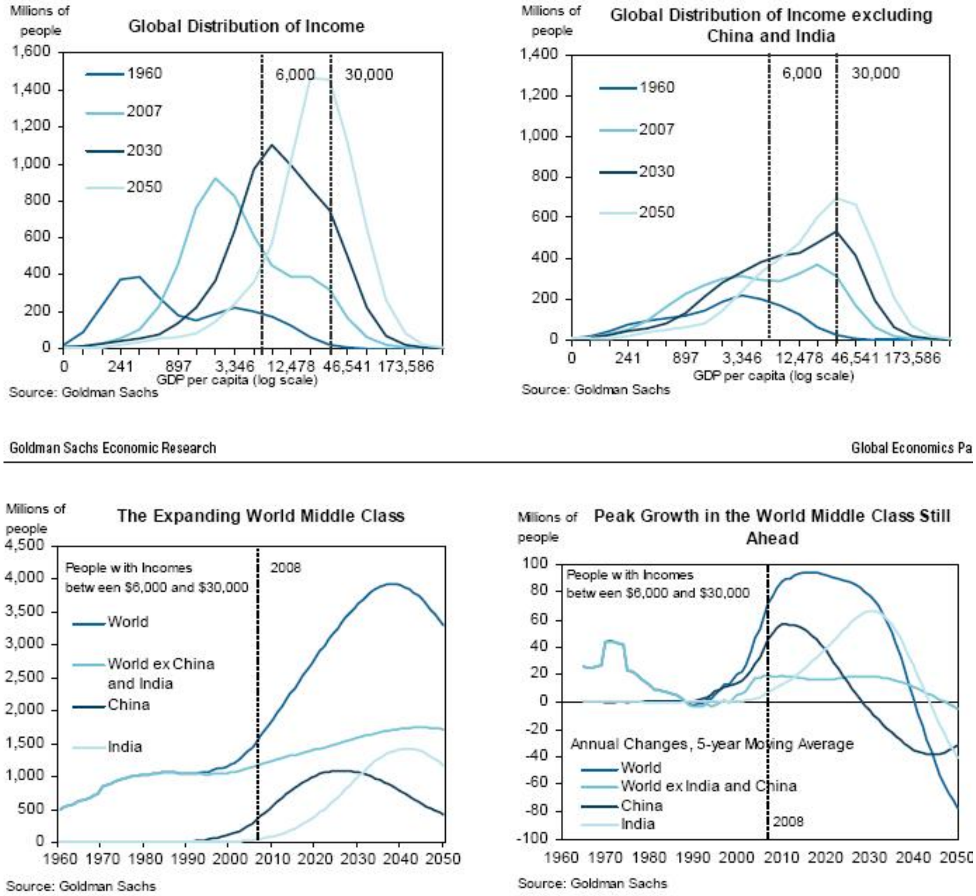
Retirement age will most likely be postponed[10] with improved health conditions of older people. More flexible and personalised working activities will be predominant. There will still be the possibility of "invited workers", who come to Europe to work for a period of time and then leave back to their origin countries. The dynamics of this phenomenon are related to border permeability policies, as weaker borders allow people to come in and leave easily. Transport industry, food processing and design niches will remain competitive up to 2050, but in other strategic sectors European industries may not be leading (microelectronics and computers, software, genetics, nanotechnology…)[11]. The service sector will remain a pillar of the European economy, and activities like tourism will grow exponentially[12] in the next decades with the estimated growth of global middle classes by approximately 100 million per year between 2010 and 2050[13], although it will be much lower in mature economies.

[10] In 2010, after months of hesitation, Spain finally set aside euphemisms in the debate over pension reform, and proposed the reference to 67 years as retirement age. Starting in 2013, the legal retirement age will be progressively deferred from 65 to 67 years until the measure is fully implemented by 2025.

[11] A. Bakas (2006), *Megatrends Europe*, published by Cyan. London UK.

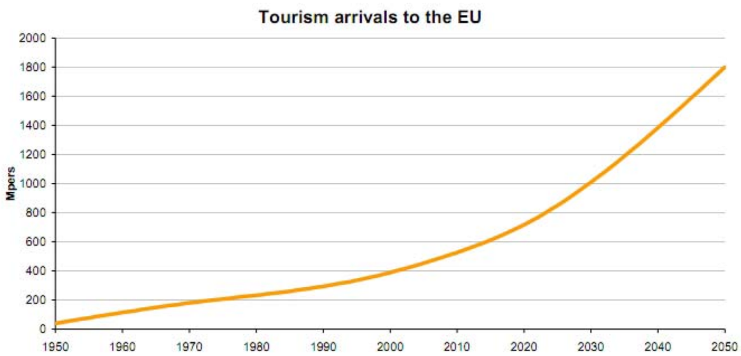
[12] *Tourism Towards 2030,* UNWTO 2011

[13] D.Wilson, R.Dragusanu (2008), *The Expanding Middle: the Exploding World Middle Class and the Falling Global Inequality*, Global Economics Paper 170, Goldman Sachs



(Source: Goldman Sachs, 2008)

Figure 3-6 The expanding middle class 2007-2050



(Source: UNWTO, 2003 & 2011)

Figure 3-7 Tourist arrivals in the EU 1950-2050

Technology will keep transforming the European societies

Moore's law describes a driving force of technological and social change in the late 20th and early 21st centuries, with continuity for more than a century. Post-carbon technologies, nanotechnology, biomedicine have strong potential to develop in the coming decades[14]. The first fruits of medical

[14] Author and inventor Ray Kurzweil speculates that it is likely that some new type of technology (possibly optical or quantum computers) will replace current integrated-circuit technology, and that Moore's Law will hold true long after 2020. Kurzweil extends Moore’s law on complexity of integrated semiconductor circuits, to include technologies from far before the integrated circuit to future forms of technology *(The Age of Spiritual Machines: when Computers Exceed Human Intelligence*, 1999)

nanorobotics and nanotechnology engineering could begin to appear in clinical treatment as early as the 2020s, according to authors. The convergence of increasingly capable wireless technology with expanding network infrastructure, miniaturised electronics, and proliferating digital information radically changes the relationships of individuals with their surrounding and with one another. ICT convergence as a double process between alignment and interoperability of technologies is in fact already impacting on individuals' every day life, and will increasingly do so in all fields of life, including transport. ICT will allow the application of more customised transport policies, for particular areas (urban or rural), moments of time, types of trips (short or long-distance) and even types of vehicle or vehicle occupancy (e.g. on-line road pricing, intelligent and self-organised traffic management systems…), delivering more effective results. Moreover, new transport modes may emerge as a result of ICT, blurring the lines between private cars and public buses or trains, such as for instance car-sharing, using smaller, user-customised, cleaner vehicles. Overall, it is expected that new ICT technologies may produce significant productivity gains in the transport sector and reduce the negative effects of transport on the environment, particularly CO2 emissions. Since more than 70% of CO2 emissions are produced by road vehicles, policies inducing the renewal of the current fleet will have the most dramatic impact in the mid term, when fleets are renewed and "gross-polluters" removed from the market. Regulation on vehicle technologies is the most powerful instrument available to reduce CO2 emissions.

More energy efficient, but still heavily based on fossil fuels in the mid term

Even though a large increase in renewable energy is expected, fossil fuels will still be the most important energy sources in the short-term[15]. The mid term possible future (10 to 25 years) will bring substantial progress in alternate and cleaner technologies. Fusion will be a major break, but most likely after 2050[16]. The most likely trend is a decline of the use of petrol, and a continuous increase of renewable sources. The electrification of transport will imply the possibility to increase the renewable energy share of the transport sector. Improvement of transport efficiency and management of transport volumes will be necessary, however, to support the reduction of CO2 emissions while fossil fuels still dominate, and to enable finite renewable resources to meet the full energy demand from transport in the long term. The most promising alternative fuel options for substituting oil as energy source for propulsion in transport are

- Electricity (limited to short-range road transport and rail);
- Hydrogen (most likely for short-distance transport); and
- As supplementary sources:
  - Liquid biofuels (technically substituting oil in all transport modes, with existing power train technologies and existing re-fuelling infrastructures, but the production of biofuels being limited by the availability of land),
  - Synthetic fuels as a technology bridge from fossil to biomass based fuels,
  - Methane (natural gas and biomethane) as complementary fuels, and
  - LPG.

[15] *Energy Outlook 2030* (2009 update), EC DGEnergy 2009.

[16] Research into developing controlled thermonuclear fusion for civil purposes began in the 1950s, and it continues to this day. Two projects, the National Ignition Facility and ITER are in the process of reaching breakeven after 60 years of design improvements developed from previous experiments. Postulating the success of ITER the next step on the road to »commercial« use of fusion energy would be the building of a first fusion reactor for energy production. Its power output would need to be approximately four times higher than the output of ITER for economic reasons. According to International Nuclear Energy Agency, commercial realisation in 2050 is a very optimistic prognosis.

Technology roadmap

Large-scale deployment of biofuels can be expected by 2020-2030. It is nevertheless necessary to identify the intermediate steps and likely timeline for development of the new options required for a strong biofuels industry and a significant biofuel use in Europe. As represented by the scheme in Figure 6.1, three main phases are to be considered:

Phase I **Short term (until 2010)**

- Improving existing technologies;
- R&D into 2[nd] generation biofuels (from lignocellulosic biomass). First 2[nd] generation biofuels demonstration plants;
- R&D into the biorefinery concept.

Phase II **Medium term (2010 - 2020)**

- Deployment of 2[nd] generation biofuel production
- Demonstration of biorefinery concept; continued R&D to improve lignocellulosic biofuel; and integrated biorefinery processes;
- Development of options for energy crops and sustainable agriculture.

Phase III **Long term (beyond 2020)**

- Large-scale production of 2nd generation biofuels; deployment of integrated biorefining complexes

Liquid biofuels, which are compatible with current technology, offer the highest potential for fast introduction of biofuel on a large scale. The preference for liquid fuels from biomass does, however, not mean that there is no place for gaseous fuels in this strategy. Biogas (methane) is likely to replace an increasing share of the CNG in automotive fuel market.

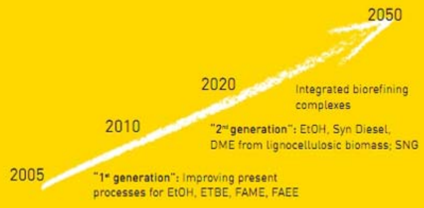


Figure 6.1 - Anticipated future roadmap

The external supply of hydrogen considerably increases the fuel yield from a given volume of biomass. The use of renewable hydrogen as a component in fuel production processes from biomass (or other carbon-containing primary energy source) is an option for today's fuel routes via synthesis gas, but will also be a serious option for future "biorefineries" that will produce a range of products from biocrude. Although the combination of biomass conversion and external hydrogen supply adds to a system's complexity and cost, this option has to be considered in future fuel routes from biomass.

Cost competitiveness

A key factor in the deployment of biofuels is cost competitiveness or cost effectiveness. This does not only refer to the production of biofuel itself, but also to other associated costs, such as investments in new vehicles or alternative logistic systems. Cost reductions will be achieved by using advanced technology, through an economy-of-scale effect and a better integration into the fuel supply chain.

BIOFUELS IN THE EUROPEAN UNION • A VISION FOR 2030 AND BEYOND 27

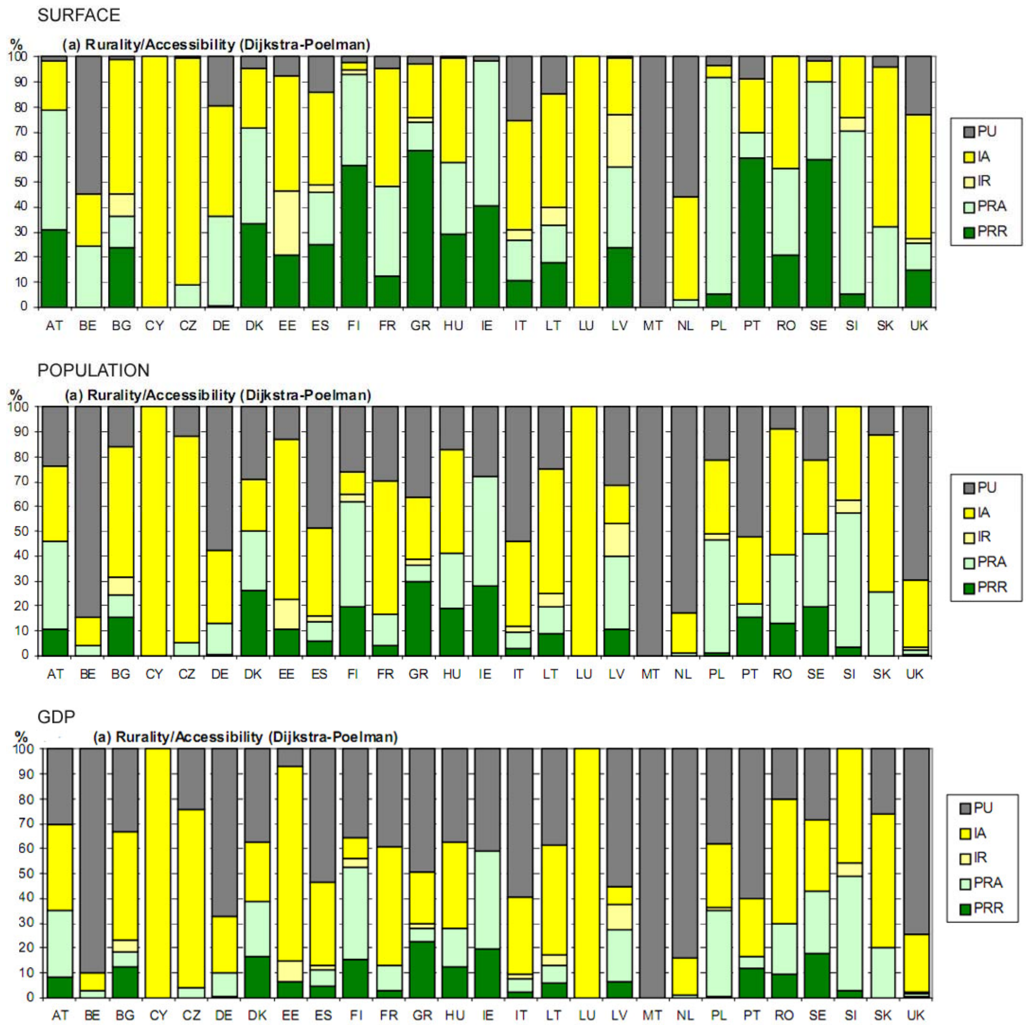
(Source: Biofuels in the European Union. A vision for 2030 and beyond)

Figure 3-8 Biofuel technology roadmap 2030-2050

More urbanised Europe, more accessible

After successive enlargements, the EU territory nearly covers the whole reached continent. More urbanised, with more or less diffused structures, and largely made of middle landscapes: urban areas in rural landscapes (e.g. urban sprawl in major metropolis, large food processing districts…), and rural areas within urban environments (e.g. garden city, urban farming…). Transport and communication technologies will reduce the costs of being at the periphery, making remote places more connected to the rest of the World when well connected to the networks. This is not to say that distance does not matter, but its impact on spatial development will be far more complex[17]. New centres will be able to emerge anywhere, rural areas facing therefore both increasing development opportunities and threats. New migration from urban to rural areas will take urban cultural values with them, so that the rural districts will also become more urbanised. Larger metropolitan areas will remain magnets of population, while some attractive rural areas will strongly develop. The most accessible regions in Europe include today the area between London, Hamburg, Paris, Munich and Milan, with an extension eastwards to eastern regions of Germany and towards the Rhone and Loire valley in France, but at a regional daily life scale the Eastern Member States have a very low level of accessibility due to the poor state or lack of infrastructures and services. These deficiencies will have an overall tendency to ameliorate due to the TEN-T program aiming at progressively balanced patterns.

[17] *Urban-rural narratives and spatial trends in Europe: the State of the Question*, Ministry of Environment, and Rural and Marine Affairs, Spanish Presidency of the EU 2010.



(Source: ESPON EDORA, 2010)

Figure 3-9 For EU countries, distribution of surface, population and GDP among different territorial typologies: *Predominatly Urban* (PU), *Intermediate Accessible* (IA), *Intermediate Remote* (IR), *Rural Accessible (PRA)* and *Rural Remote* (PRR)

Synthesis of key socio-economic indicators

Socio-economically, all variables in ORIGAMI scenarios were quantified using existing knowledge from previous studies, expert evaluation and literature review. All sources are indicated. Values for 2050 are only indicative.

The socio-economic framework hereby defined is shared by all ORIGAMI scenarios in 2030. Scenarios deviate in 2050 to portray the impact of different socio-economic trends on transport.

Table 3-1 ORIGAMI Reference Socio-economic Scenario 2010-2050 (assumptions)

Variable	Source for Baseline	2010	2020	2030	2050
POPULATION					
Population (millions)	ECFIN *Ageing Report*[18]	501.3	515.7	521.8	517.2
0-14	ECFIN *Ageing Report*	15.50%	15.30%	14.50%	14.10%
15-64	ECFIN *Ageing Report*	67.10%	64.60%	61.90%	57.10%
65-79	ECFIN *Ageing Report*	12.70%	14.40%	16.70%	17.80%
80+	ECFIN *Ageing Report*	4.70%	5.70%	6.90%	11.00%
Fertility rate (births per woman)	ECFIN *Ageing Report*	1.52	1.55	1.57	1.65
Population increase due to migrations with respect to 2010 (cumulated M.inh)	ECFIN *Ageing Report*	0	13.9	25.8	45.9
Life expectancy at birth (males)	ECFIN *Ageing Report*	76.43	78.29	80.01	83.1
Life expectancy at birth (females)	ECFIN *Ageing Report*	82.4	83.92	85.34	87.87
SOCIETY					
Average people per household	DGENERGY *Energy Trends 2030*[19]	2.31	2.22	2.15	2.02
Participation rate (active population / 15-64)	ECFIN *Ageing Report*	71.40%	73.20%	73.40%	73.90%
Participation rate males (active population / 15-64)	ECFIN *Ageing Report*	78.20%	78.80%	78.40%	78.70%
Participation rate females (active population / 15-64)	ECFIN *Ageing Report*	64.50%	67.50%	68.30%	69.10%
Activity rate (active population / total population)	Dependant parameter	47.91%	47.29%	45.43%	42.20%
Employment rate (working population / 15-64)	Dependant parameter	64.80%	67.50%	67.70%	68.20%
Unemployment rate	ECFIN *Ageing Report*	6.60%	5.70%	5.70%	5.70%
Active population (millions)	Dependant parameter	240	244	237	218
Working population (millions)	Dependant parameter	218	225	219	201
Unemployeed (millions)	Dependant parameter	22	19	18	17
Labour mobility (EU citizens living in other EU MS / total population)	Transport White Paper (2011) [20]	2.80%	3.50%	5.00%	7.00%
Personal budget devoted to transport (% GDP/capita)	EEA[21]	13.50%	13.50%	13.50%	13.50%
Transport equipment (Purchase of vehicles)	EEA	4.00%	4.00%	3.90%	3.20%
Fuel and electricity	EEA	7.00%	6.90%	7.00%	7.70%
Other costs (including taxes and charges)	EEA	2.50%	2.50%	2.60%	2.60%
Increased budget to transport respect 2005 (XX% - 2005%)	EEA	-0.15%	0.00%	0.40%	1.30%
Transport equipment (Purchase of vehicles)	EEA	-0.40%	0.00%	0.50%	1.60%
Fuel and electricity	EEA	0.20%	0.10%	-0.70%	-1.70%
Other costs (including taxes and charges)	EEA	0.10%	-0.10%	0.60%	1.40%
ECONOMY					
GDP (billion euros. 1.000.000 million euros)	ECFIN *Ageing Report*	13.23	16.56	19.69	26.52
GDP per capita (euros)	Dependant parameter	26391	32112	37735	51275
Productivity (euros/worker)	Dependant parameter	60697	73642	90046	131670
GDP growth (annual average % between periods)	Dependant parameter	-	2.30%	1.90%	1.50%
GDP per capita growth (annual average % between periods)	Dependant parameter	-	2.0%	1.6%	1.5%
Productivity growth (annual average % between periods)	Dependant parameter	-	2.00%	2.20%	1.90%
Yearly public investment (% of GDP)	Eurostat	2.50%	2.50%	2.50%	2.50%

18 *The 2009 Ageing Report : Economic and budgetary projections for the EU-27 Member States (2008-2060)* http://ec.europa.eu/economy_finance/publications/publication_summary14911_en.htm. All figures shown correspond to the Ageing Report Baseline scenario.

19 DG Energy, *Energy Trends to 2030 (2009 update)* http://ec.europa.eu/energy/observatory/trends_2030/

20 *Roadmap to a Single European Transport Area*, Transport White Paper by EC DGMOVE (2011)

21 EC FIN *Trends in share of personal expenditure of transport (% of total spending EEA-32)* http://www.eea.europa.eu/data-and-maps/figures/term24-trends-in-share-of-household-expenditure-on-transport-percentage-of-total-spending-eea

Variable	Source for Baseline	2010	2020	2030	2050
Yearly private investment (% of GDP)	Eurostat	19.0%	21.0%	21.0%	21.0%
Yearly R+D investment (% of GDP)	ECFIN *Ageing Report*	1.90%	2.00%	2.00%	2.00%
Yearly R&D investment in transport (% of GDP)	GHG-TransPoRD[22]	0.36%	0.57%	0.57%	0.57%
Public R&D transport investment (% total transport R&D)	GHG-TransPoRD	18.90%	18.90%	18.90%	18.90%
Total transport R&D (1000 million €)	GHG-TransPoRD	44.1	87.4	105.6	142.2
Investment in transport infrastructure (% of GDP)	Eurostat	1.22%	1.22%	1.22%	1.22%
Social security expenditures (% of GDP)	ECFIN *Ageing Report*	10.20%	10.50%	11.40%	12.30%
Inbound Tourism (million overnight visitors per year. tourist arrivals)	UNWTO[23]	400	602	849	1391
Inbound tourism growth (annual average %)	UNWTO	-	4.20%	3.50%	2.50%
bound to the Mediterranean (million visitors)	UNWTO	144.7	218	307	503
bound to Western Europe (million visitors)	UNWTO	153.3	231	325	533
bound to Central/Eastern Europe (million visitors)	UNWTO	46.7	70	99	162
bound to Northern Europe (million visitors)	UNWTO	55.3	83	117	192
% of domestic tourism / inbound tourism	UNWTO	71%	71%	71%	71%
Outbound tourism (million yearly outbound overnight visitors)	UNWTO	416.4	508.1	606.1	823.6
Outbound tourism growth (annual average %)	Dependant parameter	-	2.00%	1.80%	1.50%
ENERGY					
Energy Intensity (MTOE/1000M€) in constant 2010€	Dependant parameter	0.13	0.10	0.08	0.06
Primary energy consumption (MTOE)	DGENERGY *Energy Trends 2030*	1764.5	1822.2	1807.2	1700
oil	DGENERGY *Energy Trends 2030*	35.8%	33.8%	31.9%	25.0%
natural gas	DGENERGY *Energy Trends 2030*	25.6%	23.1%	22.4%	21.0%
coal	DGENERGY *Energy Trends 2030*	16.4%	14.7%	14.4%	13.5%
nuclear	DGENERGY *Energy Trends 2030*	13.5%	12.7%	13.9%	14.0%
renewables	DGENERGY *Energy Trends 2030*	8.7%	15.7%	17.4%	26.5%
Energy consumption respect 1990 (1990=100)	DGENERGY *Energy Trends 2030*	106	99	97	96
Biofuel production (Mtoe)	BP 2030 outlook[24]	10.4	23.5	41.4	121.6
Biofuel production increase respect 2005 (in %)	BP 2030 outlook	209%	595%	1125%	3497%
Share of renewable energy in transport (% of non-ICE cars)	**IEA. Renewable Energy Roadmap target[25]**	2%	10.00%	27.50%	45.00%
ENVIRONMENT					
Land uses. Agricultural land (% over total)	PASHMINA[26]	28.70%	29.50%	30.30%	29.90%
Land uses. Land for meadows (% over total)	PASHMINA	15.50%	15.60%	15.70%	15.50%
Land uses. Land for forests (% over total)	PASHMINA	37.30%	37.10%	36.90%	36.10%
Land uses. Land for biofuel production (% over total)	PASHMINA	0.00%	1.30%	2.70%	4.30%
Land uses. Other uses (% over total)	PASHMINA	18.50%	16.50%	14.40%	14.20%

22 GHG-TransPoRD Project (2010) co-funded by EC 7FP http://www.ghg-transpord.eu/ghg-transpord/inhalte/deliverables.php

23 *Tourism Towards 2030,* UN World Tourism Organisation (UNTWO) 2011 http://www.e-unwto.org/content/u87761/fulltext?p=23d62f2f6df64767b6f5bbd53b40d03b&pi=0#section=972978&page=5&locus=0

24 *BP Energy Outlook 2030*, British Petroleum (BP), 2011 http://www.bp.com/sectiongenericarticle800.do?categoryId=9037134&contentId=7068677

25 10% by 2020 is a target by the *Renewable Energy Roadmap Communication* by the EC, 2007.

26 PASHMINA Project (2010), co-funded EC 7FP, http://www.pashmina-project.eu/

Variable	Source for Baseline	2010	2020	2030	2050
Total CO2 emissions (million tonnes)	Transport White Paper (2011)	3900	3500	3200	2600
Total CO2 emissions reduction respect to 1990 (in %)	Transport White Paper (2011)	-5%	-15%	-22%	-37%
Emission / Energy ratio (Mton/MTOE)	*Dependant parameter*	2.21	1.92	1.77	1.53
Carbon intensity (Mton/1000€ GDP)	*Dependant parameter*	0.29	0.21	0.16	0.10
GOVERNANCE					
Economic cohesion index of new EU members (0-1)	TRANSvisions (DGTREN'09)	0.5	0.5	0.5	0.5
Economic convergence index of new EU members (0-1)	TRANSvisions (DGTREN'09)	0.5	0.5	0.5	0.5

3.1.3 Transport and Mobility Baseline

Economic growth will still determine the growth of the transport sector. Important changes are expected in the different transport market segments. Passenger transport demand with both origin and destination within Europe is expected to grow less than the economy, and especially in northern and central regions. Overseas traffic is expected to grow much faster, measured in pax-km. Technological improvements leading to faster and cheaper air services between Europe and America, or Asia, may result in greater increases of overseas traffic. Intercontinental flights and flights with neighbouring countries will have an important impact on major European airports[27]. A reduction of the social and environmental externalities of transport activities is very likely in the mid term. In urban short distance mobility, there will be an increasing use of public transport on high demand links and new individual forms of public transport on extended metropolitan areas (new taxi concepts, car-sharing, car rentals, assisted bicycles…).

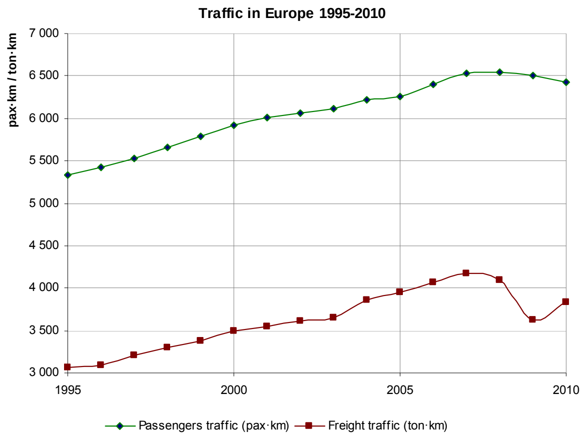
The car will remain crucial in lower populated areas, but vehicles will be cleaner and quieter. High speed rail will become increasingly important in the range of journeys between 300km to 1000km, especially in more populated areas. Transport infrastructure will be increasingly equipped with ITS enhancing capacity, safety and comfort (ATM, ERTMS, road ITS)[28]. While it is expected that ICT will produce the substitution of a number of trips (e.g. short-distance commuter and business trips) by electronic communication, it will also facilitate enormously the creation of new social and economic relations worldwide, generating more trips, especially long-distance.

The reference mobility scenarios for ORIGAMI are based on DGMove's TEN-CONNECT[29] study (2009). This study was aimed at assisting the process of definition of the future TEN-T core network. The study proposed different sets of infrastructure to guarantee adequate Level Of Service considering traffic forecasts to 2030.

ORIGAMI takes from TEN-CONNECT OD trip matrixes for 2005 and 2030. These matrixes where produced in TEN-CONNECT using the official EC's transport model TRANS-TOOLS.

ORIGAMI's mobility figures for 2010 are based on TEN-CONNECT's 2005 trip matrixes. Due to the decreasing trend in passenger traffics since 2007, passenger kilometres in 2010 were the same as in 2006, just 2.7% higher than in 2005.

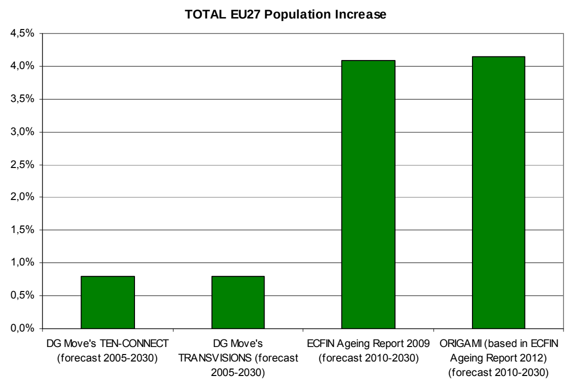
27 According to recent studies made by DGMOVE (e.g. TRANSVISIONS, TENCONNECT)
28 All listed above objectives are policy aims of the 2011 EC Transport White Paper
29 Petersen M.S., Bröcker J., Enei R., Gohkale R., Granberg T., Hansen C.O., Hansen H.K., Jovanovic R., Korchenevych A., Larrea E., Leder P., Merten T., Pearman A., Rich J., Shires J., Ulied A. (2009): Report on Scenario, Traffic Forecast and Analysis of Traffic on the TEN-T, taking into Consideration the External Dimension of the Union – Final Report, Funded by DG TREN, Copenhagen, Denmark

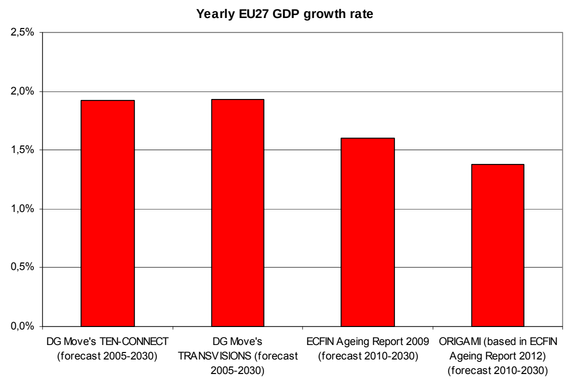


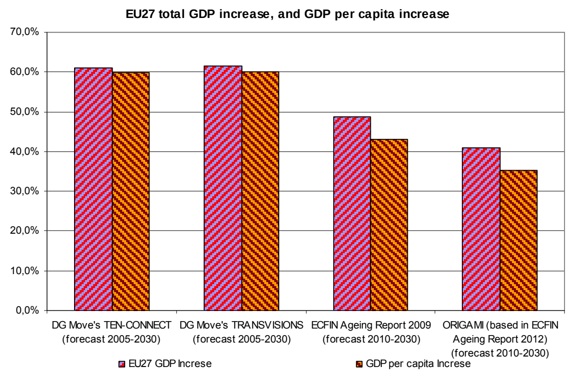
(Source: DG Move Transport Pocketbook, 2012)

Figure 3-10 Passenger traffic increase 1995-2010 (green), freight traffic as a reference

All ORIGAMI scenarios in 2030 use the TEN-CONNECT 2030 matrix (Baseline, four Explorative and Normative). The demographic economic and social hypothesis established by the TEN-CONNECT study to produce 2030 transport forecasts were based on official EC forecasts to 2030 existing in 2009, but these forecasts being carried out before the economic crisis, the resulting number of trips may be considered an optimistic forecast. The difference in GDP development to 2030 between the latest ECFIN estimate (2012) and TEN-CONNECT's (2009) differs by almost 20% (60% increase versus 40% increase). Considering a GDP to long-distance passenger transport elasticity between 0.3 and 0.5 according to TEN-CONNECT, this would result on a 6% to 10% traffic overestimate.







	DG Move's TEN-CONNECT (forecast 2005-2030)	DG Move's TRANSVISIONS (forecast 2005-2030)	ECFIN Ageing Report 2009 (forecast 2010-2030)	ORIGAMI (based in ECFIN Ageing Report 2012) (forecast 2010-2030)
EU27 Population Inc.	0.8%	0.8%	4.1%	4.1%
EU27 GDP Increse	61.0%	61.4%	48.8%	40.9%
GDP yearly growth	1.9%	1.9%	1.6%	1.4%
GDP per capita Increse	59.7%	60.1%	43.0%	35.3%

(Source: DGMove 2009, ECFIN 2009,2012)

Figure 3-11 Socio-economic assumptions in TEN-CONNECT and ORIGAMI, TRANSVISIONS and ECFIN 2009 as a reference

Using a unique OD matrix for all scenarios in ORIGAMI implies that the total number of trips for each scenario will be considered the same. However, the different transport policies implemented in the ORIGAMI scenarios will result on different route choices and modes to fulfil these trips (as the assignment of the OD matrix is done on an integrated multi-modal graph generated during the 7FP INTERCONNECT Study[30]), therefore producing different traffics on the networks, and consequently, different trip km figures and different modal splits.

Despite this fact, the relative impacts of policies in the different 2030 Scenarios will remain valid.

Long-distance trips in the ORIGAMI 2030 scenarios will be considered as trips between different NUTS3 (inter-NUTS3). Results will be provided for different distance classes <300km, 300 – 1000 km, 1000 – 2000 km, >2000 km.

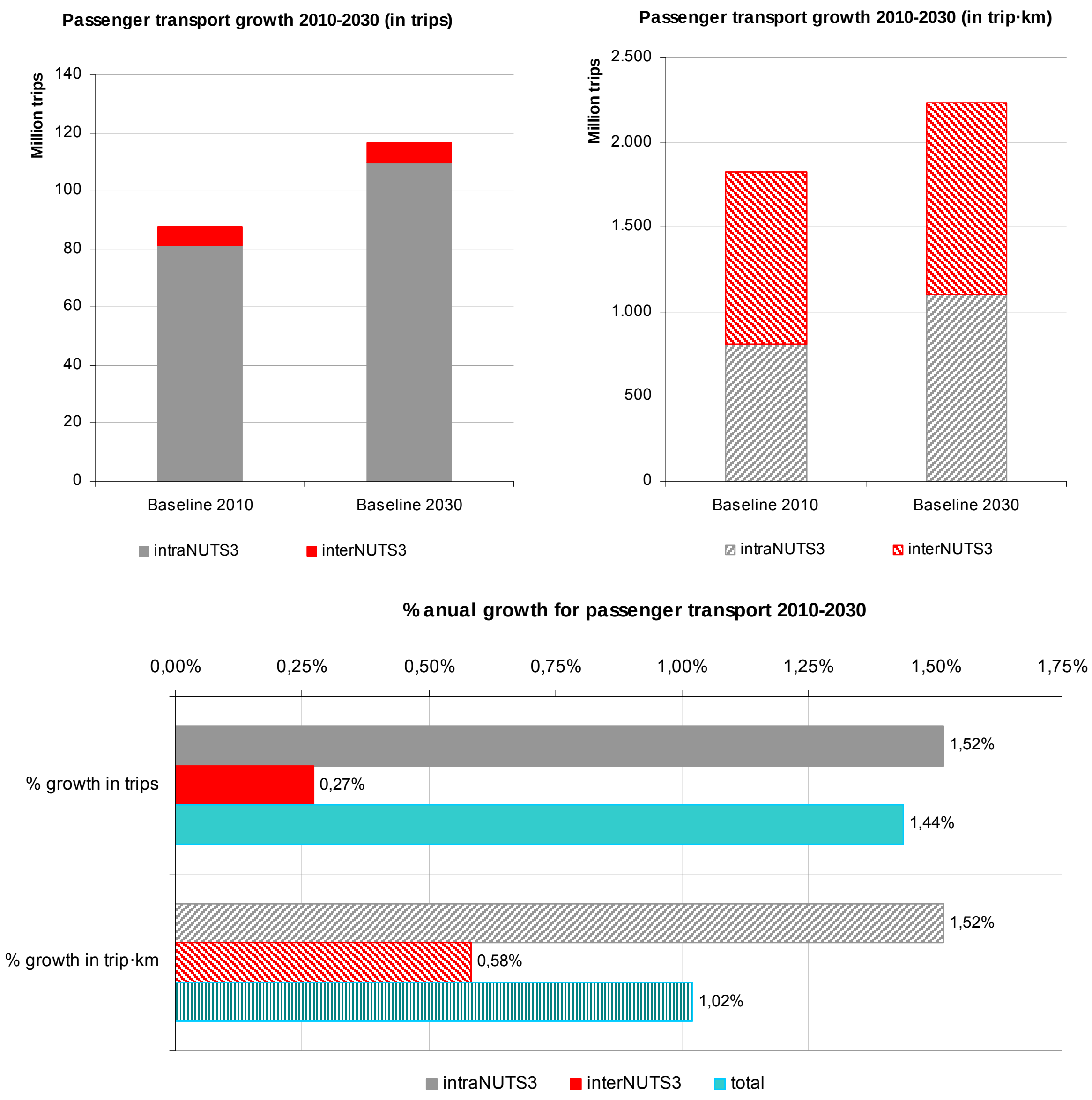
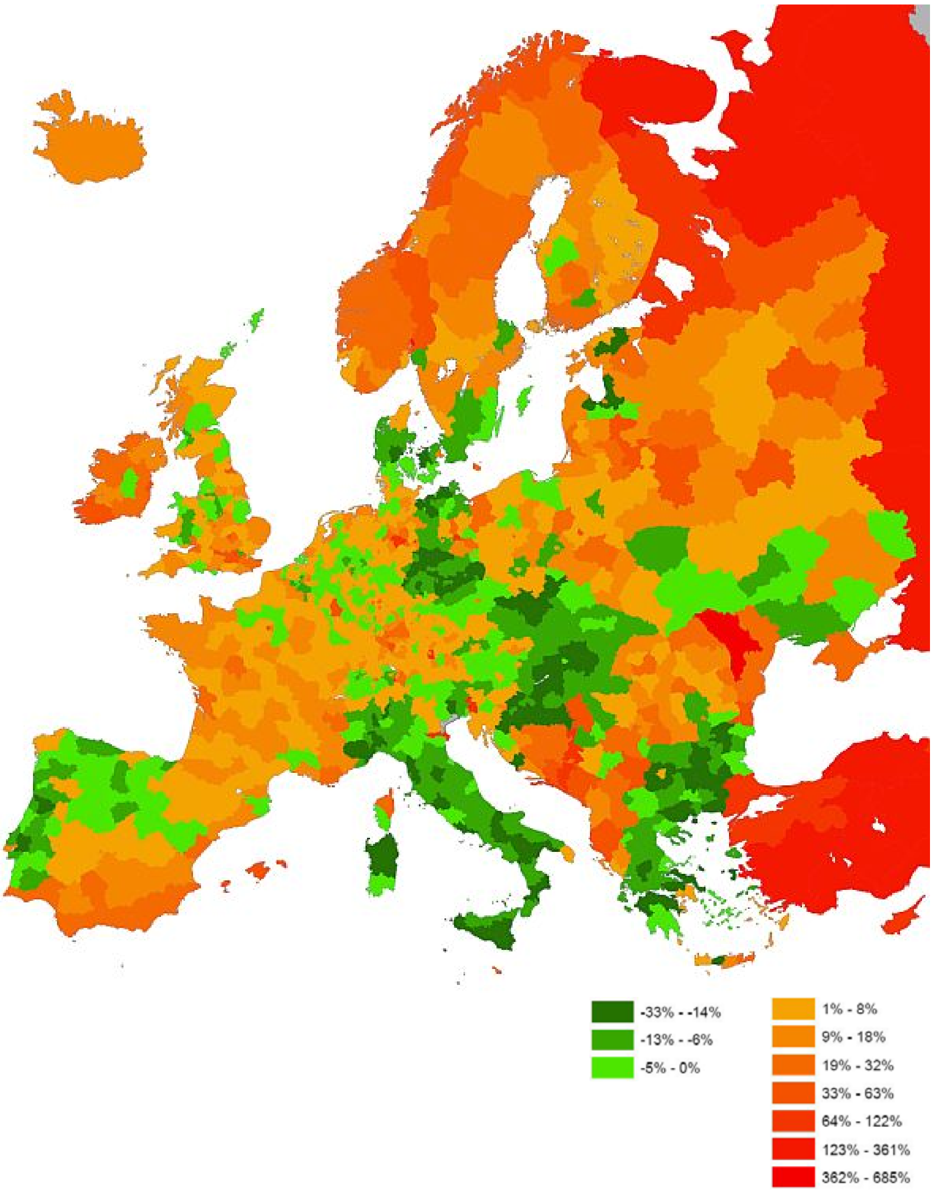


Figure 3-12 Passenger transport growth in trips and trip km, inter and intra NUTS3, 2010-2030, all trip purposes included

[30] See INTERCONNECT Delivery 4.1 for further information on the model and the mulit-modal graph applied in ORIGAMI.



(based on TRANS-TOOLS 2008)

Figure 3-13 Increase of the number of trips originated in each NUTS3, 2010-2030, all trip purposes included

The next table synthesises the assumptions for mobility growth in long-distance transport in Europe between 2010 and 2030 in the Baseline. The table shows the number of trips in between EU27 NUTS3 (intra-EU transport) and between EU27 NUTS3 and neighbouring regions. The numbers do not consider intra NUTS3 trips.

Table 3-2 Number of trips increase by trip purpose in ORIGAMI Baseline
(Source: ORIGAMI / TEN-CONNECT)

2010

	Business	Holiday	Private	Commuter	TOTAL
Intra-EU27 trips	331.628	873.810	4.009.885	244.271	5.459.594
EU27-neighbours trips	9.805	61.105	28.942	310	100.162
Total	341.433	934.915	4.038.827	244.581	5.559.756

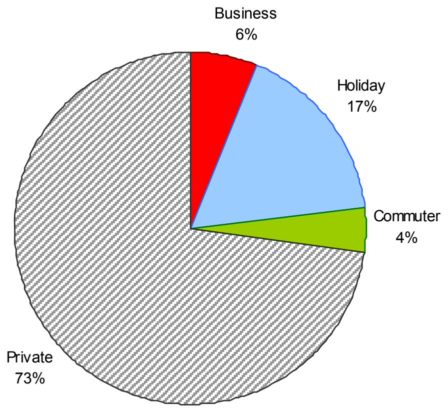
2030

	Business	Holiday	Private	Commuter	TOTAL
Intra-EU27 trips	431.924	969.790	4.226.007	176.427	5.804.148
EU27-neighbours trips	25.600	138.922	54.256	218	218.996
Total	457.524	1.108.712	4.280.263	176.645	6.023.144

2010-2030 variation

	Business	Holiday	Private	Commuter	TOTAL
Intra-EU27 trips	+ 30%	+ 11%	+ 5%	- 28%	+ 6%
EU27-neighbours trips	+ 161%	+ 127%	+ 87%	- 30%	+ 119%
Total	+ 34%	+ 19%	+ 6%	- 28%	+ 8%

Total number of trips in 2010, per trip purpose



Total number of trips in 2030, per trip purpose

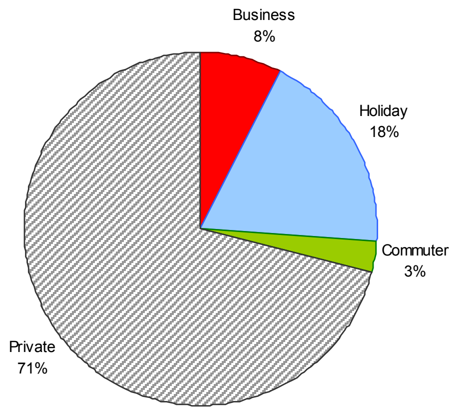


Figure 3-14 Distribution of the total number of long-distance trips in Europe, 2010 and 2030

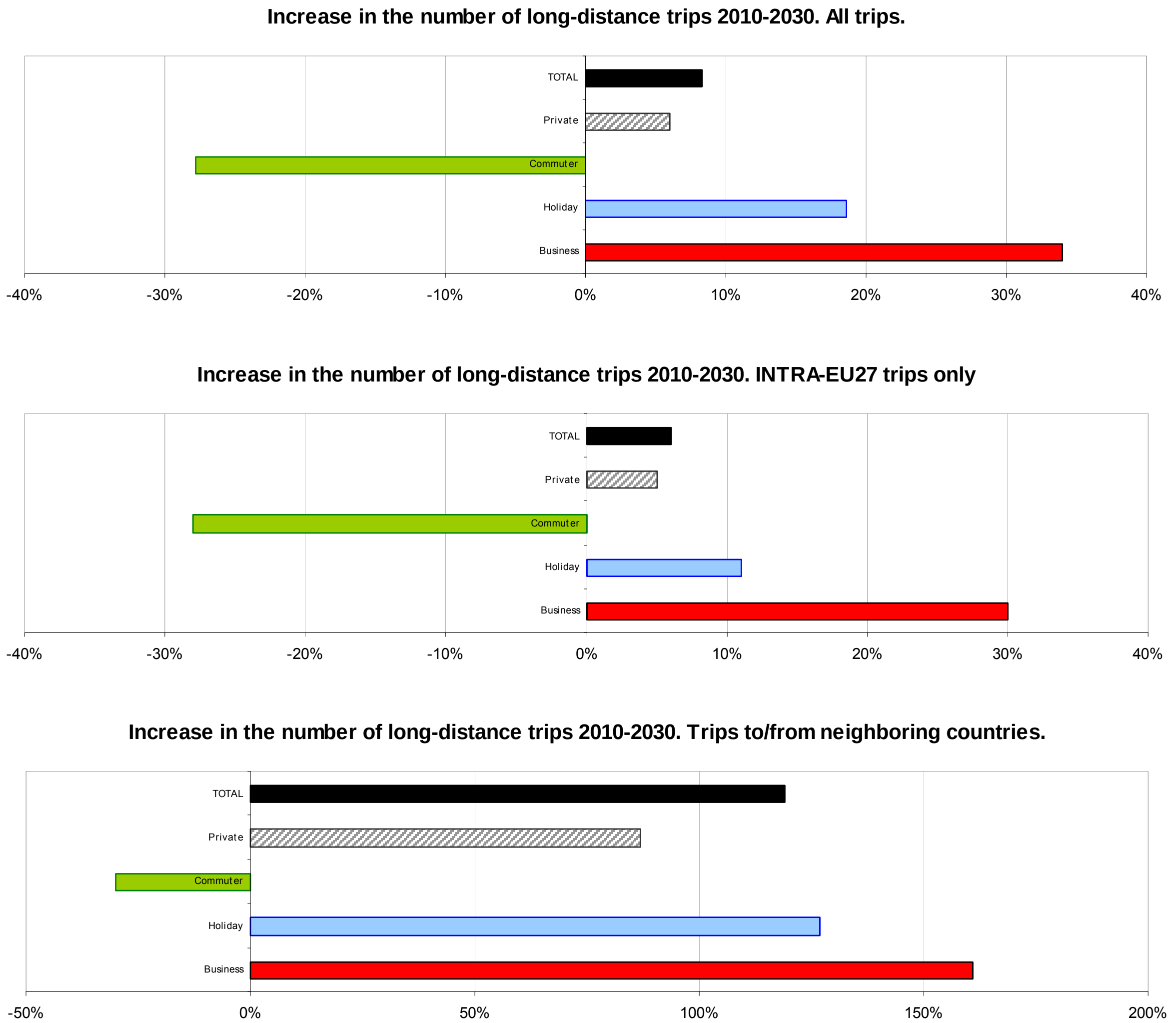


Figure 3-15 Number of long-distance trips increase in Europe 2010 – 2030, all trips, intra-EU27 and extra-EU27

Transeuropean transport networks

The amount of infrastructure constructed between 2005 and 2030 in the TEN-T networks has been decided based on the analysis of trends in infrastructure investment in the last 15 years, and proposing a likely investment timeline up to 2030.

Transport investments are defined as % of the GDP for each year. Budgets are then used to build core network infrastructure in Europe. Specific links to which investments are dedicated are chosen following criteria of efficiency (links with highest levels of traffic) and cohesion (links in lagging regions).

The full procedure to determine infrastructure scenarios (for Baseline, Exploratory Scenarios and Normative Scenarios) is reported in chapters 0 and 0.

Table 3-3 New infrastructure provided in ORIGAMI Baseline 2030

Transport Investment in Europe	2012	Baseline	2012-2030
Average anual GDP growth 2012-2030		1,6%	
% GDP spent in transport investment	1,04%	0,93%	€ 2.594.682
in new TEN-T infrastructure	26,0%	25,2%	€ 653.688
in core network	*40,0%*	*46,2%*	€ 301.724
in comprehensive network	*60,0%*	*53,8%*	€ 351.964
in new non TEN-T infrastructure	38,9%	35,9%	€ 930.729
in management and maintenance	35,1%	38,9%	€ 1.010.264

New TEN-T investment abatement			
% road	30,5%	31,5%	€ 206.140
core		12,5%	**€ 25.768**
comprehensive		87,5%	€ 180.373
% rail	43,2%	44,0%	€ 287.843
core		50,0%	**€ 143.922**
comprehensive		50,0%	€ 143.922
% air	11,3%	9,1%	€ 59.491
core		75,0%	€ 44.618
comprehensive		25,0%	€ 14.873
% ports & IWW	7,5%	7,8%	€ 51.187
core		75,0%	€ 38.391
comprehensive		25,0%	€ 12.797
% intermodal and combined	7,5%	7,5%	€ 49.027

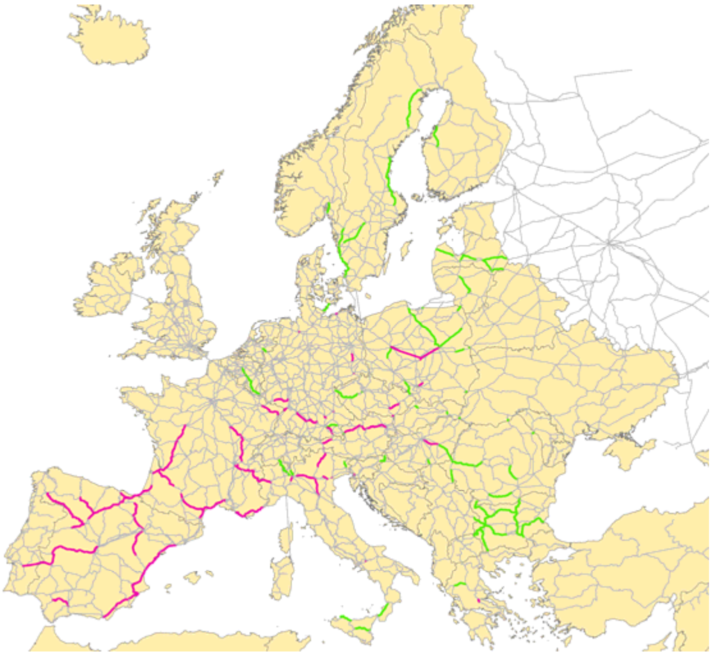
Provision of new infrastructure		
Construction of roads (km)		38.831 km
core		4.854 km
comprehensive		33.977 km
Construction of HSR (km)		12.583 km
core		6.292 km
comprehensive		6.292 km
Construction of conventional rail (km)		13.099 km
core		6.550 km
comprehensive		6.550 km

Fulfilment of TEN-T core network investment objectives (White Paper)

	Estimated needs (White Paper)	Completition degree
Overall TEN-T	500000 M€	
Road	66.000 M€	39%
HSR	236.000 M€	52%
Conventional rail	65.700 M€	52%
Air	72.000 M€	62%
Ports	60.300 M€	64%

The following two maps show the implemented networks in ORIGAMI Baseline up to 2030.

Rail network in ET2050 Baseline 2030 scenario. In red, new high speed rail; in green new conventional rail lines. MOSAIC model.



Road network in ET2050 Baseline 2030 scenario. In red, new motorways. MOSAIC model.

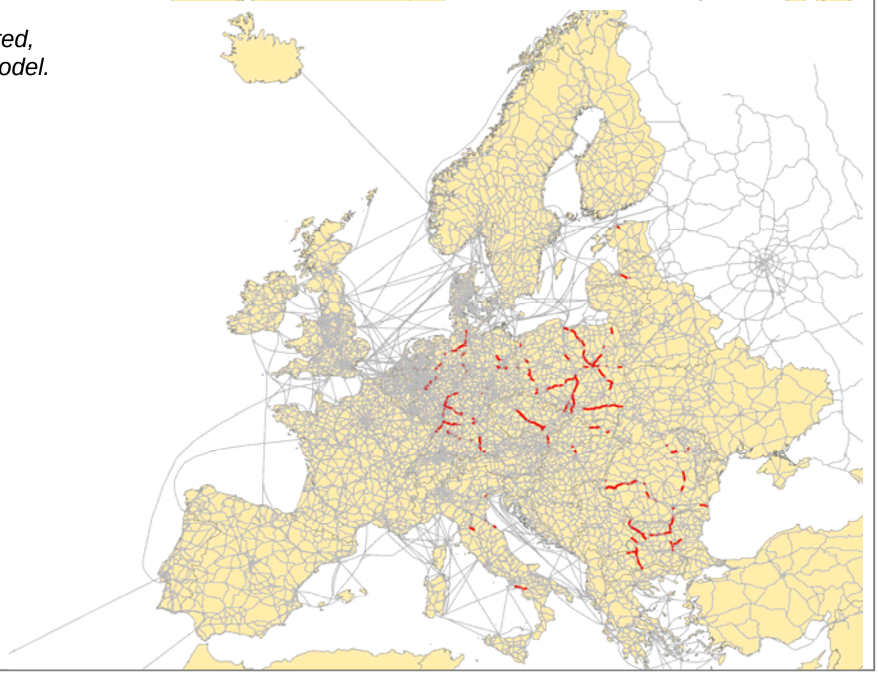


Figure 3-16 New infrastructure provided in ORIGAMI Baseline 2030 (maps)

3.2 DEFINITION OF 2030 EXPLORATORY SCENARIOS

3.2.1 Introduction

The preliminary exploratory scenarios have been built based on scenarios proposed by the Impact Assessment report of the 2011 transport White Paper.

Exploratory scenarios are defined as policy oriented scenarios by 2030. They were defined considering alternative policy packages directly related to long-distance passenger transport.

Four different transport policy packages OR1. OR2. OR3 and OR4 have been defined, each one of them having a relatively higher emphasis on certain set of policy instruments than the others, thus leading towards a different 2030 scenario.

The reference socio-economic framework is shared for all Scenarios by 2030. The number of trips remains unchanged (TRANS-TOOLS OD matrix for 2030).

Exploratory scenarios integrate alternative stakeholder views on the future of transport and transport policy. Scenarios were initially inspired by stakeholder contributions in the several activities carried out between 2009 and 2010 by the EC in the process of preparation for the 2011 transport White Paper[31] and were later refined with further inputs by stakeholders in the ORIGAMI expert consultation held during November 2011[32].

ORIGAMI policy packages are in line with scenarios defined by the 2011 tansport White Paper (Impact Assessment report).

3.2.2 Definition of Policy Packages

General Assumptions

ORIGAMI policy packages are as follows:

- OR1. Better public regulation and infrastructure investment, mostly financed by public funds with some regulation.
- OR2. Better public regulation, especially on vehicle technological standards and little emphasis on infrastructure.
- OR3. More liberalisation and more emphasis on infrastructure management. Technology applied to improve efficiency of transport infrastructure.
- OR4. More liberalisation and more investment in efficient infrastructure co-financed by the private sector.

Table 3-4 Focus of ORIGAMI policy packages on key policy aims

	OR1	OR2	OR3	OR4
Focus on infrastructure	High	Low	Low	High
Focus on management	Medium	High	High	Low
Focus on technology	Low	High	High	Medium
Focus on liberalisation	Low	Low	High	High

31 A synthesis of contributions to the 2011 Transport White Paper by several transport stakeholders during the public consultations in 2009 and 2010 can be found in the Annexes.

32 Full report on the ORIGAMI Expert Consultation is available at the project website: http://www.origami-project.eu/component/content/article/59

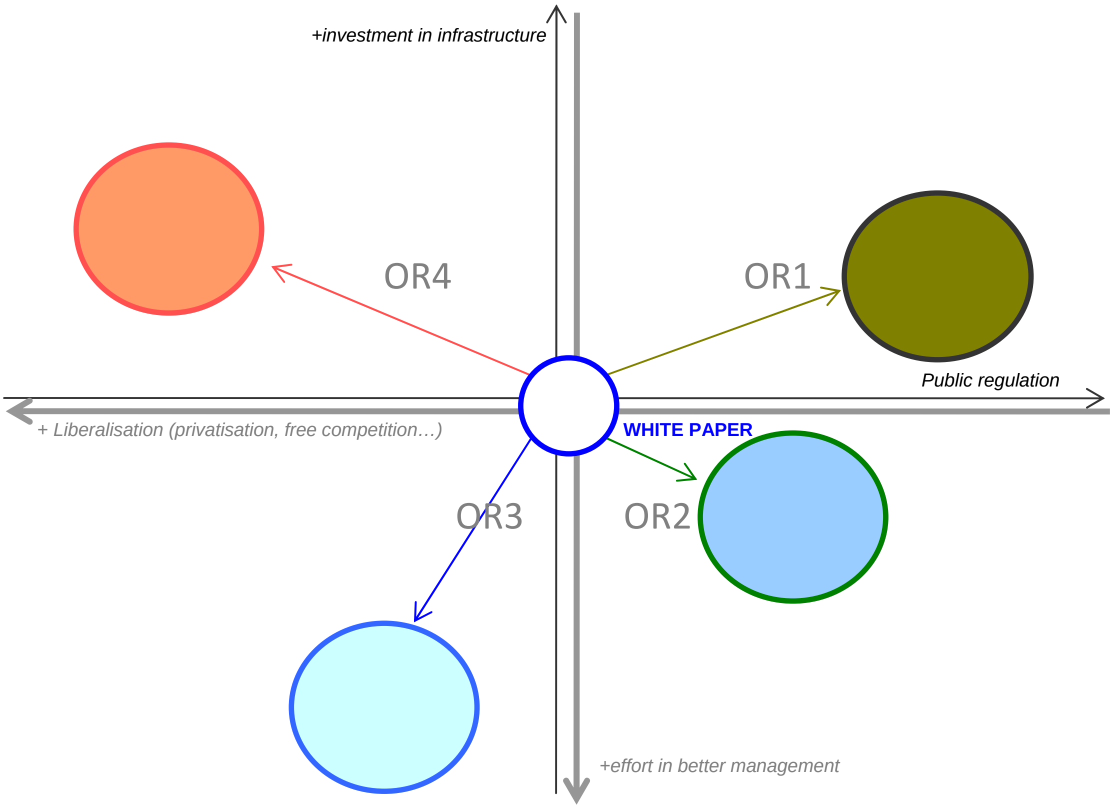


Figure 3-17 ORIGAMI Policy Packages 2011-2030
(qualitative illustration of the relative importance of key policy aims)

The four ORIGAMI Policy Packages OR1, OR2, OR3 and OR4 can be summarised as follows:

OR1

The OR1 policy package considers a rising level of transport infrastructure investment, especially focused on rail programs aimed to enlarging current HSR network in Europe in line with White Paper targets and mostly financed from public funds. Air-rail interconnections are enhanced to promote inter-modal chains. Most airports in Europe are connected to the long-distance rail network, and local connections from surrounding cities allow for easy and cheap access and egress by public transport. A regulation framework is set up to encourage the use of more environmentally friendly modes, and this includes increased road pricing as an extension of Eurovignette to cars, extended air taxation, limited maximum speeds in motorways to disencourage the use of private cars for passenger transport. Subsidies are dedicated to greener transport services or aiming at territorial cohesion.

Table 3-5 Assumptions of the Policy Package OR1

POLICY INSTRUMENTS	Indicators modelled in ORIGAMI	OR1 compared to Baseline 2030
Market liberalisation	Average Road travel cost (€/km)	-
- Market opening (free competition)	Average Rail travel cost (€/km)	-
- Privatisation (PPPs)	Average Air travel cost (€/km)	-
	Average Ferry travel cost (€/km)	-
Bans and regulation	Average Car vehicle emissions (grams/veh·km)	-10%
- Efficiency standards	Electric vehicles (% of non-ICE vehicles)	+10%
- Speed limitations	Car occupation (people/vehicle)	-
- Accompanying measures	Average Rail emission factors (grams/pax·km)	-5%

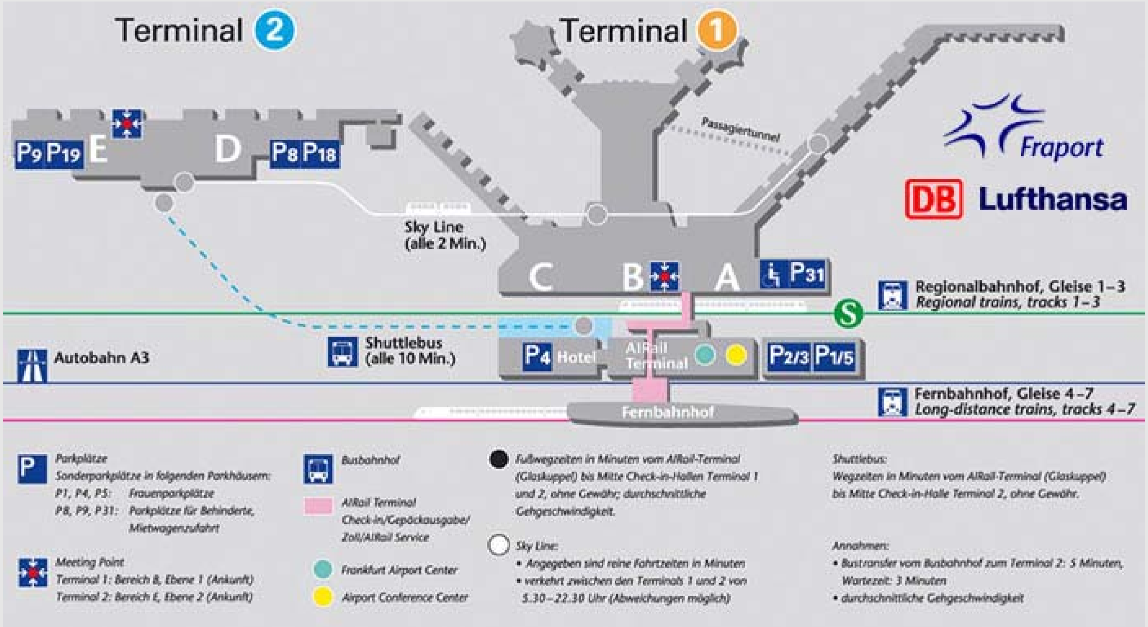
POLICY INSTRUMENTS	Indicators modelled in ORIGAMI	OR1 compared to Baseline 2030
(behavioural incentives)	Average Air emission factors (grams/pax·km)	-5%
	Average Ferry emission factors (grams/pax·km)	-5%
	Road speed (km/h)	-5%
Pricing and Taxation	Road travel cost (€/km)	+10%
- Road pricing	Rail travel cost (€/km)	-10%
- Vehicle taxation	Air travel cost (€/km)	+5%
- Rail subsidies	Ferry travel cost (€/km)	+5%
- Fuel taxation	Cost of accessing a city from road network (€/km)	+10%
- Air taxation	Cost of accessing an airport from road network (€/km)	+10%
Infrastructure management	Road speed (km/h)	-
- New technological solutions	Rail speed (km/h)	-
- Organisational issues	Air speed (km/h)	-
- Optimisation of precedures	Ferry speed (km/h)	-
	Speed when accessing a city from the road network (km/h)	-
	Speed when accessing a city from the rail station (km/h)	+7.5%
	Cost of accessing an airport from the road network (€/km)	-
	Cost of accessing an airport from the rail network (€/km)	-10%
	Cost of accessing a rail station from the road network (€/km)	-10%
	Time penalty between consecutive air trips (transit)	-
	Time penalty before starting an air trip (check-in / security)	-
Infrastructure provision	More road links (km) in core network	+33% (+6,500km)
- Missing links	More HSR links (km) in core network	+125% (14,000km)
- Bottlenecks	More conventional rail links (km) in core network	+125% (14,750km)
- Interconnections between networks	More air links (km)	-
	More ferry links	-
	Airport - rail interconnections	All airports within 10km from rail connected

Table 3-6 Examples of solutions considered by Policy Package OR1

Example: Frankfurt airport air-rail interconnections

Read more in http://80.33.141.76/origami/index.php?option=com_content&view=article&id=25

Improvement of rail-airport interconnections resulted in Frankfurt airport in increased rail demand. With time savings of up to 100 minutes generated by the new links. passenger figures for long-distance trains at Frankfurt airport more than doubled within a few years and are at about 22,500 per working day, resulting in a mode share of more than a third for public transport for originating air passengers. This allowed for more efficient use of air and rail infrastructure (co-modality) as the slots no longer needed for feeder flights were immediately used by the network carriers for additional long-haul flights using the full capacity of Frankfurt airport. Lufthansa passengers heading for Frankfurt airport have a check-in facility at Stuttgart and Cologne central stations under the exclusive AIRail agreement between Lufthansa and Deutsche Bahn. Furthermore, there are integrated tickets for the rail journey to Frankfurt and the onward flight available. Frankfurt Airport is the largest airport of Germany and the third largest in Europe, serving as an important hub for international flights from all around the world.

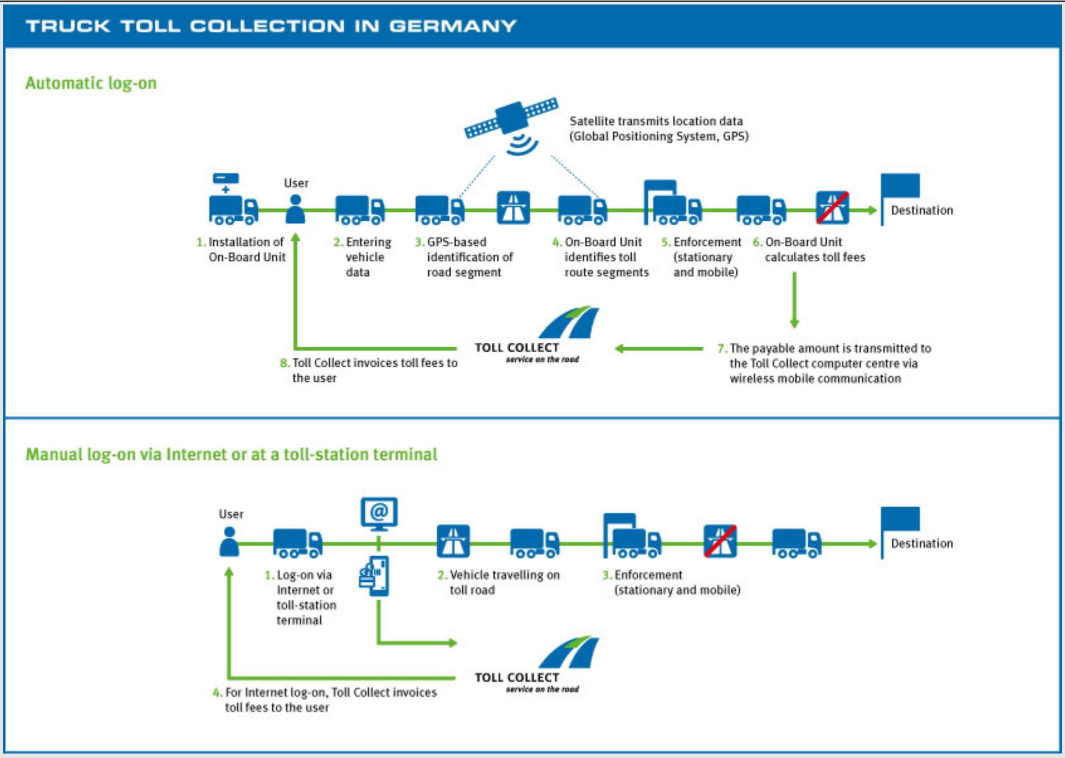


The integration of the Frankfurt airport with the German rail network promoted more efficient use of both the air and rail modes

Example: Vehicle Miles Travelled taxation; Mobimiles in Netherlands and LKW-MAUT in Germany

Read more in http://80.33.141.76/origami/index.php?option=com_content&view=article&id=87

A vehicle miles travelled (VMT) tax based on GPS technologies for passenger vehicles has been proved feasible in several pilot trials in the past (e.g. USA Oregon State. 2007). but has yet not been implemented anywhere. In Europe. the Netherlands is willing to transition to a VMT by 2018 and while Denmark and several USA states are considering this system as well. Distance based taxation is already implemented for freight in Europe in certain areas. as a consequence of the Eurovignette directive. Member States may apply an "external cost charge" on trucks, complementing already existing infrastructure charging. They may also modulate the infrastructure charge to take account of road congestion, with a maximum variation rate of 175 % during peak periods limited to five hours per day. The level of tolls can vary depending on the emissions of the vehicle. the distance travelled. and the location and the time of road use. Such differentiated charging is intended to encourage the move to transport patterns which are more respectful of the environment. Based on GPS technology and relying on transponders installed inside vehicles. Germany applies since 2005 the LKW-MAUT tax for trucks based on the distance driven in kilometres, time of the trip, number of axles and the emission category of the truck. The tax is levied for all trucks using German autobahns whether they are full or empty, foreign or domestic, and raises €2.4 billion per year mostly dedicated to road investment.



LKW-MAUT tax collecting and enforcement system in Germany

OR2

The OR2 policy package promotes the introduction of cleaner vehicles and more responsible user behaviour. Increased vehicle research and Euro Standard regulations over the private sector bring down vehicle emissions from new vehicles, lowering average emission factors of the vehicle fleet: from 200 to 90 grams per kilometre for cars (+35% more than trend line); from 130 to 55 grams per passenger kilometre for aviation (+20% more than trend line); from 22 to 10 grams per passenger kilometre for rail (+20% more than trend line). Favourable taxation and technological developments promote expansion of an alternatively fuelled cars fleet, which stands in 2030 for 30% of total fleet (mostly biodiesel, hybrid electric and compressed natural gas and ethanol). The technological promotion will as well foster the development of vehicles with less weight than traditional engines leading to much lower gas consumption. More efficient driving regimes are favoured with enhanced vehicle technologies and user training. Train, airplane and ship load factor increases are promoted by environmental regulation; spread of car sharing and car pooling schemes brings more rational use of cars and increased vehicle occupancy.

Table 3-7 Assumptions of Policy Package OR2

POLICY INSTRUMENTS	Indicators modelled in ORIGAMI	OR2 compared to Baseline 2030
Market liberalisation	Average Road travel cost (€/km)	-
- Market opening (free competition)	Average Rail travel cost (€/km)	-
- Privatisation (PPPs)	Average Air travel cost (€/km)	-
	Average Ferry travel cost (€/km)	-
Bans and regulation	Average Car vehicle emissions (grams/veh·km)	-35%
- Efficiency standards	Electric vehicles (% of non-ICE vehicles)	+50%
- Speed limitations	Car occupation (people/vehicle)	+35%
- Accompanying measures	Average Rail emission factors (grams/pax·km)	-20%
(behavioural incentives)	Average Air emission factors (grams/pax·km)	-20%
	Average Ferry emission factors (grams/pax·km)	-20%

POLICY INSTRUMENTS	Indicators modelled in ORIGAMI	OR2 compared to Baseline 2030
	Road speed (km/h)	-
Pricing and Taxation	Road travel cost (€/km)	-
- Road pricing	Rail travel cost (€/km)	-
- Vehicle taxation	Air travel cost (€/km)	-
- Rail subsidies	Ferry travel cost (€/km)	-
- Fuel taxation	Cost of accessing a city from road network (€/km)	-
- Air taxation	Cost of accessing an airport from road network (€/km)	-
Infrastructure management	Road speed (km/h)	-
- New technological solutions	Rail speed (km/h)	-
- Organisational issues	Air speed (km/h)	-
- Optimisation of precedures	Ferry speed (km/h)	-
	Speed when accessing a city from the road network (km/h)	-
	Speed when accessing a city from the rail station (km/h)	-
	Cost of accessing an airport from the road network (€/km)	-
	Cost of accessing an airport from the rail network (€/km)	-
	Cost of accessing a rail station from the road network (€/km)	-
	Time penalty between consecutive air trips (transit)	-
	Time penalty before starting an air trip (check-in / security)	-
Infrastructure provision	More road links (km) in core network	-60% (+2,000km)
- Missing links	More HSR links (km) in core network	-60% (+2,500km)
- Bottlenecks	More conventional rail links (km) in core network	-60% (+2,600km)
- Interconnections between networks	More air links (km)	-
	More ferry links	-
	Airport - rail interconnections	-

Table 3-8 Examples of solutions considered by Policy Package OR2

Example: Renewable energies to power railways in Belgium

Read more in http://80.33.141.76/origami/index.php?option=com_content&view=article&id=100

Given that electric power may be produced by a number of sources, some of them with a very low carbon footprint. The use of electric power increases rail's environmental advantages. An example of this is Infrabel's 'Solar Tunnel': the roof of a two mile stretch of tunnel over Belgium's high speed rail line has been fitted out with 16,000 solar panels to provide power for trains running through Antwerp Central Station and the surrounding railway infrastructure. Solar solution provider Enfinity says that about 4,000 trains per year - or the equivalent of a full day's worth of Belgian rail traffic - will be able to run entirely on solar power generated by the installation. Another good example, also by Infrabel, is the 'wind farm' concept to power the High Speed Line between Leuven and Liege. Moreover, ProRail has signed an agreement with an energy company to develop Railwind, a unique concept involving wind turbines above railway tracks. Apart from the obvious and substantial environmental benefits of the project, Railwind also contributes to better and efficient use of space and existing infrastructure. It is expected that the first energy generated from this project will be available in 2012.

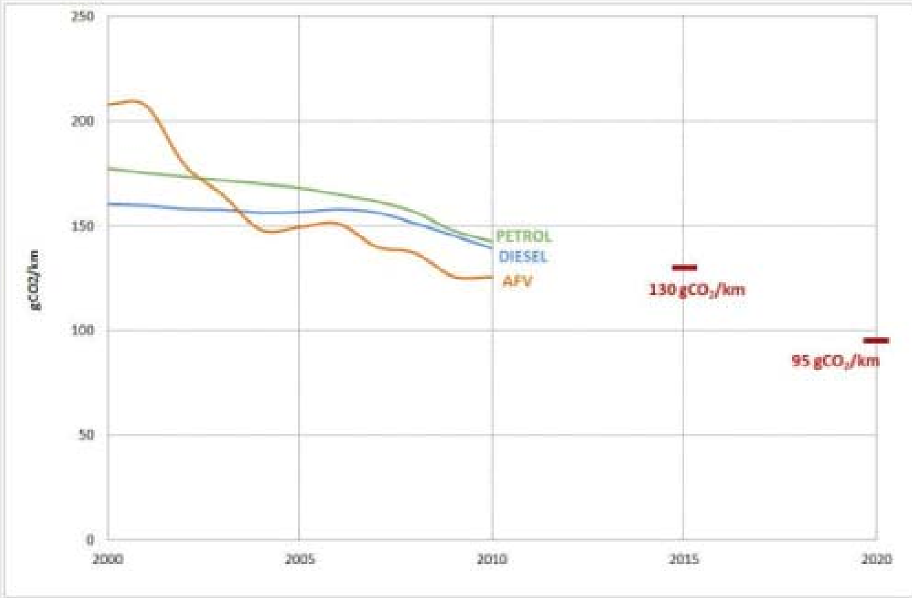
The Solar Tunnel is part of Belgium's HSL4 high-speed rail line that runs from Antwerp to Amsterdam

Example: Emission Standards for Vehicles in Europe

Read more in http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm

European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in EU Member States. The emission standards are defined in a series of European Union directives staging the progressive introduction of increasingly stringent standards. Successive 'Euro' emission standards for passenger cars and light vehicles were initiated in the EU as of 1993. Diesels have more stringent CO standards but are allowed higher NOx emissions, while petrol-powered vehicles are exempted from particulate matter (PM) standards through to the Euro 4 stage, although vehicles with direct injection engines will be subject to a limit of 0.005 g/km for Euro 5 and Euro 6. Euro Standards have already helped achieve considerable reduction in air pollution from cars, for example by forcing car makers to fit catalyst filters to exhaust pipes. Following up on a European Commission strategy adopted in 2007, the EU has put in place a comprehensive legal framework to reduce CO2 emissions from new light duty vehicles. The legislation sets binding emission targets for new car and van fleets. As the automotive industry works towards meeting these targets, average emissions are falling each year. For cars, manufacturers are obliged to ensure that their new car fleet does not emit more than an average of 130 grams of CO2 per kilometre (g CO2/Km) by 2015 and 95g by 2020 (compared to 160g in 2007 and 135.7g in 2011). In terms of fuel consumption, the 2015 target is approximately equivalent to 5.6 litres per 100 km (l/100 km) of petrol or 4.9 l/100 km of diesel, while the 2020 target equates approximately to 4.1 l/100 km of petrol or 3.6 l/100 km of diesel. In parallel, the new US rules by the Obama administration require cars and light trucks to achieve 54.5 miles on a gallon of fuel, with an interim standard of 35 miles by 2016 (equivalent to 70g of CO2 per kilometre, possibly rising to 83g once various exemptions, credits and size factors have been taken into account). Currently only hybrids or part-electric can achieve this performance. The European Commission planned to issue a new communication seeking stakeholders' views on post-2020 emission targets for new cars and vans. Some stakeholders claim a 2020 target of 80g and 60g for 2025 would be possible. The intention is to ensure that CO2 emissions from vehicles continue to be reduced while giving the automotive industry the certainty it needs to carry out long-term investments and develop innovative technologies. The issue of standards is becoming a competition issue in the car industry as fuel economy becomes more and more relevant[33]. A total of 30 car models on the German market already have CO2 emissions below 95g. The rush for stricter standards could throw the focus more onto electric vehicles, but the origin of electricity remains key to determine then the amount of emissions (an average electric car could emit as low as 20g of CO2 per kilometre in France. where much of the electricity comes from nuclear power, but 114g in Great Britain[34].

[33] T&E “Stricter CO2 standards needed or Europe won’t be able to compete”, Sep2012
[34] ICCT “Calculating electric drive vehicle GHG emissions”, Aug2012



Evolution of CO2 emissions for new passenger cars by fuel (EU27). EEA 2011

OR3

The OR3 policy package aims at intensively increasing performance of existing infrastructure through better management and higher technological implementation. New technologies optimise flows in all modes: ICTs in large urban areas result in less congested road traffic allowing for greater speeds in city access and egress; satellite guidance allows optimal routing; revised airport procedures reduce check-in / security times to 15 minutes for short-haul and 30 minutes to long haul-flights; integrated EU air space management to accommodate three times more air movements and better management of landing and take off manoeuvres at airports optimises air transport so that 99% of flights arrive and depart within 15 minutes of their scheduled time in all weather conditions[35]; ERTMS systems allow for 15% faster operating rail. Further liberalisation and consolidation of the air transport sector and increased competition among European airports and airlines contribute to a reduction of fees having an impact on flight fares, especially in largest European hubs and airports. Several agreements between different transport operators increase the offer of integrated inter-modal services (e.g. air and HSR integrated ticketing). Increased comfort conditions and services reliance increase the willingness to travel on rail and air.

Table 3-9 Assumptions of Policy Package OR3

POLICY INSTRUMENTS	Indicators modelled in ORIGAMI	OR3 compared to Baseline 2030
Market liberalisation	Average Road travel cost (€/km)	-2.5%
- Market opening (free competition)	Average Rail travel cost (€/km)	-2.5%
- Privatisation (PPPs)	Average Air travel cost (€/km)	-2.5%
	Average Ferry travel cost (€/km)	-2.5%
Bans and regulation	Average Car vehicle emissions (grams/veh·km)	-
- Efficiency standards	Electric vehicles (% of non-ICE vehicles)	-
- Speed limitations	Car occupation (people/vehicle)	+10%
- Accompanying measures	Average Rail emission factors (grams/pax·km)	-
(behavioural incentives)	Average Air emission factors (grams/pax·km)	-10%
	Average Ferry emission factors (grams/pax·km)	-10%
	Road speed (km/h)	-
Pricing and Taxation	Road travel cost (€/km)	-
- Road pricing	Rail travel cost (€/km)	-

[35] As reflected in ACARE Vision 2020 (and Flightpath to 2050, Targets on Levels of Service

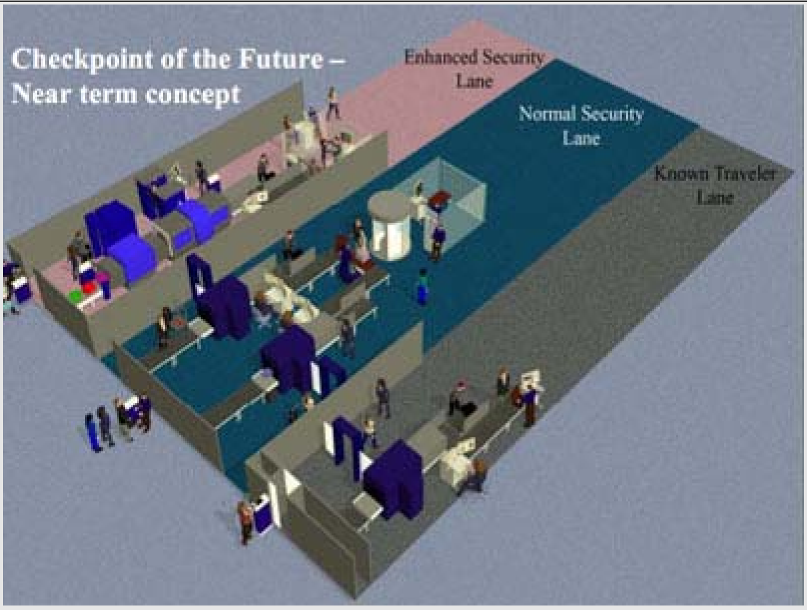
POLICY INSTRUMENTS	Indicators modelled in ORIGAMI	OR3 compared to Baseline 2030
- Vehicle taxation	Air travel cost (€/km)	+5%
- Rail subsidies	Ferry travel cost (€/km)	-
- Fuel taxation	Cost of accessing a city from road network (€/km)	
- Air taxation	Cost of accessing an airport from road network (€/km)	
Infrastructure management	Road speed (km/h)	-
- New technological solutions	Rail speed (km/h)	+15%
- Organisational issues	Air speed (km/h)	-10min per flight
- Optimisation of precedures	Ferry speed (km/h)	+15%
	Speed when accessing a city from the road network (km/h)	+15%
	Speed when accessing a city from the rail station (km/h)	+15%
	Cost of accessing an airport from the road network (€/km)	-20%
	Cost of accessing an airport from the rail network (€/km)	-20%
	Cost of accessing a rail station from the road network (€/km)	-20%
	Time penalty between consecutive air trips (transit)	-15%
	Time penalty before starting an air trip (check-in / security)	-15%
Infrastructure provision	More road links (km) in core network	-60% (+2.000km)
- Missing links	More HSR links (km) in core network	-60% (+2.500km)
- Bottlenecks	More conventional rail links (km) in core network	-60% (+2.600km)
- Interconnections between networks	More air links (km)	-
	More ferry links	-
	Airport - rail interconnections	-

Table 3-10 Examples of solutions considered by Policy Package OR3

Example: IATA Check Point of the Future

Read more in http://80.33.141.76/origami/index.php?option=com_content&view=article&id=68

The Checkpoint of the Future ends the one-size-fits-all concept for security. Passengers approaching the checkpoint will be directed to one of three lanes: ‘known traveller’, ‘normal’, and ‘enhanced security’. The determination will be based on a biometric identifier in the passport or other travel document that triggers the results of a risk assessment conducted by government before the passenger arrives at the airport. The three security lanes will have technology to check passengers according to risk. “Known travellers” who have registered and completed background checks with government authorities will have expedited access. “Normal screening” would be for the majority of travellers. And those passengers for whom less information is available, who are randomly selected or who are deemed to be an “Elevated risk” would have an additional level of screening. Screening technology is being developed that will allow passengers to walk through the checkpoint without having to remove clothes or unpack their belongings. Moreover, it is envisaged that the security process could be combined with outbound customs and immigration procedures, further streamlining the passenger experience.



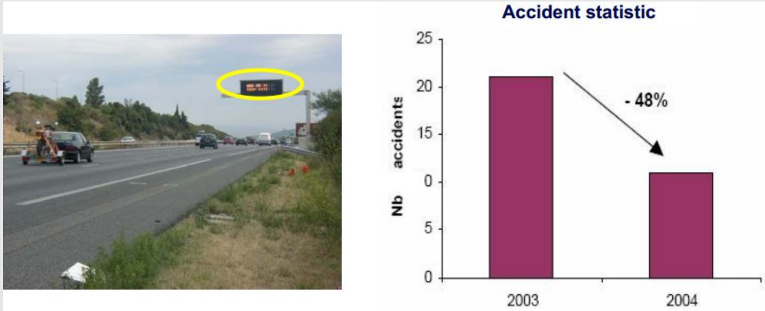
Near term concept for airport checkpoint of the future by IATA. aimed at drastically reducing check-in and security times at airports (allowing for access to airports up to 15 minutes only before a flight departure)

Example: Motorway Control Systems in Stockholm and France

Read more in http://80.33.141.76/origami/index.php?option=com_content&view=article&id=76

The Motorway Control System (MCS) installed on the E4 motorway through Stockholm is aimed at better managing the flow of traffic in Stockholm's motorways through ICTs. The system has been in operation since the late nineties and is currently being expanded. It includes a dynamic speed limit system based on real-time speed detection on the motorway. Studies by the KTH in Stockholm (K.Bang. A.Nissan et al) indicate that MCS decreases the variation of speeds on the motorway, which would indicate an improvement in homogeneity and traffic safety. MCS also reduced the frequency of very short headways as well as the frequency of lane changes between the middle and the left lane. Also in France, in the Rhone Valley motorway network (A7-A9 motorways from Lyon to the Spanish border) ITS are being implemented. This motorway corridor is particularly busy during the summer time and recurring congestion deeply lowers the level of service. ASF, the motorway manager, designed and implemented a variable speed limit system in order to increase the corridor capacity, traffic safety and driver comfort. Following the very positive results of the 2004 experiment, ASF decided to extend the variable speed limits service to 330 km of the A7/A9 motorway network. The system reduced accidents by 20 to 30%, congestion by about 20% and increased capacity in the corridor by 3 to 5%.

The Motorway Control System in Stockholm improves homogeneity and traffic safety, reduces the frequency of very short headways as well as the frequency of lane changes between the middle and the left lane.



Dynamic Speed Control on the A7/A9 motorway corridor in France resulted between 2004-2005 on 30.000 saved congestion hours and a 48% decrease of accidents.

OR4

OR4 is focused on further liberalisation of the transport market. Reduction of rules and harmonisation for all Member States enhances competition within modes and across modes. A substantial reduction of subsidies to infrastructure investment (public funding) and service operation forces each mode to become more economically self-sufficient, sometimes requiring increases of transport fees in currently more subsidised modes. A diversification of funding sources involves the private sector to a higher level (e.g. PPPs, MACs, project bonds). High levels of infrastructure investment are attained, but investments are mostly selected through strict cost benefit criteria. Many economically unsustainable regional airports will go out of operation due to missing public funding. High speed rail is implemented only on those links where services are economically profitable (e.g. between major metropolitan city pairs in Europe), while motorway investments are undertaken to address bottlenecks and missing links, and increasing endowment in eastern Member States. ITS are able to substantially improve road transport safety (vehicle to vehicle communication, automatic incident detection), reducing accidents and allowing for increased vehicle speeds. Highway tolls are introduced across Europe where not already existing.

Table 3-11 Assumptions of Policy Package OR4

POLICY INSTRUMENTS	Indicators modelled in ORIGAMI	OR4 compared to Baseline 2030
Market liberalisation	Average Road travel cost (€/km)	-5%
- Market opening (free competition)	Average Rail travel cost (€/km)	-5%
- Privatisation (PPPs)	Average Air travel cost (€/km)	-5%
	Average Ferry travel cost (€/km)	-5%
Bans and regulation	Average Car vehicle emissions (grams/veh·km)	-15%
- Efficiency standards	Electric vehicles (% of non-ICE vehicles)	+25%
- Speed limitations	Car occupation (people/vehicle)	-
- Accompanying measures	Average Rail emission factors (grams/pax·km)	-
(behavioural incentives)	Average Air emission factors (grams/pax·km)	-
	Average Ferry emission factors (grams/pax·km)	-
	Road speed (km/h)	-
Pricing and Taxation	Road travel cost (€/km)	+5%
- Road pricing	Rail travel cost (€/km)	+10%
- Vehicle taxation	Air travel cost (€/km)	-
- Rail subsidies	Ferry travel cost (€/km)	-
- Fuel taxation	Cost of accessing a city from road network (€/km)	-
- Air taxation	Cost of accessing an airport from road network (€/km)	-
Infrastructure management	Road speed (km/h)	+15%
- New technological solutions	Rail speed (km/h)	+5%
- Organisational issues	Air speed (km/h)	-3min per flight
- Optimisation of precedures	Ferry speed (km/h)	-
	Speed when accessing a city from the road network (km/h)	-

POLICY INSTRUMENTS	Indicators modelled in ORIGAMI	OR4 compared to Baseline 2030
	Speed when accessing a city from the rail station (km/h)	-
	Cost of accessing an airport from the road network (€/km)	-10%
	Cost of accessing an airport from the rail network (€/km)	-
	Cost of accessing a rail station from the road network (€/km)	-10%
	Time penalty between consecutive air trips (transit)	-
	Time penalty before starting an air trip (check-in / security)	-
Infrastructure provision	More road links (km) in core network	+200% (+15,000km)
- Missing links	More HSR links (km) in core network	-25% (+4,700km)
- Bottlenecks	More conventional rail links (km) in core network	-25% (+4,900km)
- Interconnections between networks	More air links (km)	-
	More ferry links	-
	Airport - rail interconnections	-

Table 3-12 Examples of solutions considered by Policy Package OR4

Example: Merseyrail Concession in Liverpool

Read more in http://80.33.141.76/origami/index.php?option=com_content&view=article&id=55

In 2003 Merseytravel took over responsibility from the Strategic Rail Authority for letting and managing the contract for provision of passenger services on the Merseyrail Electrics network, the first and only Passenger Transport Executive to date to do so. The Merseyrail concession is unique in the UK, though it is based on a franchising model popular in Germany, Denmark, Sweden and the Netherlands, where it is credited with having established a virtuous circle of new trains and station modernisation, close integration with local bus services – and more passengers. Since these new arrangements have been in place, there has been significant improvement in performance on the network with reliability and punctuality figures at record levels. The role of the Department for Transport in awarding rail franchises has been delegated by Parliament to the Merseyside Integrated Transport Executive Merseytravel and the concession agreement is between the operator and Merseytravel. This gives much better local control of local services to local people. Another unique feature is the length of the concession which is 25 years from 20 July 2003, with specified interim review dates. The local rail services both form part of national networks (mainly rail) and local networks (mainly bus).

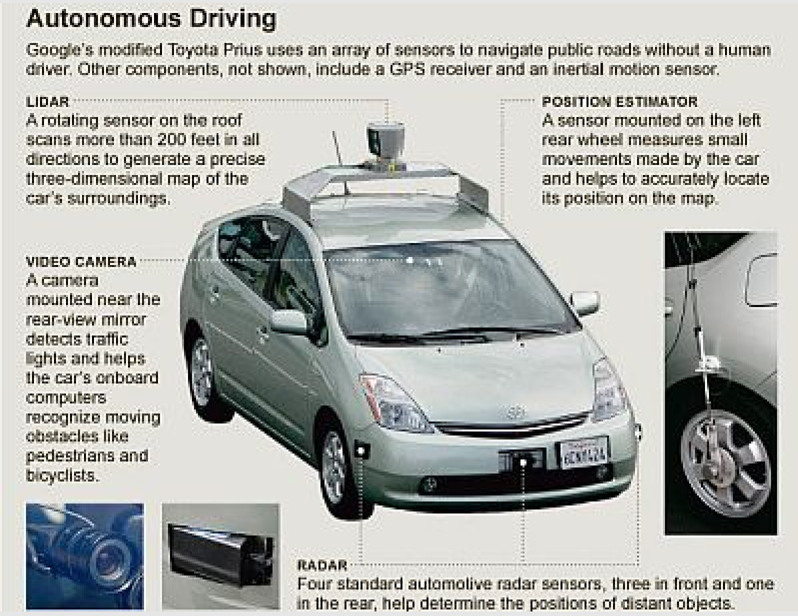
The intervention of the private sector in the Merseyrail concession in Liverpool has resulted on increased rail reliability and punctuality, ridership and traveller satisfaction

Examples: SARTRE project and automatically driven vehicles

Read more in http://80.33.141.76/origami/index.php?option=com_content&view=article&id=81

The SARTRE project envisions a future with intelligent transport networks traversed by so-called “road trains”: six to eight driverless cars guided along by a lead truck of some sort. Motorists could automatically become a part of such a train by driving to the right place and then letting go of the steering wheel; to leave the train they would retake the wheel and resume driving the traditional way. Such “assisted convoys” would not only free motorists from the hassle of actually having to drive for parts of trips, but could improve highway safety and reduce fuel consumption, as experts involved in the project say. By falling into formation behind one another, a group of travellers can reduce the amount of energy each individual would otherwise have to expend alone to cover the same distance. “Road trains” could cut gas consumption by some 20% according to SARTRE. All the project requires are navigation systems that communicate with the lead vehicle and control acceleration and steering. The project’s lead agencies estimate that a full-scale rollout is likely within a decade.

In the meantime, Google is developing a driverless car based on a information gathered from Google Street View with artificial intelligence software that combines input from video cameras inside the car, a sensor on top of the vehicle, radar sensors on the front of the vehicle and a position sensor attached to one of the rear wheels that helps locate the car's position on the map. The USA states of California, Georgia and Nevada have legalised the use of driverless cars, anticipating a possible commercial development of this technology.



The development of autonomous driving cars is to allow increased road safety and could allow for increased road speeds in the mid term.

Scenario comparison with regard to ORIGAMI solutions

The next figure shows to what extent each of the policy packages in ORIGAMI relies on different families of solutions to improve co-modal and intermodal passenger transport in Europe. It is possible in the ORIGAMI solutions library (http://80.33.141.76/origami) developed in WP5 to read about more than 150 solutions which can be characterised according their contribution to better management of transport in more or less regulated frameworks.

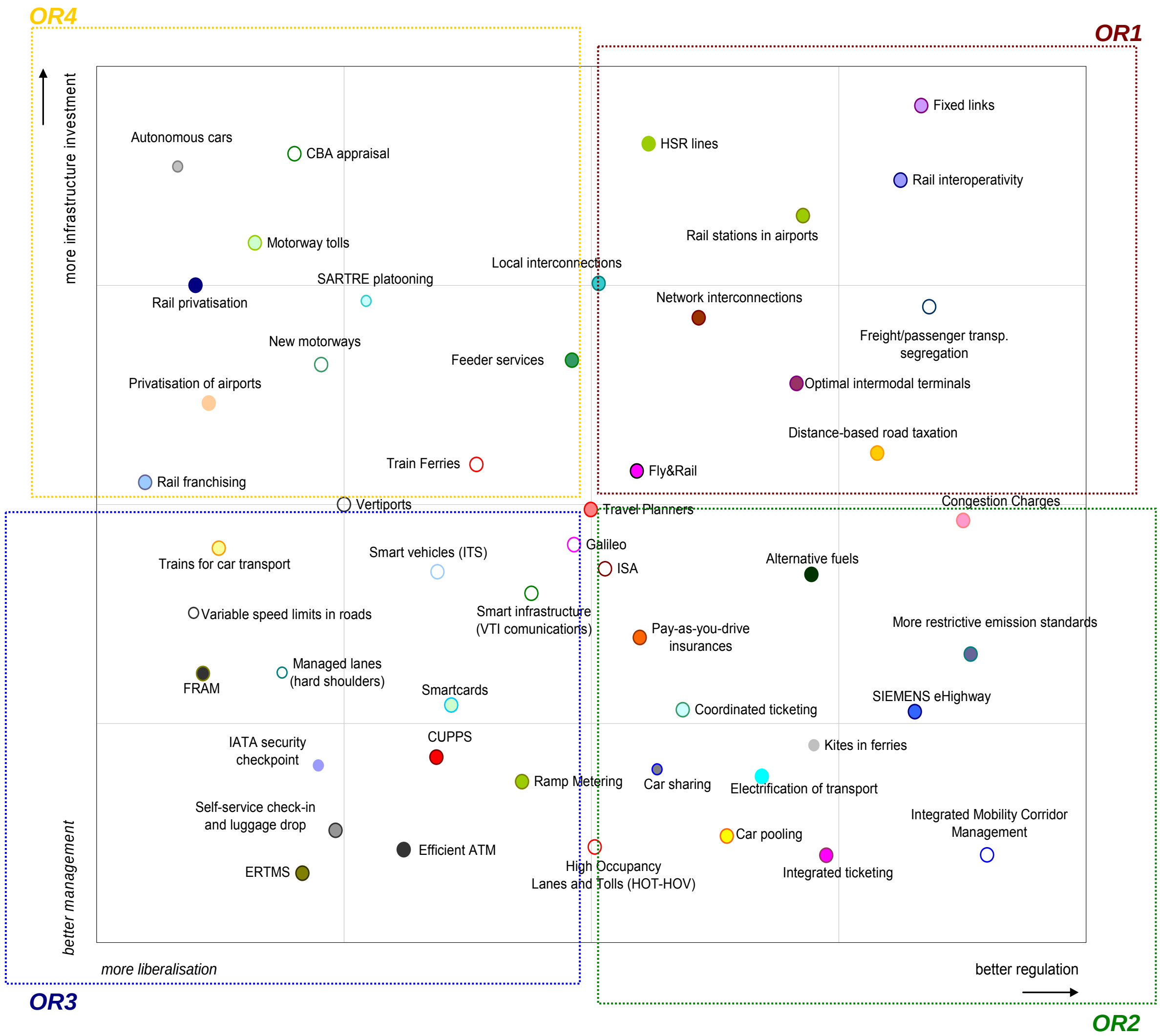


Figure 3-18 Relative reliance of ORIGAMI policy packages on identified best practice solutions

The table below presents the relative degree in which each ORIGAMI policy package will rely on the different families of identified solutions in WP5 to reach their policy goals.

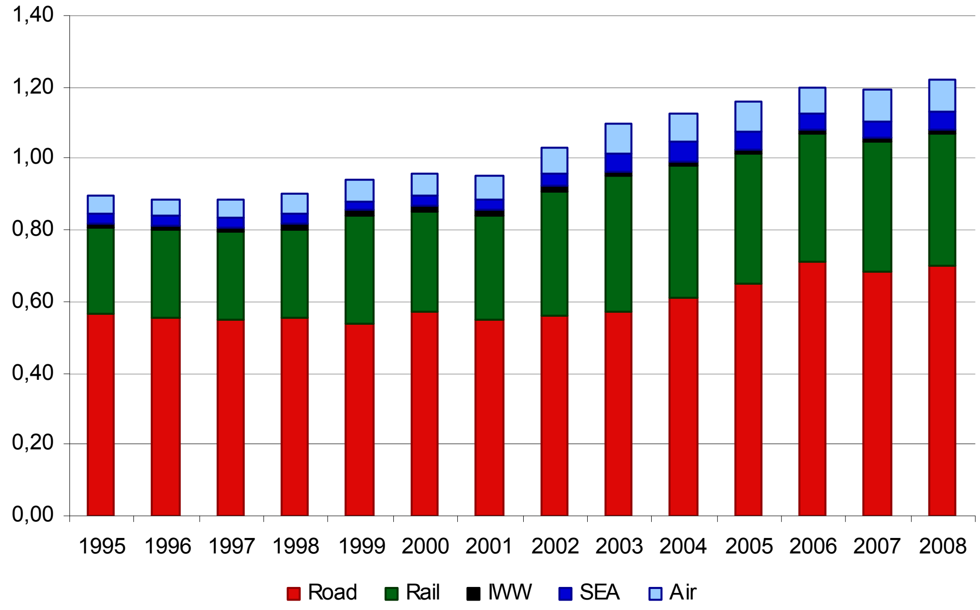
Table 3-13 Relative reliance of ORIGAMI policy packages on identified best practice solutions

	Baseline	OR1	OR2	OR3	OR4
Long-distance interconnections	5	10	2	3	8
Local interconnections	5	9	3	5	7
Missing links: megaprojects	5	8	1	2	8
Dual mode solutions	5	5	6	5	3
Enhanced vehicle performance	5	3	10	5	6
Traffic management	5	4	7	10	5
Organisational arrangements	5	1	3	7	10
Segregation of freight & passenger traffic	5	7	3	5	7
Innovative ticketing schemes	5	5	7	9	5
Travel planners and user information	5	10	10	10	10
Security & fee collecting procedures	5	6	5	10	8
Environmental management	5	5	9	7	4
Enhanced safety	5	6	7	7	6

Justification of infrastructure scenarios

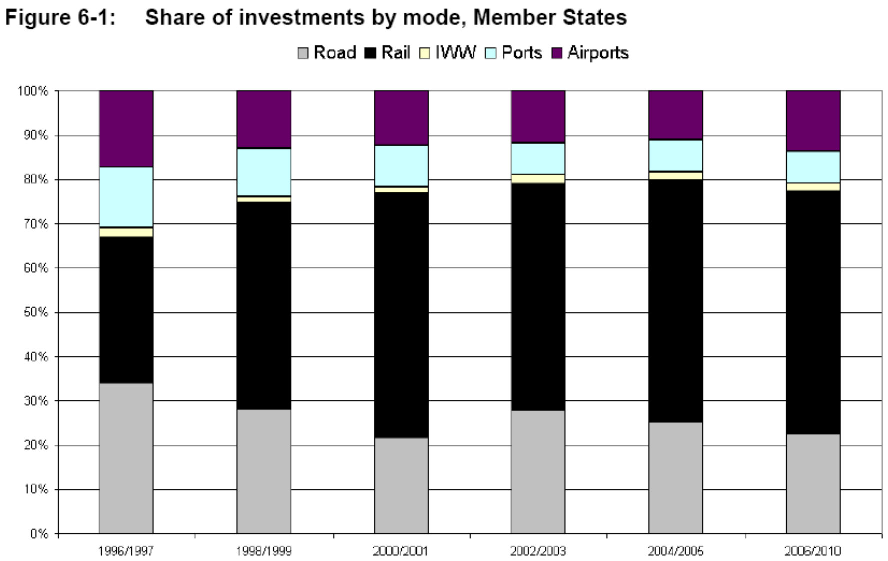
Infrastructure scenarios have been defined based on the determination of fund availability for infrastructure investment from 2012 till 2030. For the period from 1995 to 2010 the following observations can be made:

- The EU has spent on average between 0.9% and 1.2% of EU GDP in infrastructure investment.
- About 1/3 of available funds have been spent on infrastructure maintenance, and the rest on construction of new infrastructure.
- More than 85% of investment is financed with Member States national budgets. EU funds represent 5% of investment, and almost 10% is constituted by EIB loans and private investments.
- Around 60% of total investment has been devoted to Road mode, 20% to Rail and 10% equally split between Air and Water modes.
- 50% of investment devoted to new infrastructure is targeted at TEN-T networks and the other half to national networks.
- Almost half of investment on TEN-T has been devoted over the last 10 years to rail and around 35% to road.



(Source: EEA 2010)

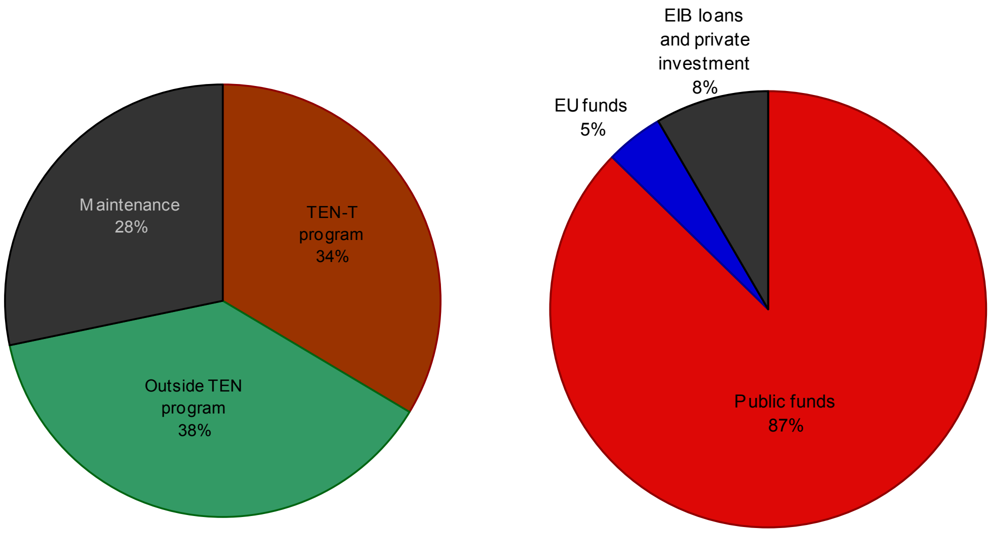
Figure 3-19 Total infrastructure investment as a share of GDP (per mode) 1995-2008



(Source: EC 2002)

Figure 3-20 Total infrastructure investment in TEN-T per mode 1995-2010[36]

[36] PLANCO (2002); *TEN-Invest Transport Infrastructure costs and Investments between 1994 and 2010 on the Trans-European,* for the EC DG Transport. Estimations in function of budget projections.



(Source: EEA. TEN-T EA. EC)

Figure 3-21 Structure of Infrastructure investment and financing 1995-2010

Based on these figures, ORIGAMI builds future trends for the Baseline and the 4 Policy Packages. Each scenario considers:

- High, medium or low global investment level on infrastructure (% of GDP);
- Split between TEN-T and National transport networks;
- Split between TEN-T core network (aimed at long-distance passenger transport) and comprehensive network (aimed at traffics of a more local scale);
- Split between modes.

The following figures synthesise all hypotheses in relation to infrastructure endowment for ORIGAMI scenarios.

Completion degree of TEN-T is defined as the amount of infrastructure provided (or investment undertaken) in each scenario in relation to the total amount required to build all missing links in the TEN-T core network, as defined in the TEN-T guidelines published by the EC in late 2011.

Table 3-14 ORIGAMI Scenarios infrastructure endowment assumptions

Transport Investment in Europe	2012	Baseline 2012-2030		OR1 2012-2030		OR2 2012-2030		OR3 2012-2030		OR4 2012-2030	
Average anual GDP growth 2012-2030		1,6%		1,6%		1,6%		1,6%		1,6%	
% GDP spent in transport investment	1,04%	0,93%	€ 2.594.682	1,07%	€ 2.981.000	0,86%	€ 2.405.320	0,86%	€ 2.405.320	1,1%	€ 2.952.138
in new TEN-T infrastructure	26,0%	25,2%	€ 653.688	32,6%	€ 972.893	21,8%	€ 525.509	21,8%	€ 525.509	32,4%	€ 957.348
in core network	*40,0%*	*46,2%*	€ 301.724	*54,1%*	€ 526.004	*28,1%*	€ 147.413	*33,4%*	€ 175.421	*42,4%*	€ 405.878
in comprehensive network	*60,0%*	*53,8%*	€ 351.964	*45,9%*	€ 446.889	*71,9%*	€ 378.096	*66,6%*	€ 350.089	*57,6%*	€ 551.470
in new non TEN-T infrastructure	38,9%	35,9%	€ 930.729	32,7%	€ 973.956	36,6%	€ 879.651	36,6%	€ 879.651	32,6%	€ 961.473
in management and maintenance	35,1%	38,9%	€ 1.010.264	34,7%	€ 1.034.150	41,6%	€ 1.000.159	41,6%	€ 1.000.159	35,0%	€ 1.033.316
New TEN-T investment abatement											
% road	30,5%	31,5%	€ 206.140	28,2%	€ 274.016	31,5%	€ 165.386	31,5%	€ 165.386	35,6%	€ 340.579
core		12,5%	€ 25.768	12,5%	€ 34.252	6,0%	€ 9.923	6,0%	€ 9.923	25,0%	€ 85.145
comprehensive		87,5%	€ 180.373	87,5%	€ 239.764	94,0%	€ 155.463	94,0%	€ 155.463	75,0%	€ 255.434
% rail	43,2%	44,0%	€ 287.843	52,1%	€ 506.475	44,0%	€ 231.212	44,0%	€ 231.212	37,1%	€ 355.097
core		50,0%	€ 143.922	65,0%	€ 329.209	25,0%	€ 57.803	25,0%	€ 57.803	30,0%	€ 106.529
comprehensive		50,0%	€ 143.922	35,0%	€ 177.266	75,0%	€ 173.409	75,0%	€ 173.409	70,0%	€ 248.568
% air	11,3%	9,1%	€ 59.491	6,7%	€ 65.144	9,2%	€ 48.328	9,7%	€ 50.931	10,7%	€ 102.874
core		75,0%	€ 44.618	75,0%	€ 48.858	45,0%	€ 21.748	100,0%	€ 50.926	75,0%	€ 77.156
comprehensive		25,0%	€ 14.873	25,0%	€ 16.286	55,0%	€ 26.581	0,0%	€ 5	25,0%	€ 25.719
% ports & IWW	7,5%	7,8%	€ 51.187	5,6%	€ 54.290	7,8%	€ 41.169	7,3%	€ 38.567	9,1%	€ 86.997
core		75,0%	€ 38.391	75,0%	€ 40.718	45,0%	€ 18.526	45,0%	€ 17.355	75,0%	€ 65.247
comprehensive		25,0%	€ 12.797	25,0%	€ 13.573	55,0%	€ 22.643	55,0%	€ 21.212	25,0%	€ 21.749
% intermodal and combined	7,5%	7,5%	€ 49.027	7,5%	€ 72.967	7,5%	€ 39.413	7,5%	€ 39.413	7,5%	€ 71.801
Provision of new infrastructure											
Construction of roads (km)		38.831 km		51.616 km		31.154 km		31.154 km		64.155 km	
core		4.854 km		6.452 km		1.869 km		1.869 km		16.039 km	
comprehensive		33.977 km		45.164 km		29.285 km		29.285 km		48.116 km	
Construction of HSR (km)		12.583 km		22.141 km		10.108 km		10.108 km		15.524 km	
core		6.292 km		14.392 km		2.527 km		2.527 km		4.657 km	
comprehensive		6.292 km		7.749 km		7.581 km		7.581 km		10.866 km	
Construction of conventional rail (km)		13.099 km		23.049 km		10.522 km		10.522 km		16.160 km	
core		6.550 km		14.982 km		2.630 km		2.630 km		4.848 km	
comprehensive		6.550 km		8.067 km		7.891 km		7.891 km		11.312 km	

Fulfilment of TEN-T core network investment objectives (White Paper)

	Estimated needs (White Paper)	Completition degree	Completition degree	Completition degree	Completition degree	Completition degree
Overall TEN-T	500000 M€					
Road	66.000 M€	39%	52%	15%	15%	129%
HSR	236.000 M€	52%	118%	21%	21%	38%
Conventional rail	65.700 M€	52%	118%	21%	21%	38%
Air	72.000 M€	62%	68%	30%	71%	107%
Ports	60.300 M€	64%	68%	31%	29%	108%

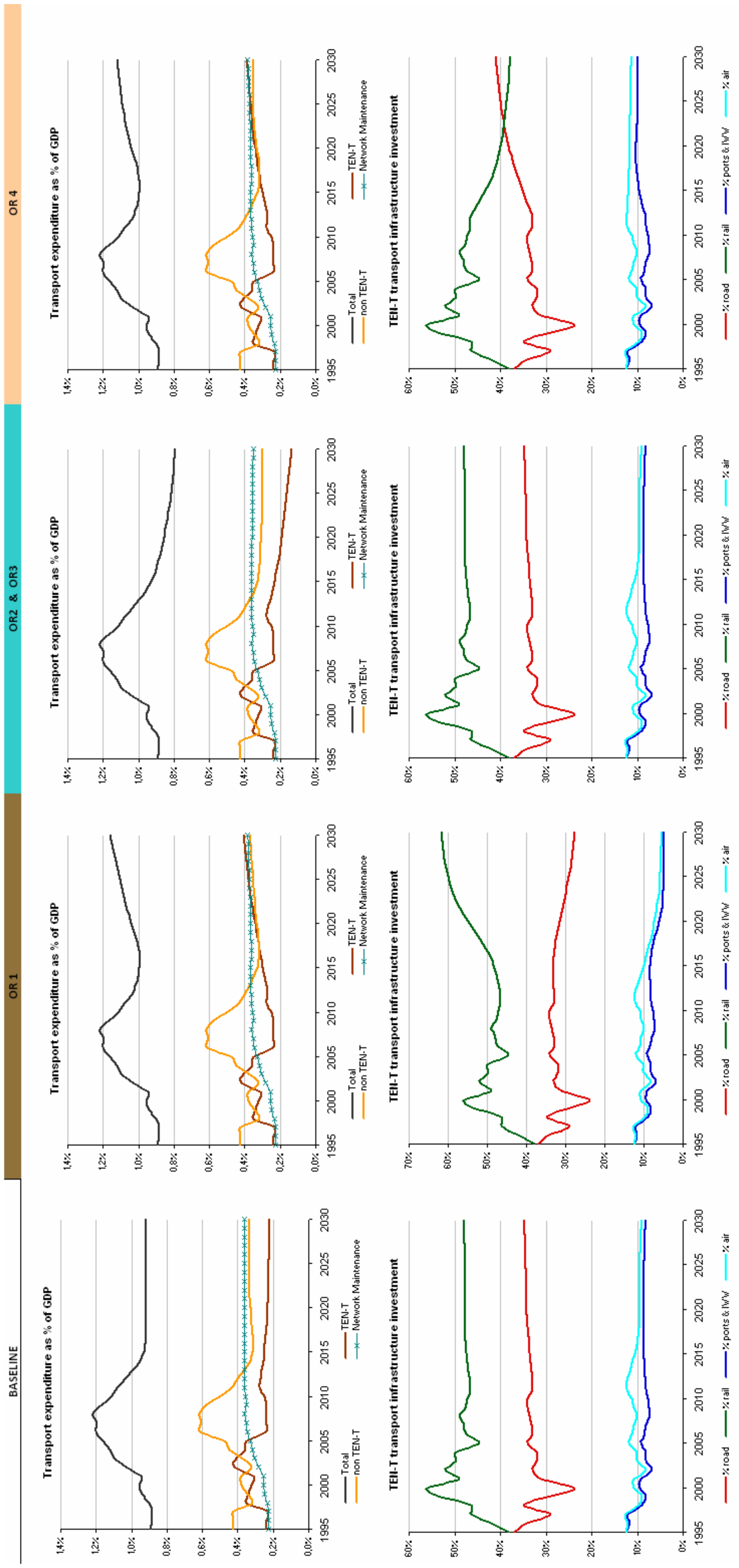


Figure 3-22 Structure of infrastructure investment and financing per scenario (1/2)

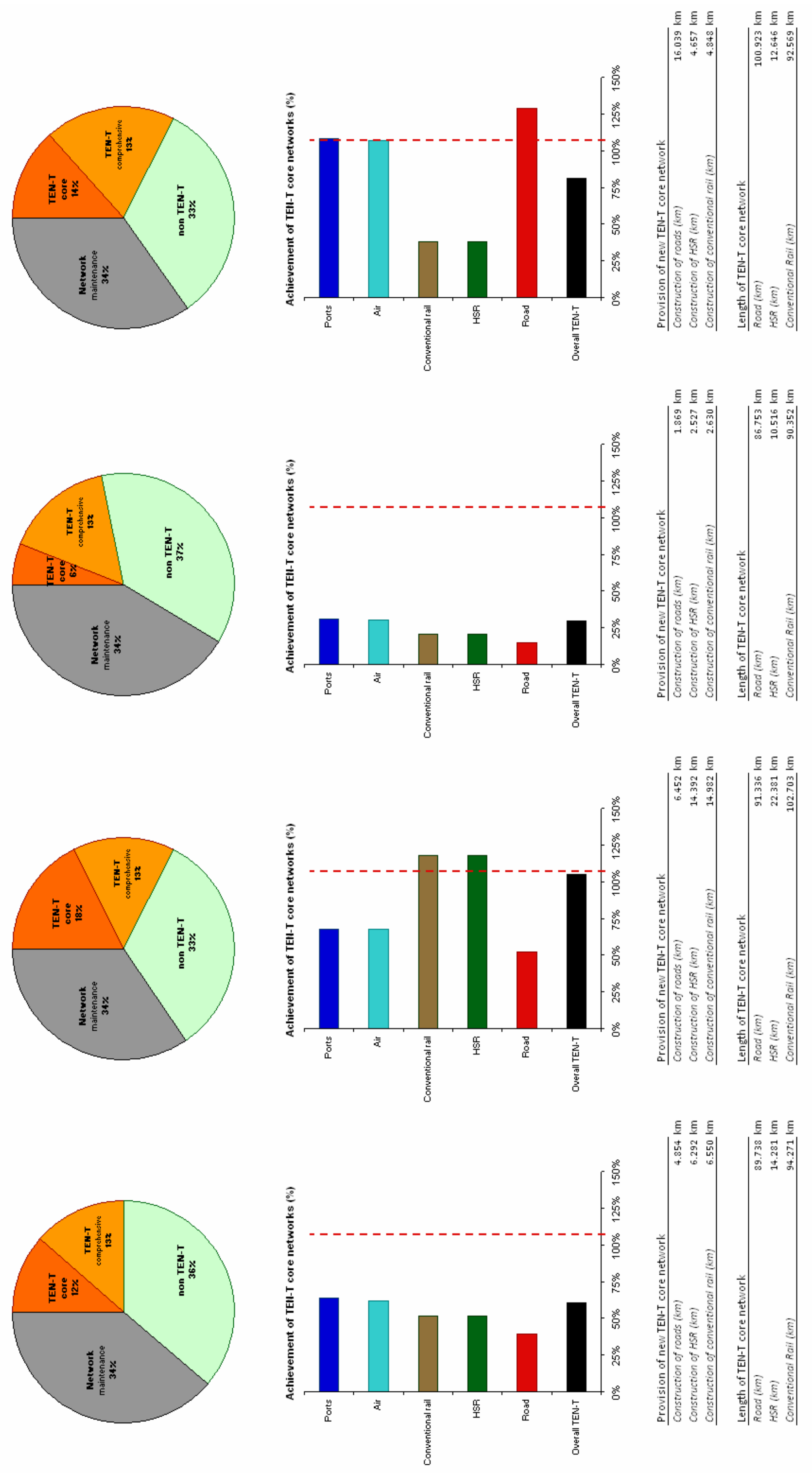


Figure 3-23 Structure of infrastructure investment and financing per scenario (2/2)

Selection of new links in the MOSAIC graph

MOSAIC will implement sets of new transport infrastructure specifically for each ORIGAMI scenario and the Baseline. The new links implemented will correspond to investments in the TEN-T core network as determined in the previous chapter. The size of the new infrastructure to be provided is synthesised in the following table:

Table 3-15 Synthesis of new infrastructure provision in MOSAIC

	Baseline	OR1	OR2	OR3	OR4
Construction of TEN-T core roads (km)	4.853	6.452	1.869	1.869	16.038
Construction of TEN-T core HSR (km)	6.292	14.982	2.527	2.527	4.658
Construction of TEN-T core conventional rail (km)	6.550	14.982	2.630	2.630	4.848

The selection of specific links in the MOSAIC graph (rail and road) is based both on "cohesion" principles (eastern European links are more likely to be selected) and on "competitiveness" principles (links with highest levels of traffic are more likely to be selected).

$$P_i = \left(\frac{Traffic_i}{MaxTraffic_{EU}} \right)^{\alpha} \left(\frac{MaxGDPcapita_{EU}}{GDPcapita_j} \right)^{\beta}$$

With

P_i . probability of link i being chosen to be upgraded
$Traffic_i$. traffic through link i
$AveTraffic_{EU}$. average traffic on all links
$GDPcapita_j$. income per capita of NUTS3 j were link i is located
$AveGDPcapita_{EU}$. average income per capita of all NUTS3
$\alpha, \beta \in [0,1]$ competitiveness and cohesion constants

The selection of links for each ORIGAMI scenario responds to the following α, β parameters is presented in the following table.

Table 3-16 Competitiveness (α) and Cohesion (β) parametres for ORIGAMI scenarios

	Baseline	OR1	OR2	OR3	OR4
α	0.5	0.10	0.40	0.60	0.90
β	0.5	0.90	0.60	0.40	0.10

In doing so, the ORIGAMI Scenarios have the following characteristics:

Baseline. Selection of links to be incorporated with balanced weights between competitiveness and cohesion criteria. Selected links need to both have relatively high levels of traffic and tend to be evenly distributed all over in Europe.

OR1. Cohesion oriented scenario, tends to select links in lower GDP per capita regions, even when there might be other links with heavier traffic levels in other areas of Europe.

OR2. Balanced selection of links, with slightly higher weight of cohesion criteria than competitiveness.

OR3. Balanced selection of links, with slightly higher weight of competitiveness criteria than cohesion.

OR4. Competitiveness oriented scenario, tends upgrade links with higher levels of traffic, regardless of their location either in wealthy or poor areas of Europe.

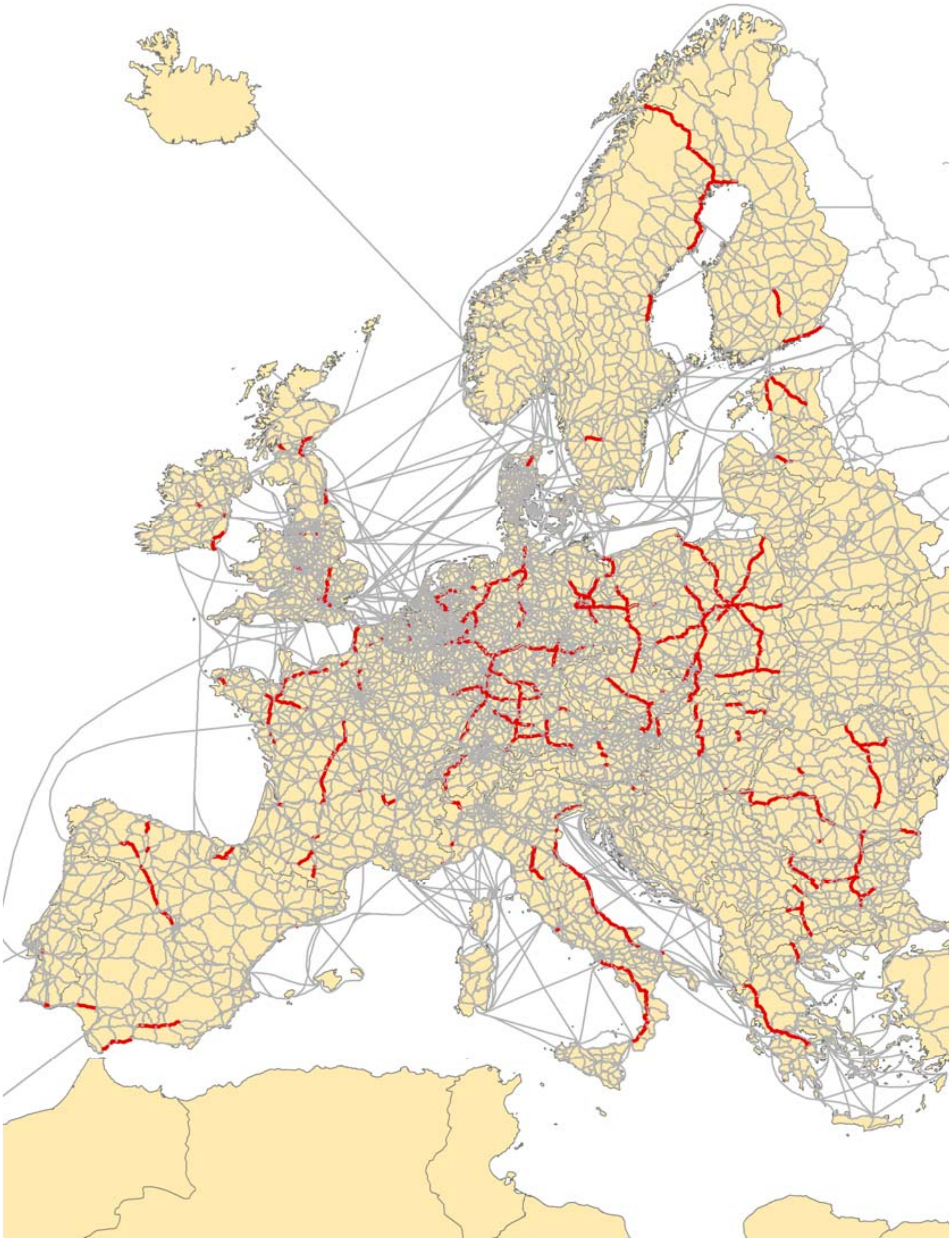


Figure 3-24 Sample of link selection in the Road Core Network for new infrastructure provision and upgrading of exisiting based on alpha=1 and beta=0 (MOSAIC graph)

3.3 DEFINITION OF THE ORIGAMI NORMATIVE SCENARIO

3.3.1 Approach

In socio-economic terms, the Normative Scenario is coincident with the Baseline. It has been built based on official strategy and prospective reports by EU institutions (mostly ECFIN's 2009 *Ageing Report*. DGTREN's *Transport and Energy Outlook 2030*. DGMove's 2011 *Transport White Paper* accompanying working papers. and EEA and Eurostat statistics and forecasts) and complemented with additional inputs from EU research projects and work by other international reference institutions and corporations (various EC 7FP projects. BP's 2011 *Energy Outlook 2030*. UNWTO's 2011 *Tourism Towards 2030*).

For transport, the Normative Scenario incorporates basic targets currently in place in the EU (mostly from EU2020 strategy and 2011 transport White Paper, adjusted for long-distance passenger transport. Starting from these pre-established targets, ORIGAMI tried to find back the required policies to approach these goals as much as possible. The policies are a combination, or even intensification, of those policies considered by ORIGAMI in the 2030 Exploratory Scenarios.

The environmental debate has driven most efforts in drawing specific commitments to targets, and most importantly the levels of GHG emissions. At the European Council in 2007 the EU committed itself to reduce GHG emissions by 20% by 2020 compared to 1990, and by 30% if other industrialised countries were to follow. At the G8 Summit in Aquila in 2009, the EU President and the President of the EC joined the resolution that the world industrialised countries reduce their GHG emissions by 80% until 2050 compared to 1990.

The Lisbon Strategy defined for 2020 targets for employment, innovation, climate change and energy, education and poverty. European, international and national policy-documents (e.g. international agreements, European Communications and White Papers…) have also defined policy targets for 2030 and beyond; concerning 2050, policy targets are mostly related to the decarbonisation of the economy, leading to a paradigm shift in relation to technologies applied on energy and transport, and inducing behavioural changes that impact on territorial patterns. ORIGAMI targets derive from these targets, but have been adapted to cover specifically long-distance passenger travel.

3.3.2 Reference Storyline

Policies applied in the ORIGAMI Reference Normative Scenario are based on the 2011 Transport White Paper. They are based on a system that will allow increasing mobility while tackling the negative impacts of transport, with the view set on reducing Europe's dependence on imported energy sources and cutting total carbon emissions of transport by 60% by 2050.

The key policy goals of the 2011 White Paper are synthesised below[37].

- **Single European Transport Area**. Elimination of remaining barriers between different modes and different national transport systems (less unnecessary regulation and bureaucracy, and more technical compatibilities). Increasing the cohesion of the transport network by establishing binding commitments of Member States towards implementation of TEN-T core network projects.
- **More diversified funding for transport**. Increased use of PPP schemes; better coordination of funding sources to meet Common Transport Policy objectives and targets: ERDF, Cohesion Fund, TEN-T budget, EIB loans; bond issuing initiatives to fund major infrastructures; "user-pays" principle.
- **Increased efficiency of investment**. Ex-ante project appraisal with cost benefit guidelines; competitive tendering, even when services of public interest may not operate under competition; clarification and uniform treatment of public funding; efficient corridor planning approach rather than project approach.
- **Environment welfare**. Internalisation of external costs of transport; EURO standards to seek further vehicle efficiency; visible links between the "polluter-pays" and "user-pays" principles and use of issued revenues.

[37] Based on 2011 Transport White Paper and synthesised by ORIGAMI.

- **Technology intensive**. More technology development more focussed on key thematic elements (alternative fuels, smart vehicles, efficient traffic and infrastructure management); European industry leader in the global market.
- **Infrastructure priorities**. To address bottlenecks, cross-border links and network interconnections; to complete HSR network by 2050 to replace air transport below 1000km; to connect all airports to rail, preferably to HSR, to promote air-rail inter-modal travel. A transport network composed of a first layer constituted by highly efficient multi-modal networks, the *Core Network,* and a second layer constituted by an EU-wide cohesive network, the *Comprehensive Network*; increasingly segregated freight and passenger traffic (enhanced flows and safer transport); increasingly balanced network between EU15 states and New Member States.
- **Transport management**. Technology, pricing and scheduling to enhance infrastructure management and increase effective capacity (ATM. ERTMS. ICT…); *European Integrated Multi-modal Information and Management Plan,* providing real-time network information all over Europe, efficient multi-modal planners and centralised ticketing.

The table below, based on the EC 2011 Transport White Paper[38], is the departing inspirational point for the definition of the ORIGAMI Normative scenario. The table provides more details on the development of the above policy objectives. The Normative scenario takes into consideration these overall objectives for the European transport system (including both urban and long-distance transport) and proposes a set of specific interventions focussed only on long-distance transport.

Table 3-17 Synthesis of major concepts included in the 2011 Transport White Paper

Market regulation	Pricing & funding	Technology	Infrastructure	Management
Single European Transport Area eliminating all residual barriers between modes and national systems (technical and bureaucratic).	**Increasing difficulty in funding of transport infrastructure** -due to ageing society (social budgets). financial crisis. and alternative fuel vehicles reducing fuel taxation incomes.	**More focused R&D efforts required in Europe**. China's R&D spending grows at double digit rate (already 2nd largest R&D world power) and is focussed in most promising areas. while European research efforts remain diffused.	**Cost of EU missing infrastructure to match demand for transport** is estimated € 1.5 trillion for 2010-2030 (€215 billion for bottlenecks). Investment in vehicles and equipment required additional €1.0 trillion.	**Co-modality implies use of each mode where especially competitive**: - urban mobility → PT & electric vehicles (EV) - travel below 300km → conventional car - travel up to 1000km → high speed rail - long distance travel → aviation
Single European Railway Area - award of public service contracts under competition. - strengthening role of the European Rail Agency. - enhancing separation between IMs and operators	**"User pays" principle** Socio-economic benefits and positive externalities may justify some level of public funding of transport but users are to pay for higher proportion implementation and operation costs.	**More efficient vehicles**. smaller and lighter. Vehicles in all transport modes need to become cleaner. safer and more silent.	**Balanced infrastructure endowment** between EU12 (New Member States) and EU15 countries.	**HSR in competition with aviation** and to provide alternatives to short haul- and feeding flights.
Single European Sky Modernised ATM infrastructure by 2020 (SESAR) and legislation changes to allow tripling airspace capacity. reduce 50% ATM costs. reduce 10% environmental impact.	**Road user charges to all vehicles on the whole network based on distance**. to reflect at least the marginal cost of infrastructure (wear and tear). congestion. air and noise pollution. Eurovignette extended to passenger transport	**Alternative fuels** - ROAD → urban EV. hydrogen & methane for mid distance). biofuels. LNG and LPG for long distance. - RAIL → electricity - AIR → biomass - WATER → biofuel. hydrogen (IWW). LPG and LNG (SSS). LNG & nuclear (deep sea)	**Dual TEN-T layer:** Multi-modal TEN-T 'core network' by 2030 (selected corridors to carry large volumes of traffic with high efficiency and low emissions). EU-wide comprehensive network' underneath the core network .	**Attractive frequencies. reliability and inter-modal integration** for enhanced quality service.

38 Transport White Paper (COM/2011/0144 final) and Commission Staff Working Document accompanying the White Paper (SEC/2011/0391 final).

Market regulation	Pricing & funding	Technology	Infrastructure	Management
Binding commitments by MS to implementation of TEN-T core network projects (granting accomplishment of agreed time frames).	**Rail ticket fees set to stand for at least full operating costs of services** (2001 Directive on infrastructure charges).	**Galileo** (European Global Navigation Satellite System) to support existing ITS solutions once operational	**Core network constituted mostly of existing infrastructure.** Missing cross-border links and links connecting modes to be a priority under the Core Network.	**Infrastructure capacity to be adjusted to real traffic needs**. To make available high capacity links on the entire core network is not an objective.
Liberalisation of rail domestic passenger transport by 2012.	**European airports to be operated as businesses** in a competitive environment	**Ubiquitous communication in Road Transport** Infrastructure to vehicles to reach zero accident targets and tackle congestion	**Transport terminals conceived as multi-modal connection platforms** - All core network airports linked to HSR by 2050. and efficiently connected to closest urban centres with PT	**Increasing separation between passenger and freight traffic** to optimise traffic flows (traffics with different needs) and increase safety
Rail infrastructure is a natural monopoly IMs under scrutiny to ensure that pricing and investment decisions are consistent with the goal of fostering railway	**Internalisation of externalities** The principle for charging should be that of marginal social cost pricing. Congestion pricing should be introduced to pay for local road externalities	**Advanced driver assistance systems** lane departure warning. anti collision. pedestrian recognition. eCall. in-vehicle speed limit regulator	**Corridor approach to infrastructure investment**. (e.g. Brenner Corridor Platform; ERTMS Rotterdam-Genoa freight corridor)	**Road management with ICT** to optimise transport and routes -10% reduction in fatalities per year (3.500 lives) -10% reduction in congestion costs (€ 12.3 billion)
Pan-European rail IMs In the long term to ensure co-ordinated development along key corridors. but allowing competition or benchmarking between different route managers. The EC will keep	**Noise-differentiated infrastructure access charges for rail** (proposed in 2010 by EC).	**Levitation rail**. Implanted in Shanghai airport. Japan plans to build Megalev between Tokyo and Osaka. EU has some trial tracks.	**Complete high-speed rail network by 2050**. Triple the length of existing HSR network by 2030 and maintain a dense rail network in all MS. By 2050 the majority of mid distance passenger transport will go by rail.	**More efficient rail management with ERTMS** (European Rail Traffic Management System). New signalling systems allow more trains to operate safely on a given section of track
EURO Standards Technological standards are effective to accelerate the introduction of cleaner vehicles by providing fixed targets for the industry.	**Airport charges** do not take into account the cost of congestion. or local externalities (noise. NOx)	**Unconventional technologies for aviation unlikely** before 2050. even if development of alternative fuels is accelerating	**Freight dedicated rail corridors**. with exclusive lines or preferential.	**More efficient Air Traffic Management (SESAR).** To reduce between 6% and 13% air trip lengths by 2020 (less air space fragmentation). Currently. Intra-EU routes are 15% less efficient than domestic.
Competitive tendering for public service contracts. and services of general interest. –competition for the market instead of competition in the market.	**Elimination of distortionary subsidies** to infrastructure financing and to service operation. Better modal choices will also have to be guided by prices that reflect all costs associated to transport	**Wind-based concepts** for waterborne transport. and LNG and Nuclear powered shipping	**Airport capacity between 2007 and 2030 will not be met** (between 11% and 25% of demand) despite a 40% capacity increase (Eurocontrol 2008).	**Better management of EU airports** - enhanced landing / take-off slot allocation - "One Stop Security**"** (no further control at transfer points if security control passed already at EU airport) - better ground-handling services
Ex-ante project appraisal. *Guide on Cost-Benefit Analysis in 2002 (updated in 2008)* to be used.	**Integrated funding framework for transport required** European Regional Development Fund (ERDF) and Cohesion Fund (13% of total) and loans from EIB (16% of total) to better focus CTP targets	**Interoperability of electronic technologies** - Electronic ticketing - Electronic tolling - Airport management systems (CUPPs).	**A corridor approach**. Transport corridors will need to be analysed within 2 years from the publication of the future EC *Corridor guidelines*. under the aegis of the European Coordinator and a multi-annual corridor development Plan	**River Information Services (RIS).** Establishment of an interoperable. intelligent traffic and transport system to optimise the existing capacity and safety of IWW and improve interoperability with other transport modes

Market regulation	Pricing & funding	Technology	Infrastructure	Management
Clear treatment of public funding to transport infrastructure and services.	**Diversification of funding sources** both public (EU. National and regional governments) and private (financial institutions and corporate). PPPs increasingly important.	**Electronic ticketing** on mobile devices (smart cards. cell phones…) can provide public transport operators and authorities with real time statistical data on users' behaviour.		**European Integrated Multi-modal Information and Management Plan** (EIMIP). Real-time transport information throughout Europe and multi-modal integrated ticketing all over EU.
	Europe 2020 Project Bond Initiative to provide support to companies issuing bonds to finance large-scale infrastructure projects. The EC would be risk-sharing with the EIB.			

3.3.3 Transport Related Targets Incorporated in the ORIGAMI Normative Scenario

In view of existing targets currently in force in Europe, the ORGIAMI Reference Normative Scenario incorporates the following ones.

Table 3-18 Transport targets

Sector	Year	Target	Source
Total GHG emissions from transport	2030	Transport emissions (including CO2 aviation. excl. maritime). 20% lower in 2030 in relation 2008	Transport White Paper 2011
	2050	Total greenhouse gas emissions reduced 60% respect to 1990	Transport White Paper 2011
GHG emissions from long-distance passenger transport	*2030*	*Transport emissions (including CO2 aviation. excl. maritime). 20% lower in 2030 in relation 2008*	***ORIGAMI***
	2050	*Total greenhouse gas emissions reduced 60% respect to 1990*	***ORIGAMI***
	2020 // 2050	Stabilisation of air emissions by 2020 (carbon neutral growth) and 50% reduction in 2050 compared to 2005	IATA
	2050	CO2 emissions from maritime transport should be cut by 40% (if feasible 50%) by 2050. compared to 2005 levels	Transport White Paper 2011
Transport Infrastructure	2030	Multi-modal TEN-T core network by 2030	Transport White Paper 2011
	2050	All core network airports connected to rail network by 2050. preferably by high-speed rail	Transport White Paper 2011
	2050	Ensured efficient connection between major airports and closest urban centres	Transport White Paper 2011
	2030	To triple the length of high-speed rail network by 2030.	Transport White Paper 2011
	2050	To complete a European high-speed rail network by 2050.	Transport White Paper 2011
	2050	By 2050. the majority of medium-distance passenger transport should go by rail. .	Transport White Paper 2011
Traffic Management	2050	By 2050. the majority of medium-distance passenger transport should go by rail	Transport White Paper 2011
	2050	Move towards full application of “user pays” and “polluter pays” principles	Transport White Paper 2011
Road safety	2020	50% fatalities in road transport.	Transport White Paper 2011
	2050	Close to zero fatalities in road transport	Transport White Paper 2011

3.3.4 Assumptions for the ORIGAMI Normative Scenario in Relation to Other Scenarios

The definition of the Normative scenario is based on a balanced combination of elements from all the ORIGAMI explorative scenarios, and aiming at fulfilling a maximum number of EU policy targets. The assumptions presented in the following table are considered at this point, including the required investment to complete the full TEN-T network projects (approach mostly inherited from OR1 and OR4), technological advances resulting in lower emissions by vehicles (approach mostly inherited from OR2), and management strategies aimed at increasing infrastructure efficiency (approach mostly inherited from OR3), targeted mostly to enhanced rail operation (resulting in increased speeds), and better interconnecting conditions between networks (resulting in lower costs of interconnection).

It should be noted that cost appear twice in this table, since costs can change either through liberalisation of through pricing and taxation.

Table 3-19 Assumptions to define the Normative scenario in relation to all other scenarios

		Scenario Policy Reliance								Changes relative to Baseline 2030				
POLICY INSTRUMENTS	**INPUTS TO MOSAIC-TT**	Baseline	OR1	OR2	OR3	OR4	Normative	Baseline value 2010	Baseline value 2030	OR1	OR2	OR3	OR4	Normative
Market liberalisation	Average Road travel cost (€/km)				Y	G		0.15	0.15	-	-	-2,5%	-5%	-
- Market opening (free competition)	Average Rail travel cost (€/km)				Y	G		0.09 to 0.20	0.09 to 0.20	-	-	-2,5%	-5%	-
- Privatisation (PPPs)	Average Air travel cost (€/km)				Y	G		variable	variable	-	-	-7,5%	-5%	-
	Average Ferry travel cost (€/km)				Y	G		0.15	0.15	-	-	-7,5%	-5%	-
Bans and regulation	Average Car vehicle emissions (grams/veh·km)		Y	G		Y	Y	200 gr/veh·km	135 gr/veh·km	-10%	-35%	-	-15%	-15%
- Efficiency standards	Electric vehicles (% of non-ICE vehicles)		Y	G		Y	Y	2%	20%	+10%	+50%	-	+25%	+25%
- Speed limitations	Car occupation (people/vehicle)			G	Y		Y	2.0 ocu/veh	1.5 ocu/veh	-	+35%	+10%	-	+10%
- Flanking measures (behavioural incentives)	Average Rail emission factors (grams/pax·km)		Y	G			Y	22 gr/pax·km	13 gr/pax·km	-5%	-20%	-	-	-10%
	Average Air emission factors (grams/pax·km)		Y	G	Y		Y	130 gr/pax·km	70 gr/pax·km	-5%	-20%	-10%	-	-10%
	Average Ferry emission factors (grams/pax·km)		Y	G	Y		Y	145 gr/pax·km	100 gr/pax·km	-5%	-20%	-10%	-	-10%
	Road speed (km/h)		G					trans-tools	trans-tools	-5%	-	-	-	-
Pricing and Taxation	Road travel cost (€/km)		G			Y	Y	0.15 €/km	0.15 €/km	+10%	-	-	+5%	+5%
- Road pricing	Rail travel cost (€/km)		G			G		0.09 to 0.20 €/km	0.09 to 0.20 €/km	-10%	-	-	+10%	-
- Vehicle taxation	Air travel cost (€/km)		Y		Y		Y	variable	variable	+5%	-	+2,5%	-	+2,5%
- Rail subsidies	Ferry travel cost (€/km)		Y				Y	0.15 €/km	0.15 €/km	+5%	-	+2,5%	-	+2,5%
- Fuel taxation	Cost of accessing a city from road network (€/km)		G		Y			0.25 €/km	0.25 €/km	+10%	-		-	-
- Air taxation	Cost of accessing an airport from road network (€/km)		G		Y			0.15 €/km	0.15 €/km	+10%	-		-	-
Infrastructure management	Road speed (km/h)					G		trans-tools	trans-tools	-	-	-	+15%	-
- New technological solutions	Rail speed (km/h)				G	Y	Y	trans-tools	trans-tools	-	-	+15%	+5%	+5%
- Organisational issues	Air speed (km/h)				G	Y		trans-tools	trans-tools	-	-	-10min per flight	-3min per flight	-
- Optimisation of precedures	Ferry speed (km/h)				G			trans-tools	trans-tools	-	-	+15%	-	-
	Speed when accessing a city from the road network (km/h)				G			40 km/h	40 km/h	-	-	+15%	-	-
	Speed when accessing a city from the rail station (km/h)		G		G		Y	15 km/h	15 km/h	+7.5%	-	+15%	-	+7,5%
	Cost of accessing an airport from the road network (€/km)				G	Y		0.15 €/km	0.15 €/km	-	-	-20%	-10%	-
	Cost of accessing an airport from the rail network (€/km)		G		G		Y	0.15 €/km	0.15 €/km	-10%	-	-20%	-	-10%
	Cost of accessing a rail station from the road network (€/km)		Y		G	Y	Y	0.25 €/km	0.25 €/km	-10%	-	-20%	-10%	-10%
	Time penalty between consecutive air trips (transit)				G		Y	90 min	90 min	-	-	-15%	-	-10%
	Time penalty before starting an air trip (check-in / security)				G		Y	90 min	90 min	-	-	-15%	-	-10%
Infrastructure provision	More road links (km) in core network		Y	Y	Y	G	G	-	+4,850 km	+33% (+1,650km)	-60% (-2,850km)	-60% (-2,850km)	+200% (+10,150km)	+135% (+6,850km)
- Missing links	More HSR links (km) in core network		G	Y	Y	Y	G	-	+6,290 km	+125% (7,710km)	-60% (-3,790km)	-60% (-3,790km)	-25% (-1,590km)	+100% (6,210km)
- Bottlenecks	More conventional rail links (km) in core network		G	Y	Y	Y	G	-	+6,550 km	+125% (8,200km)	-60% (-3,950km)	-60% (-3,950km)	-25% (-1,650km)	+85% (+5,550km)
- Interconnections between networks	More air links (km)									-	-	-	-	-
	More ferry links									-	-	-	-	-
	Airport - rail interconnections		G				G	60 airports	60 airports	airports < 10km also connected	60 airports	60 airports	60 airports	airports < 10km also connected

G: Scenario considers this policy intensively
Y: Scenario considers this policy as complementary to others
Scenario doesn't specifically consider this policy

3.4 Other Exogenous Assumptions for All Scenarios

During the development of the assessment framework for the scenarios a number of indicators were identified, for which it would have been desirable to include them in the evaluation of the scenarios. However, it became clear that these indicators do not constitute any output from MOSAIC, but exogenous assumptions that are background to the scenario description. They fall under five headings:

- Transport costs;
- Environment;
- User needs;
- Efficiency; and
- Economic development.

Table 3-20 Other exogenous assumptions

	Baseline 2030	OR1	OR2	OR3	OR4	Normative
Transport cost variables and indicators						
Investment costs	€300,000 million in TEN-T core network	€530,000 million in TEN-T core network	€150,000 million in TEN-T core network	€180,000 million in TEN-T core network	€410,000 million in TEN-T core network	€600,000 million in TEN-T core network
User pays for full costs of transport	Increased costs of transport due to increased fuel costs, and moderate internalisation of road transport externalities	Taxation on air and car trips increase the level to which these modes pay for their internal and external costs, while revenues are used to increase rail and ferry subsidies	No significant differences to Baseline	In line with Baseline	Subsidies on urban public transport substantially lowered. Long-distance and high-speed rail services only where economically profitable for operators. Tolls generalised on most motorways	Moderate internalisation of road transport externalities. Subsidies reduced
Environmental variables and indicators						
Phase out conventionally fuelled cars	From 2% to 20% cars not using fossil fuels	22% cars not using fossil fuels	30% cars not using fossil fuels	20% cars not using fossil fuels	25% cars not using fossil fuels	25% cars not using fossil fuels
Use cleaner and renewable energy	Progressive increase in the use of renewable energies to power electric modes (mostly rail), and cleaner technologies for other modes (autogas, biofuels)	Sharp modal change towards electricity based modes such as rail.	Increased use of biofuels and increased electrification of transport. Hydropower, wind farms and solar farms to partially power railways, and some motorways	Increased share in biofuels applied to transport	More renewable energies used in the transport sector, through increased use of biofuels and increased electrification of transport	More renewable energies used in the transport sector, through increased use of biofuels and increased electrification of transport

	Baseline 2030	OR1	OR2	OR3	OR4	Normative
High percentage of low-carbon fuels in aviation and shipping	Progressive penetration of low-carbon fuels in aviation and maritime transport	Slightly higher penetration of low-carbon fuels in air and maritime modes in relation to Baseline	Substantial increase in the share of low carbon and low contaminating technologies in air and maritime modes	Moderate increase in the share of low carbon and low contaminating technologies in air and maritime modes	In line with Baseline	Moderate increase in the share of low carbon and low contamina-ting technologies in air and maritime modes
Average CO2 emissions per 100 km per mode (TTW, tank-to-wheel)	from 200 to 135 grams per kilometre for cars; from 130 to 70 grams per passenger per kilometre for aviation; from 22 to 13 grams per passenger per kilometre for rail; from 145 to 100 grams per passenger per kilometre for ferries	from 200 to 120 grams per kilometre for cars (-10% more than Baseline); from 130 to 65 grams per passenger per kilometre for aviation (-5% more than Baseline); from 22 to 12 grams per passenger per kilometre for rail (-5% more than Baseline).	from 200 to 90 grams per kilometre for cars (-35% more than Baseline); from 130 to 55 grams per passenger per kilometre for aviation (-20% more than Baseline); from 22 to 10 grams per passenger per kilometre for rail (-20% more than Baseline).	Same emission factors for road and aviation as in Baseline. 5% lower emissions per passenger on rail, due to increased load factors	from 200 to 115 grams per kilometre for cars (-15% more than Baseline); same as Baseline for aviation and rail	from 200 to 115 grams per kilometre for cars (-15% more than Baseline); from 130 to 60 grams per passenger per kilometre for aviation (-10% more than Baseline); from 22 to 11.5 grams per passenger per kilometre for rail (-10% more than Baseline).
Noise pollution	Progressive decline in noise, mostly due to improved technologies in cars, airplanes, trains and ferries	Slightly decrease in access to cities, but increases in rail corridors	Sharp decrease in transport noise. More silent vehicles in all modes: car / rail / air / ferry	Relative decline in road corridors in urban areas, due to more homogenous road traffic flows, and increased vehicle technology	Not substantially different from Baseline	Sharp decrease in transport noise. More silent vehicles in all modes: car / rail / air / ferry
Water pollution	Moderate decrease	Moderate decrease	Sharp decrease thanks to technology	Moderate decrease	Moderate decrease	Sharp decrease thanks to technology
User needs variables and indicators						

	Baseline 2030	OR1	OR2	OR3	OR4	Normative
Safety	General increase of transport safety in line with observed trends over the last 2 decades	Increased regulation leads to increased safety of transport	A mix of increased regulation and smarter infrastructure increases safety of transport	Mostly smarter infrastructure increases transport safety	Smarter vehicles allow for almost zero road accidents.	A mix of regulation and smarter infrastructure and vehicles allow for almost zero accidents in all modes.
Security	Despite no significant strengthening of security procedures and regulation, transport security remains relatively good	Regulation on security standards in transport terminals results in increased transit times due to more time required for security procedures	As Baseline	Security standards strengthened but technological advances allow still to reduce time devoted to security procedures in transport terminals	As Baseline	Security standards strengthened but technological advances allow still to reduce time devoted to security procedures in transport terminals
Accessibility for people with impaired mobility	Regulation favours that most significant obstacles for impaired users are addressed in largest transport terminals	All transport terminals and interchangers fully adapted to impaired mobility users	Improved accessibility for impaired users in transport terminals but also in cars, as vehicles become increasingly customisable to different user needs, and more automated	As Baseline	As Baseline	Improved accessibility for impaired users in transport terminals but also in cars, as vehicles become increasingly customisable to different user needs, and more automated
Comfort and convenience	Moderate increase in transport comfort, mostly thanks to improved vehicles, and better user information	Increased transport comfort in rail, access/egress public transport modes and interconnections between modes, mostly due to upgrading of infrastructure Decreased comfort for car users.	Increased comfort for users mostly derived from improved vehicles	As Baseline plus increased convenience of road transport due to reduction of urban congestion	Increased comfort for users mostly derived from improved vehicles	As Baseline plus enhanced transport terminals
Efficiency variables and indicators						

	Baseline 2030	OR1	OR2	OR3	OR4	Normative
Attractive service frequencies	Progress in the provision of attractive service frequencies for services with high levels of demand. Some DRT systems in areas with low demands	Substantially increased frequencies for rail and public transport. DRT spread in areas with low demand	As Baseline	Progress for services with high levels of demand, but decrease of offer where services do not meet sufficient economic profitability	Progress for services with high levels of demand, but decrease of offer where services do not meet sufficient economic profitability	As Baseline
Reliable transport services	Increased reliability of services. Just in time traveller information allows passengers to adapt more easily to incidences in service provision	As Baseline	As Baseline	Substantially more reliable, especially for rail services and air services, mostly due to large technology deployment allowing for more efficient management.	Substantially more reliable, mostly due to large technology deployment allowing for more efficient management.	Substantially more reliable, especially for rail services and air services, mostly due to large technology deployment allowing for more efficient management.
High quality mobility services	Increased overall quality of mobility services	High quality mobility services, especially in rail and public transport	As Baseline	Increased quality of services, especially in air sector	As Baseline	High quality mobility services, in rail and public transport, and in air
Intermodal integration of services	No significant integration beyond specific commercial agreements reached by operators	Integrated tickets for easier intermodal services promoted and subsidised by the public sector, especially air-rail and access / egress from cities	Public sector is receptive to integration, but no specific actions are envisaged to promote agreements between operators	Intermodal integration takes place only when economically profitable.	As Baseline	Public sector is in receptive integration, but no specific actions are envisaged to promote agreements between operators
Awareness of intermodal services	Users become more aware of transport alternatives, and on the carbon footprint they bring associated	As Baseline	As Baseline	As Baseline	As Baseline	As Baseline
IT for simpler transfers	ITs are mostly deployed for increased user information (just-in-time service information)	As Baseline	As Baseline	As Baseline	As Baseline	As Baseline

	Baseline 2030	OR1	OR2	OR3	OR4	Normative
Deployment of air traffic management infrastructure	Advances in ATM allow for moderate improvements in management efficiency of air space and airport capacity	Limited. Less than in Baseline	As Baseline	Substantial advance in ATM systems (Direct routing, optimisation of airport slot allocation, enhanced weather services)	Progress in ATM systems	Advances in ATM allow for moderate improve-ments in management efficiency of air space and airport capacity
Road and Rail ITS deployment	Advances in ITS implementation in transport infrastructure allow for moderate improvements in management of available capacity	Limited	Limited	Ubiquitous smart infrastructure allows for reduced road / rail congestion (MCS / ERTMS) and enhanced capacity with low investment rates in infrastructure. Wide-spread VTV and VTI technologies (cooperative transport)	Enhanced management of access/egress roads.	Advances in ITS implementa-tion in transport infrastructure allow for moderate improve-ments in management of available capacity
Deployment of maritime transport management systems	Advances in maritime services operation	Limited advances	Limited advances	Substantial advances in maritime services operation	Limited advances	Advances in maritime services operation
Economic development variables and indicators						
Administrative burden	Not significantly reduced	Increased due to more restrictive security standards (customs, documentation required for international trips)	Not significantly reduced	Significantly reduced	Moderately reduced	Significantly reduced

Transport costs

Concerning investment costs, the differences between scenario OR2 and OR3 on the one side and OR1 and OR4, and even more so the Normative scenario, on the other side, are significant, with the last one being twice as high as the Baseline scenario. Concerning the user pays principle, OR2, OR3 and the Normative scenario do not differ very much from the Baseline scenario, while in OR4 public transport subsidies are reduced and most motorways are tolled. In contrast, in OR1 taxation on air and car travel means that these modes pay for their internal and external costs while rail and ferry travel is subsidised.

Environment

The level of conventionally fuelled cars is similar in all scenarios, with only OR2, with its combined emphasis on regulation and technology investment, showing a slightly higher percentage. In line with this, OR2 also shows the strongest emphasis on renewable energy sources in general as well as highest increase in the use of low carbon fuels in aviation and shipping, while OR3, with less regulation and its main reliance on biofuels, is the least environmentally benign scenario.

As a result, also the reduction in GHG emissions from cars is largest in OR2, where an output of 90 grams per kilometre is being achieved, while OR1, OR4 and the Normative scenarios only manage to get down to 115 or 120 grams per kilometre, and O3 even has with 135 grams per kilometre the same level as the Baseline scenario. Similarly GHG emissions from aviation are lowest in OR2, with Baseline and OR4 highest and the other scenarios lying in between. For rail the picture is the same, although the absolute differences are very low with values only ranging from 10 to 13 grams per kilometre. For ferries the assumptions are the same in all scenarios.

OR2 also assumes the highest reduction in noise and water pollution, but for these indicators also the Normative scenario assumes the same sharp decrease. For water pollution there is no difference between the other four scenarios. For noise, in OR1, with its shift from car to rail travel, there is a reduction in the access to cities, but an increase on the rail corridors; for OR3 there is some decline due to more homogenous traffic flows and improved vehicle technology.

User needs

For safety there is an increase in all scenarios, but in OR1 for all modes, while the other scenarios only have safer cars, in particular in OR4 and the Normative scenarios where there are almost no accidents.

For security, two of the scenarios are the same as the Baseline, while increased security will increase transit times in OR1 and decrease in OR3 and the Normative scenario due to advanced screening technology.

Concerning mobility impaired passengers, Baseline, OR2 and O4 all assume that most significant obstacles in transport terminals will be removed by 2030, while OR1 assumes that regulation has made sure that impaired passengers have full access in all terminals. OR2 and the Normative scenario assume in particular that advanced vehicle technology has enabled this user group to become car drivers.

All scenarios assume increased comfort and convenience for passengers, and in particular for car drivers, except for OR1, where the use of public transport is encouraged through relevant infrastructure investment while less is invested in improving cars.

Efficiency

Service frequencies increase for services with high levels of demand in all scenarios, but actually decrease where demand is low in OR3 and OR4, and while demand responsive services spread at least to some extent in low demand areas in the Baseline, OR2 and the Normative scenario, it is only in OR where they are becoming widespread. Transport services are becoming somewhat more reliable in the Baseline, OR 1 and OR2, but substantially more reliable in the other three scenarios. They also are going to have a higher standard of quality in all scenarios, but particularly for rail and public transport in OR1, for air in OR3 and rail, public transport and air in the Normative scenario. Concerning intermodal integration, the only scenarios standing out if OR1, where integrated tickets are promoted and even subsidised, and in all scenarios awareness of intermodal offers is increasing.

It is in all scenarios deployed for user, and in particular, real-time information to ensure easy transfers within one mode or from one mode to another. Differences between scenarios exist concerning air traffic management: the most substantially advances are made in scenario OR3 – hence also the increased quality of services – while the least effort into air traffic management is made in OR1, which favours rail. OR 3 also had the biggest advances in ITS deployment for road, rail and the maritime sector, while they are all rather limited in OR1 and OR2, with the other scenarios somewhere in between.

Economic development

Differences between scenarios only exist for the administrative burden. This is significantly reduced in OR3 and the Normative scenario, while the strong regulation in OR1 increases it.

4 EVALUATION OF THE SCENARIOS FOR 2030

4.1 BASIC INDICATORS

4.1.1 Network Usage and Mobility

Network usage by passengers

In accordance with the assumption made in the Baseline 2030 scenario that there will be no new policies so that the development of traffic follows current trends, network usage by long-distance passengers increases from just over 1 trillion to 1.136 trillion passenger kilometres (pax km) by year, and increase of 12.3% (Table 4-1).

Table 4-1 Network usage by passengers (total passenger kilometres)

	Network usage (million passenger kilometres / year)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	678,506	688,238	532,758	641,589	652,430	725,591	647,915
Rail	60,494	70,924	227,020	66,090	96,502	39,771	101,935
Air	259,646	363,493	364,984	392,927	375,915	353,940	372,969
Maritime	12,740	13,426	14,233	6,032	13,725	12,414	14,461
Total	**1,011,386**	**1,136,082**	**1,138,995**	**1,106,638**	**1,138,571**	**1,131,716**	**1,137,280**

Figure 4-1 visualises the relative usage overall and by mode.

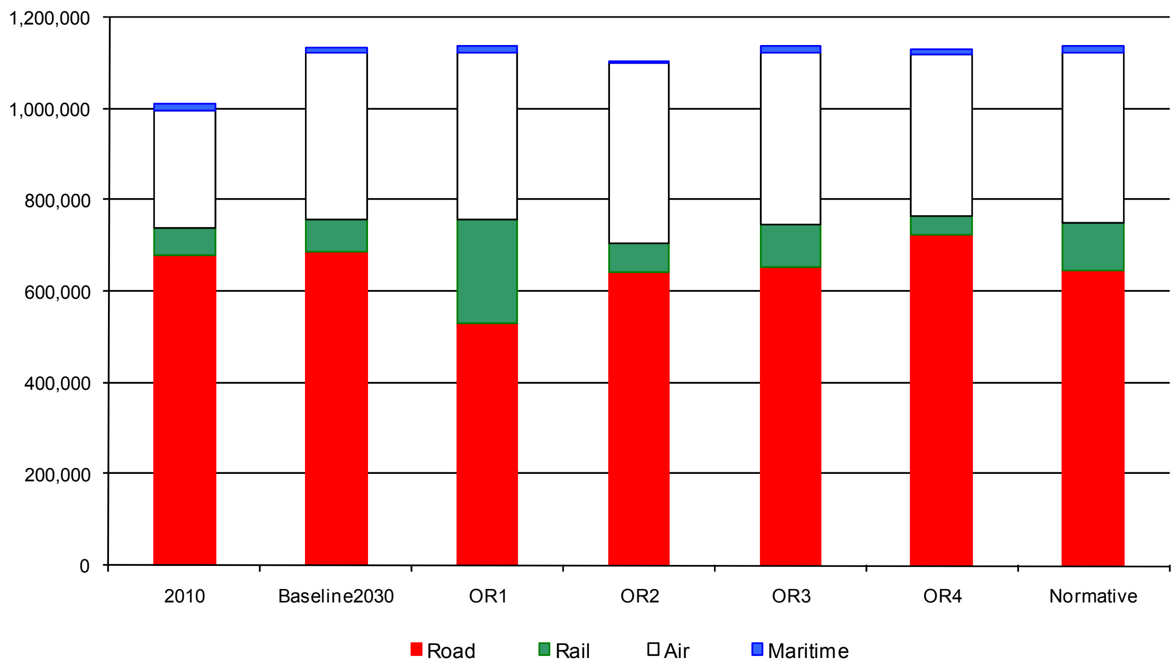


Figure 4-1 Distribution of network usage by passenger kilometres

Despite the fact that all scenarios in 2030 have the same number of trips between each Origin-Destination NUTS3 pair (OD), total pax km travelled in Europe differ from one to another scenario, even if these differences are not always substantial. Different costs of operation and different infrastructure availability in each of the 2030 scenarios leads to different route choices by passengers to travel between NUTS3 OD pairs, with different lengths, resulting in variations of the total number of pax km travelled (Figure 4-2).

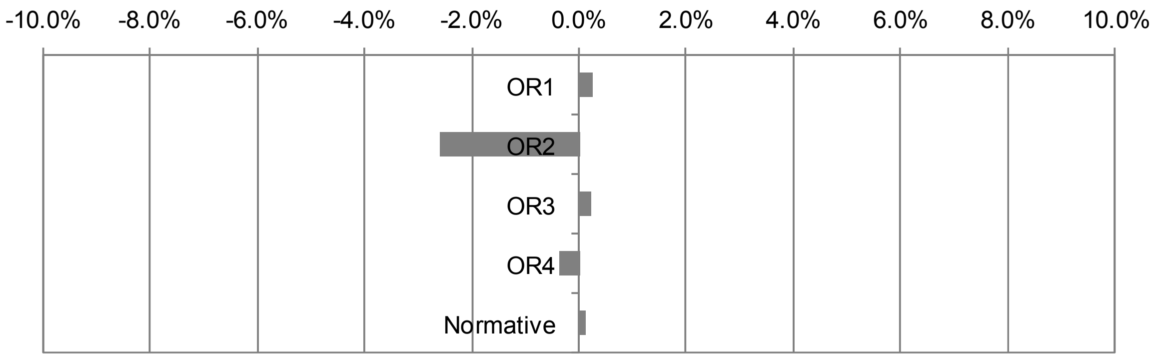


Figure 4-2 Change in total traffic (passenger kilometres) in relation to Baseline 2030, all modes and trip purposes included

Most notable is the difference for OR2, where there are 2.6% pax km less than in Baseline 2030. As Table 4-1 shows, this is also the scenario with the highest share of air travel, and air travel – if not involving flight connections - is more direct than travel on road or railways, thereby saving pax km. In OR2 air mode wins traffic from all modes but mainly from the road. Fewer investments in new road and rail infrastructures, with unchanged operating costs for all modes, lead to an increase of the air modal share with a reduction of road modal share.

On the other end of the spectrum is OR4 with the lowest air share although cost and time savings for air are larger than for OR2. However, this is compensated through the fact that OR4 heavily invests into infrastructure, leading to much higher speed on rail and even more so road, in turn leading to the largest share of road traffic of all scenarios for OR4. Rail loses most passengers since rail subsidies are reduced and average rail increases as a consequence.

The Normative scenario has slightly more pax km than the Baseline 2030, and it is the emphasis on rail combined with the fact that this is often the least direct form of travel that leads to this outcome. In line with this argument, OR1 has the most pax km of all scenarios. OR1 shows a strong transfer of traffic from road to rail, hence OR1 is the scenario with the highest rail share (20%). Such an increase is due to the important investments in rail infrastructure and the improvement in access/eggress conditions to rail, as well as the reduction of rail costs (increased subsidies to services) and the increase of road costs (eurovignette applied to road passenger transport).

Pax km in OR3 are nearly as high as in OR1, although it has more air and less rail travel than OR1. This is due to the strong but not necessarily very efficient intermodality in this scenario. The penalties for interchange are very low here, which results in particular in connecting flights through hubs that incur large detours from the direct route. Actually, it is OR1 that has the highest multimodality of all, but here the connections are less complex incurring fewer detours in the air mode, even if overall it is also the one with the highest pax km. These results are not in line with earlier ones in the INTERCONNECT project (Ulied at all, 2011, D5.3) where it was found that multimodality decreased overall pax km, even if only by a very small amount. The difference stems from the fact that in INTERCONNECT only the interchange penalty was reduced, while in ORIGAMI a much range of factors was varied, in particular pricing structures, which will have led OR1 and OR3 into using the cheapest route and not always the shortest one. Therefore no general conclusion on the effect of multimodality on pax km can be drawn.

Figure 4-3 visualises the changes against the Baseline for all modes. Most striking is the change from road to rail in OR1, which was already mentioned above. OR2 is the only one where the rail share is hardly affected at all by the scenarios assumptions. The absolute change in air pax km is only significant in OR2, which together with OR3 has the lowest investment in infrastructure, but is not as liberalised as OR3.

The Normative scenario has a modal shift similar to that of scenario OR3 but favouring rail a little more than the air mode. The scenario has a slight increase in air transport (+0.8%) and rail transport (+3%). The Normative scenario achieves this modal shift through some changes in transport costs but especially through high investments in new infrastructure, while scenario OR3 achieves a similar modal shift thanks to important reductions in transport costs and improvements in access/egress to long distance travel as well as reductions in transport interchange penalties.

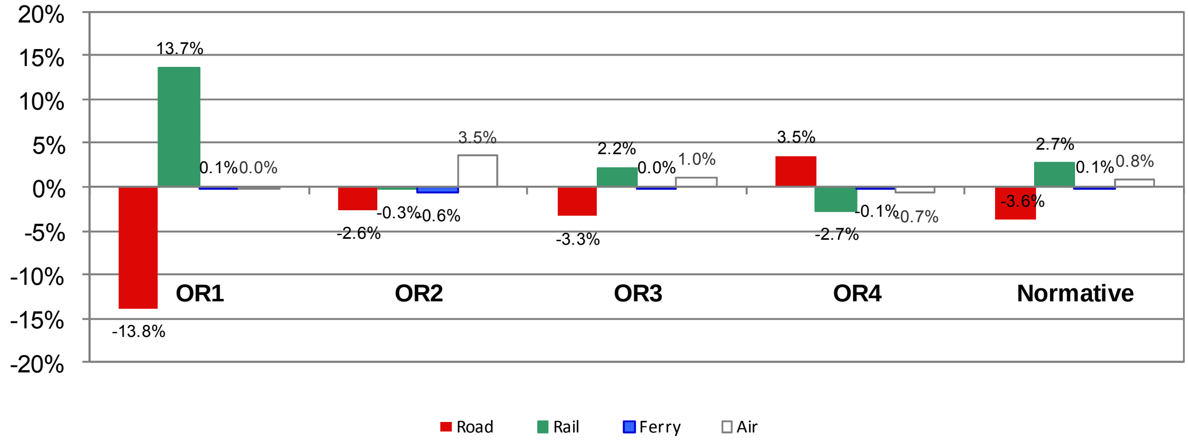


Figure 4-3 Change in long-distance modal shares in relation to Baseline 2030 (based on passenger kilometres), all trip purposes included

What also stands out for OR2, although possibly more from Table 4-1 than from Figure 4-3, is that this is the only scenario where maritime traffic is significantly lower than in all of the other scenarios. The absolute share of the maritime mode is very low in all scenarios, but in OR2 it is less than half of that in the others. This goes back to the low investment in infrastructure, which particularly affects ports that become increasingly unattractive and drive passengers to fly instead of using ferries.

Network usage by vehicles

Table 4-2 lists the network usage by vehicles. Network usage by vehicles for each transport network is defined as the total amount of vehicle kilometres travelled during one year on that specific network. It corresponds to the total number of passenger kilometres divided by the average vehicle occupancies.

Table 4-2 Network usage by vehicles (total vehicle kilometres)

	Network usage (million veh km / a)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	339,253	458,825	355,172	316,834	395,412	483,727	431,943
Rail	242	284	908	264	386	159	408
Air	1,527	2,138	2,147	2,311	2,211	2,082	2,194
Maritime	64	67	71	30	69	62	72
Total	**341,086**	**461,314**	**358,298**	**319,440**	**398,078**	**486,031**	**434,617**

What is striking immediately is that vehicle km are really only significant for cars, all other three paling into insignificance by comparison, which is no surprise given that road is the mode which has a lowest capacity of vehicles, only up to five occupants for cars, the most dominant type of road vehicles, a few more for vans and around 50 for the relatively few long-distance coaches, and the actual average vehicle occupancy being only between 1.5 and 2.025 in the different scenarios. In 2010 the actual average for Europe is somewhere between 1.5 and 2, with the higher values to be found in Eastern European countries with lower car ownership. However, since for long-distance trips average occupancy is higher than for commuting or shopping trips, 2.0 has been chosen for the 2010 scenarios. For most 2030 scenarios the value is 1.5, reflecting increasing car ownership in the East. The exception is OR2, a scenario with an important emphasis on behavioural change. In OR2 society is more concerned about using cars responsibly. Also the administration may reward responsible behaviour of drivers. In this scenario, car sharing and car pooling systems as well as high capacity lanes HOV-HOT are very successful. Coupled with the fact that OR2 also has the second lowest pax km, even lower than the 2010 figure (Table 4-1) in spite of a general growth of mobility between 2010 and 2030, this leads to the lowest number of veh km.

For rail, the additional demand in the Normative scenario and above all in OR1, which goes together with a much increased network, can clearly only be met with additional rolling stock, leading to much increased veh km. In contrast, in OR4, with reduced passengers and a reduced network size compared to Baseline 2030, services will be withdrawn, leading to lower veh km. More difficult to manage is OR3 with increased passenger numbers and increased veh km on a decreased rail network, but OR3 is the scenario which particularly emphasises traffic management and technology in particular to meet this challenge.

For air, there is a strong increase in veh km from 2010 to 2030, but the differences between the 2030 scenarios are relatively small, which is in line with the fact that, although the absolute number of pax km is very high, the differences are also small with a maximum of 11% difference between them.

Finally, maritime traffic does not differ much between 2010 and most of the 2030 scenarios with the marked exception of OR2, which in line with the reduced pax km also withdraws more than half of today's existing services.

Network usage by passengers, represented on a NUTS3 basis

Figure 4-4 shows the passenger kilometres generated in each EU NUTS3 for the Baseline 2010 in total and per inhabitant on top left and right, the change for Baseline 2030 against Baseline 2010 on the bottom left, and the change for the Normative scenario against Baseline 2030 on the bottom right. They show the regional differences in the level of mobility. The blue dots represent the population of each zone and are located in the largest city of the zone rather than in the geometric centre as in TRANSTOOLS. Outside the EU the zones are generally larger than NUTS3, and hence some of the largest dots are to be found there.

In absolute terms, the highest levels of mobility can be found in Turkey, some of the most northerly parts Russia, large parts of a corridor from the South of England through France and parts of Switzerland to Northern Italy, and around some of the European capitals. However, it would be misleading to judge the levels of personal mobility from that, since, as stated above, the regions do not all have the same size. The figure with the pax km travelled per inhabitant therefore gives a truer picture of personal mobility.

In the top right picture mobility is cleaned from differences in inhabitants. High mobility levels in one NUTS3 can still now indicate two things: either intense economic activity or very long trips being originated in the NUTS3 (e.g. because of being peripheral), or both at the same time.

In the figure it becomes clear that peripherality only accounts for larger personal mobility in parts of Scandinavia and Russia and not in as many areas as indicated by the first figure. The areas around capital cities do now show no longer higher mobility than the surrounding regions. And most significantly, the picture is now very similar for all of the UK, France, most of Italy, but also Germany, Austria, Slovenia, Croatia, Belgium, The Netherlands and Denmark, with only some of the more rural areas of France still standing out with particularly high pax km per inhabitant. For Spain higher levels of mobility are only showing for some parts in the northern part of the country. Pockets of very high mobility show up for three largely rural regions in north and west Serbia, but in general mobility is relatively low east of Germany, Austria and Croatia and south of northern Spain.

The comparison between Baseline 2030 and 2010 shows that there is some growth in most parts of Europe. In particular peripheral areas are catching up on mobility fast, even if the picture is not uniform, with generally strongest growth in the east. In the west, mobility in Ireland is growing fast, Iceland at a medium rate, while there is little growth or even a marginal decline in most parts of Spain and Portugal.

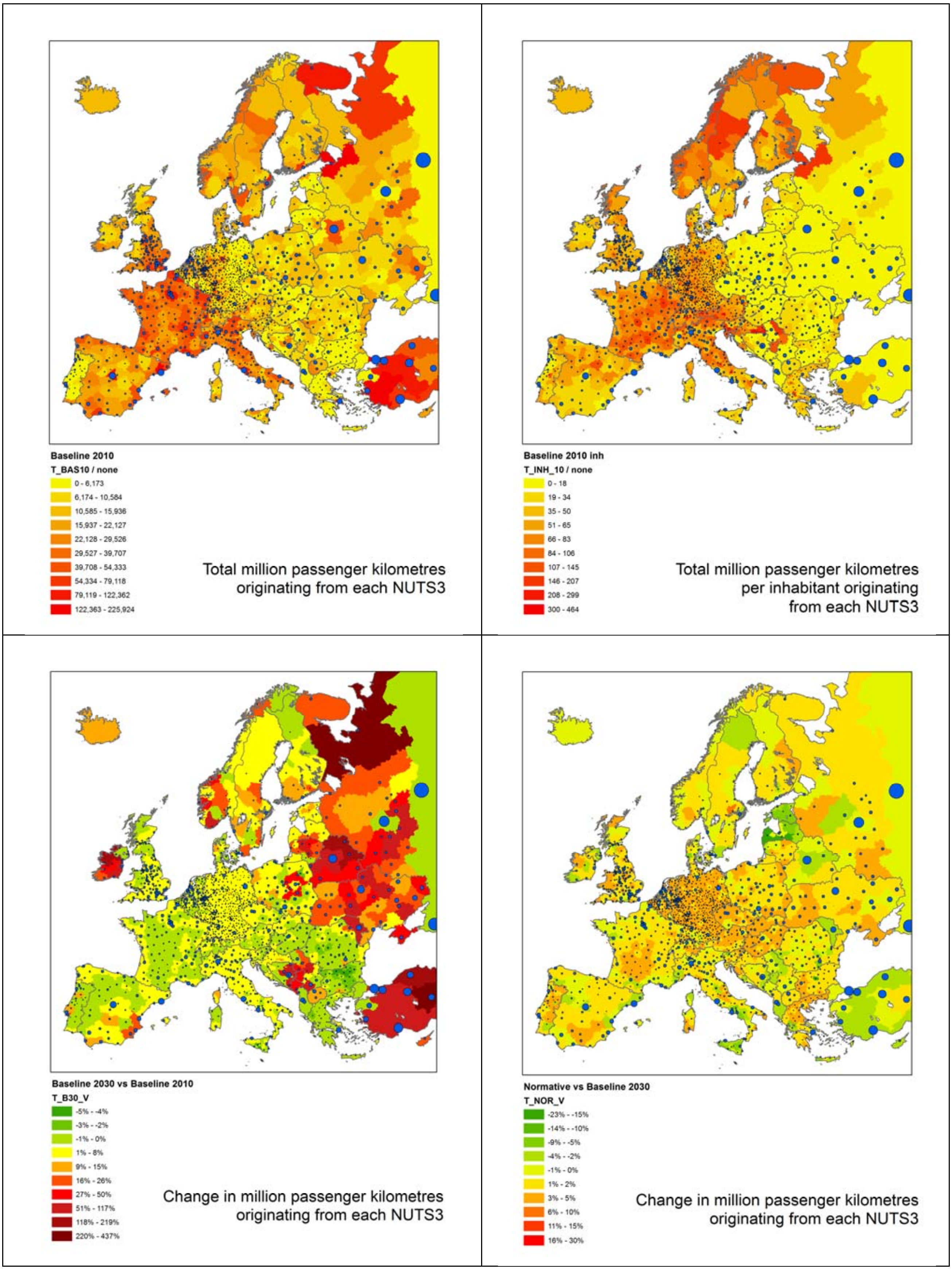


Figure 4-4 Passenger kilometres generated in each NUTS3 Baseline 2010 and relative change Baseline 2030 and Normative scenario

Another pocket of growth is in the area in Montenegro, the east of Bosnia-Herzegovina and the west of Serbia. In contrast, there even areas of relatively strong negative growth in practically all of Bulgaria, nearly half of Romania and some parts of Poland, where it is thought that there will be strong outward migration.

The Normative scenario only shows moderate changes to Baseline 2030. The main colours on the map are different shades of yellow, indicating modest passenger growth, in particular in the most central parts of Europe where the quality of mobility services is improved, while most of the green areas with a passenger decline are at the European periphery, where the length of trips does not increase as much as in the Baseline 2030.

A comparison with Figure 4-5 also shows that the Normative scenarios is the one that is closest to the Baseline, while the four exploratory scenarios OR1 to OR4 all show either much more orange or much more green, i.e. much stronger changes to the Baseline 2030.

OR1 and OR3 both had the highest growth in pax km according to Table 4-1 and the difference between them is minimal. Therefore the amount of yellow and orange is also very similar in both, but the distribution within Europe is not quite the same: in OR1 there is more growth in the north east and even some decline in the south west, while in OR3 pax km are growing more on the Iberian Peninsula and growth is also stronger in Poland and south eastern Europe. The reasons lie mainly in the distribution of the infrastructure and to a lesser extent in the pricing structure.

First of all, the costs in OR1 clearly favour rail, while in OR3 there is a general reduction of costs and also improvement of speeds that leads to some more rail usage but not as much as in OR1. A second reason for differences is that in OR1 the investment on new infrastructures is about four times that of OR3, leading to very different infrastructure scenarios.

In OR1 there are new High Speed Rail links in Spain that connect it to France. This new network of rail is so comprehensive that most major cities have a new faster and shorter route. This is the reason why in Spain there are several regions with decreased mileage. Something similar happens in Romania and Bulgaria where now there is a new network of conventional rail. On the other side there is Poland, with many new roads and motorways that offer a good chance of making longer multimodal trips combined with the existing rail.

In OR3 some new sections of rail appear in Spain, France or Poland, but they do not have too much continuity and thus are only attractive for relatively short distance travel or as part of a longer multimodal trip. Some new road sections also appear on Germany, Poland and Bulgaria, adding more possibilities for multimodal trips.

In contrast to OR1 and OR3, OR2 and OR4 are largely green and yellow, with only very few localised orange pockets, but again the distribution across Europe is very different between them. In OR2, where there is little investment in infrastructure, there is some slight increase in pax km for the more central and eastern parts of Europe and all the emphasis is on direct flight connections from and to the peripheral parts, reducing pax km by more than 35% in the Azores, Malaga, Barcelona, Malta, western Crete, Turkey, Iceland, central Sweden, Copenhagen and northern Finland. These strong decreases more than compensate for the yellow areas in the centre of Europe, because they affect the trips with the longest distances. This makes OR2 overall by far the scenario with the lowest mileage.

In OR4 the reduction is mileage is much more uniform throughout Europe and in contrast to OR2 it goes nowhere over the maximum of 14%. The rail network has been reduced against the Baseline 2030 and the emphasis is here on road building and reduction on flight time and cost. The biggest beneficiaries from the road building programme are the Eastern European countries where bottlenecks and missing links are in particular addressed and people find it much easier to reach their destination by car. The reduction of pax km in Northern Scandinavia, in contrast, is due to the market liberalisation and the cheaper and faster flight connections to other parts of Europe.

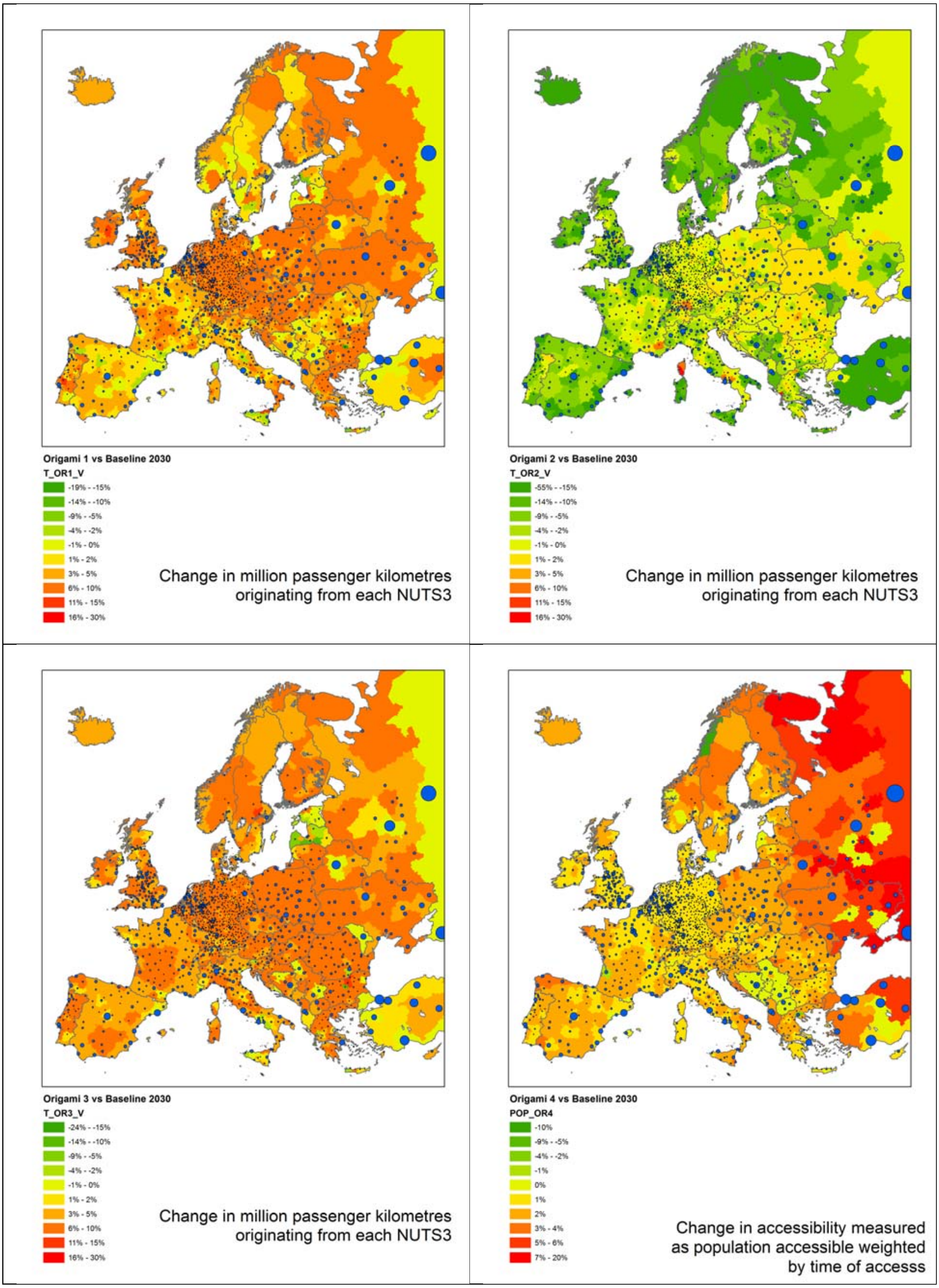


Figure 4-5 Relative change of passenger kilometres generated in each NUTS3, between OR1 to OR4 Scenarios against Baseline 2030

Network usage for unimodal and multimodal trips

Multimodal trips in the ORIGAMI scenarios are defined as those trips using two or more different modes, where the second most used mode represents at least 15% or more of the total trip distance. Access/egress to rail stations or airports from nearby areas by road or by rail usually do not account for multimodal trips, since in most cases access/egress accounts for less than 15% of the total trip length.

The level of multimodality is defined in ORIGAMI as the share of trip kilometres in multi-modal trip chains out of the total. Multimodality depends in each scenario on the cost of each transport mode for any origin-destination pair. When interconnections between modes become faster and cheaper, multimodality tends to grow.

The OR1 scenario has the highest multi-modality that is it has a larger number of passenger kilometres allocated on multi-modal travel chains (24%), while the OR2 scenario has the lowest, with only 9%. This is due to the fact that OR1 has the huge increase in rail journeys, many of which are connected with road journeys to the rail station which are above the 15% threshold. OR2 in contrast is dominated by the very long flights, as shown in the previous section, and for these flights nearly all access legs will be below the 15% of the overall trip.

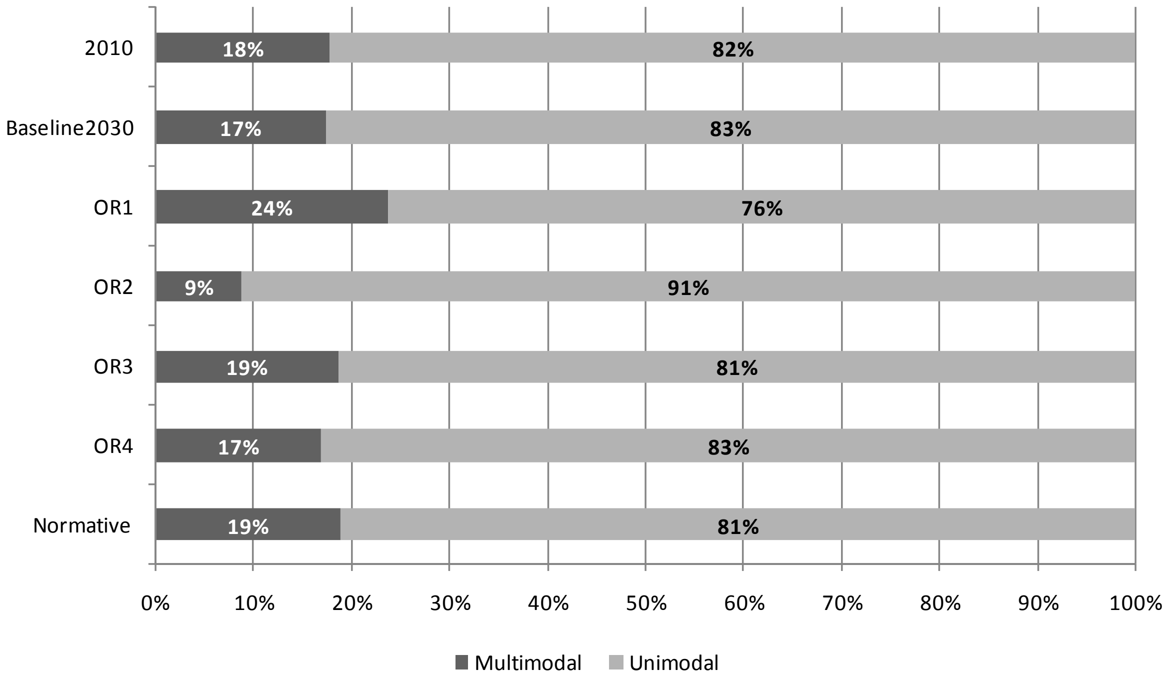
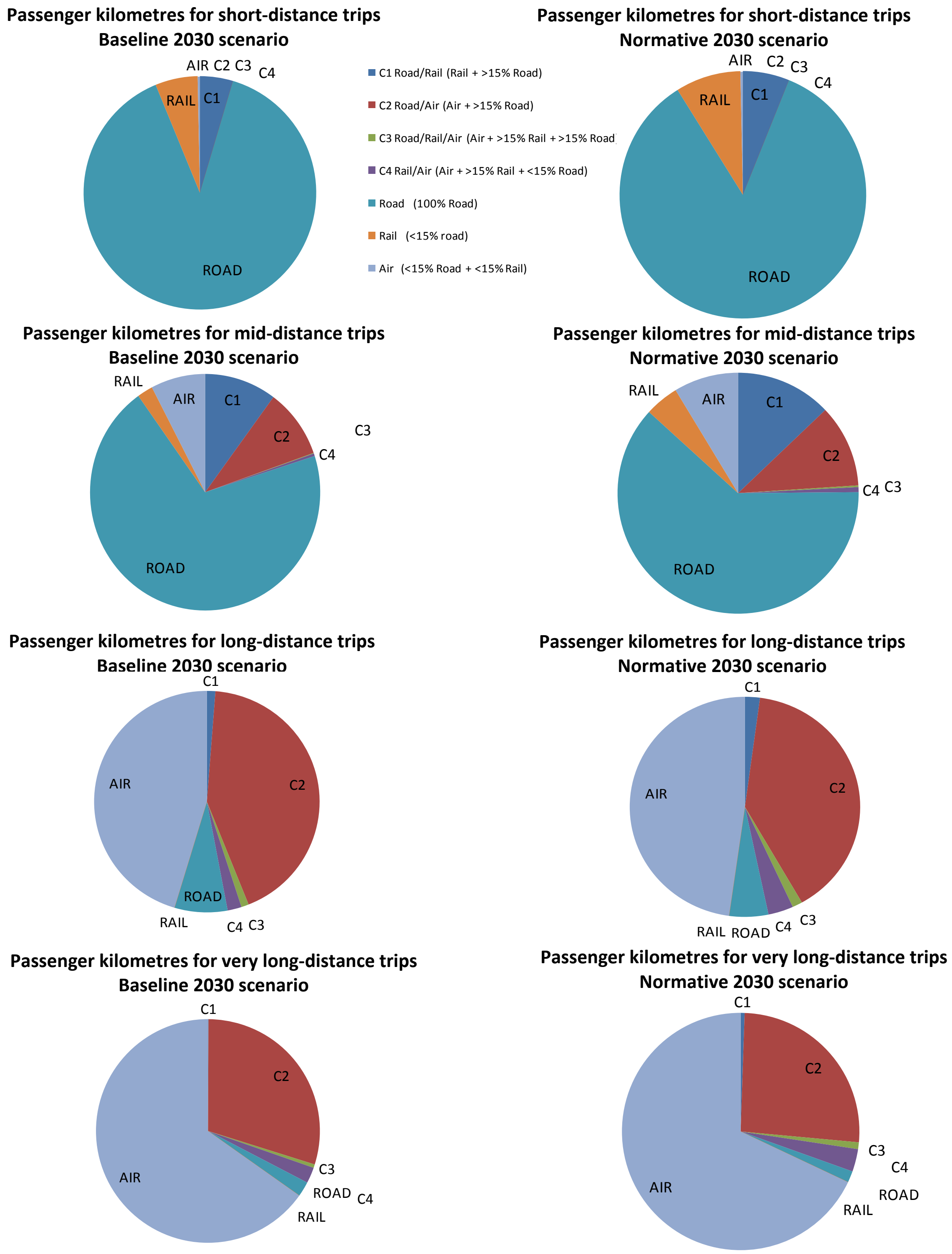


Figure 4-6 Share of passenger kilometres on multimodal travel chains and unimodal travel chains for year 2010 and all 2030 scenarios

The Normative Scenario and the 2011 White Paper

Figure 4-7 represents the way in which passenger kilometres are allocated to different transport chains. The road, rail and air chains represent unimodal trips, while the C1 to C4 chains represent multimodal trip chains. C1 represents trips using rail and road; C2 represents trips using air and road; C3 represents trips using rail, air and road; and C4 represents trips using rail and air. Trip lengths are short-distance (below 300km), mid-distance (between 300km and 1000km), long-distance (between 1000 and 2000km) and very long-distance (above 2000km).

The figure focuses on the comparison between the Baseline 2030 and the Normative scenario in order to establish how far the Normative scenario goes towards fulfilling the 2011 White Paper policy target of accommodating most mid-distance transport in Europe by rail by 2050, although it shows the results for all distance categories for completeness.



Short-distance are trips under 300km; Mid-distance are trips 300 to 1000km;Long-distance are trips 1000 to 2000km; Very long-distance are trips over 2000km

Figure 4-7 Modal share for different modal chains in total trips for Baseline 2030 and Normative scenario

The general tendencies in Figure 4-7 are the same for both scenarios:

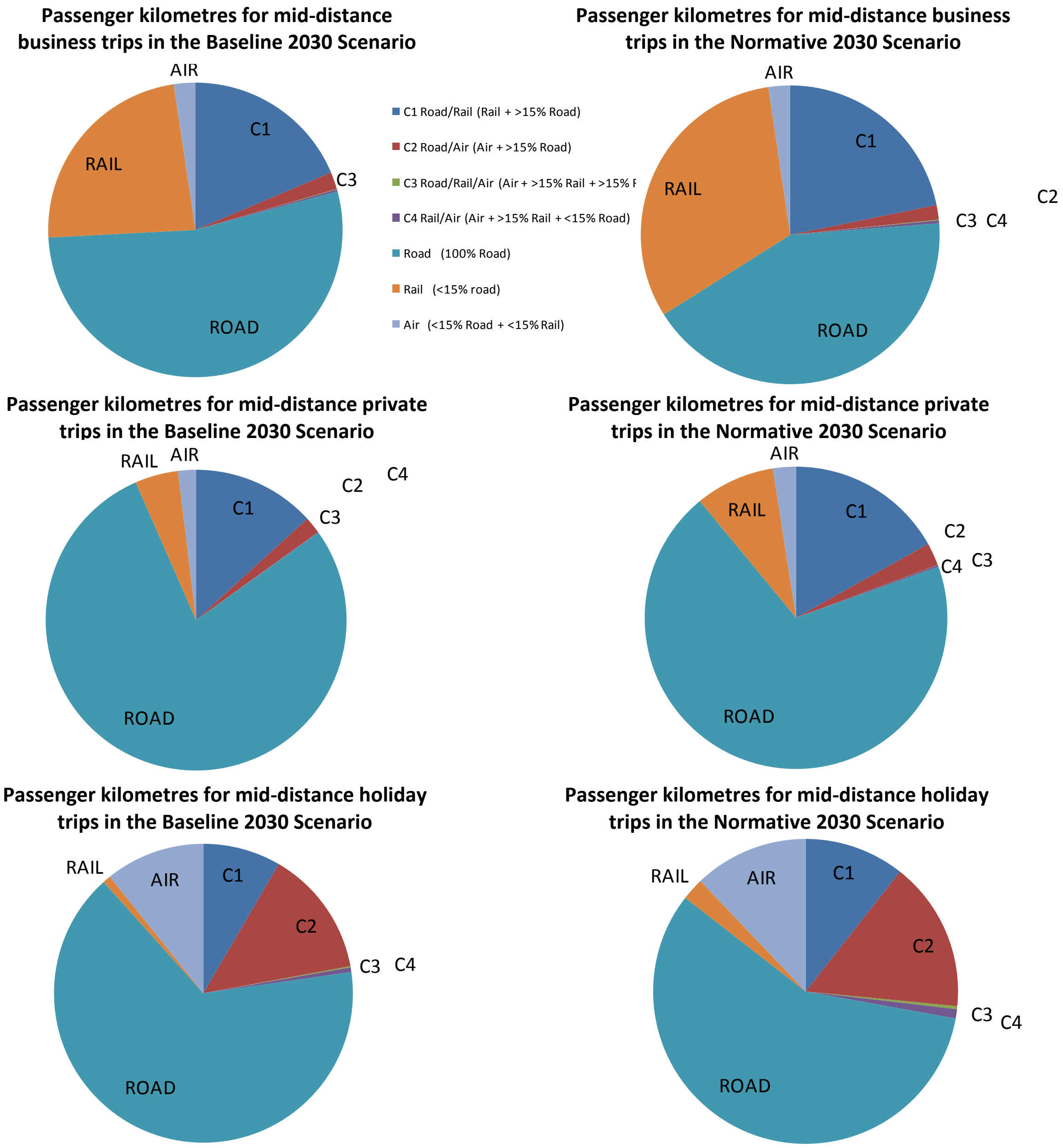
- For short-distance trips unimodal road traffic is totally dominant, with some share for rail along and some for the combination of road and rail. The share of unimodal road traffic goes down in the Normative scenario, but not to a large amount, just from 89 % to 85 %. The share of unimodal or combined rail traffic goes up accordingly, because air traffic does not play any significant role in trips below 300 km distance.
- For mid-distance trips, which are at the core of this section, also road is the dominant mode with 70 %, and in the Normative scenario does go down as intended, but only to 62 %, and rail is not the only mode benefitting from this, since the share of air traffic goes up from 8 % to 9 % and C2, i.e. road and air combined from 9 % to 11 %. This leaves only an increase from 2 % to 5 % for rail alone, from 10 % to 13 % for C1, i.e. road and rail, and from under 1 % to just over 1 % for C4, rail and air. The share C3 (road + air +rail) is under 1 % in both scenarios. This means that, with a total increase from 13 % to 20 % for all chains that involve rail at all together, the Normative scenario only goes a very short way towards the White Paper target.
- In long-distance trips the picture changes totally. At this distance air travel becomes the dominant mode either alone or in combination with road travel (C2). The total is 88% in both scenarios with a slight shift from combined to pure air travel in the Normative scenario. Rail on its own has a mere share of under 1 % for both the Baseline and Normative and so do all three combined (C3). Road and rail (C1) have a share of 1 % increasing to 2 %, and only rail / air (C4) has a slightly larger share with 2 % and 4 %. So all chains involving rail at some stage increase from only 4 % to just 8 %.
- For very long-distance trips the picture is similar to the one for long-distance with regard to rail travel. The big difference is that pure air travel has here already in the Baseline 65 %, increasing to 68 % in the Normative scenario, thereby mainly reducing the share of combined car and air travel from 30 % to 26 %.

Figure 4-8 is showing the trip chains for the mid-distance traffic, the focus of this section, for three different trip purposes: business, private (visiting relatives or friends), and holidays.

The differences between the three user segments are very marked:

- For business travellers, road is with 53% the dominant mode in Baseline 2030, followed by rail with 23% and road / rail with 19%. The rail share is already significant in the Baseline, since the cost of rail travel is less relevant than for other groups a) because business travellers have a high value of time, b) because the fares are often paid by employers and / or can be offset against tax and c) because time in trains can be used productively for work in contrast to travel by car. In the Normative scenario the share of rail grows further to 32% on its on and 22% in combination with road, so for both together from 42% to 54%.
- However, for private trips the picture is very different. Here road alone has a share of 78% in the Baseline and still 70% in the Normative scenario. The share of air traffic is with 2% in both scenarios exactly the same as for business travellers. But for private travel, often undertaken by entire families or groups of friends, rail travel becomes much more expensive than the shared cost of road travel and is therefore unattractive for this group. The rail share is therefore only 5% in the Baseline rising to 9% in the Normative scenario, and the figures for combined road and rail are 13% and 17% respectively.
- For holiday travellers, air travel is a much more attractive option than for the other user groups, in part certainly due to the prevalence of package holidays that practically all use air travel and in part due to the attraction of low-cost airlines that may not offer much comfort, but are often cheaper than travel by car and certainly by rail. Therefore the share of pure air travel is 11% and 12 % respectively. The least attractive option for this user group is rail travel, certainly due to a combination of costs and the inconvenience of rail travel with heavy luggage. The pure rail share here is just 1% and 2% and for road / rail a bit more with 8% and 11%.

Therefore, for business travellers the White Paper target is already achieved in 2030 rather than only by 2050, while for private travellers and even more so for holiday travellers this target is a long way away.



Mid-distance are trips 300 to 1000km

Figure 4-8 Modal share for different modal chains in business/private/holiday trips of mid-distance for Baseline 2030 and Normative scenario

4.1.2 Travel Time

Total travel time

Table 4-3 lists the total travel time spent in each scenario in each mode, and Figure 4-9 visualises this information.

Table 4-3 Total travel time (million hours spent travelling)

	Travel time (million hours / year)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	6,772	6,877	5,613	6,432	6,553	6,312	6,458
Rail	488	553	1,643	513	646	337	728
Air	784	1,010	1,021	1,092	1,070	976	1,060
Maritime	359	377	400	170	335	348	406
Total	**8,403**	**8,817**	**8,678**	**8,207**	**8,604**	**7,972**	**8,652**

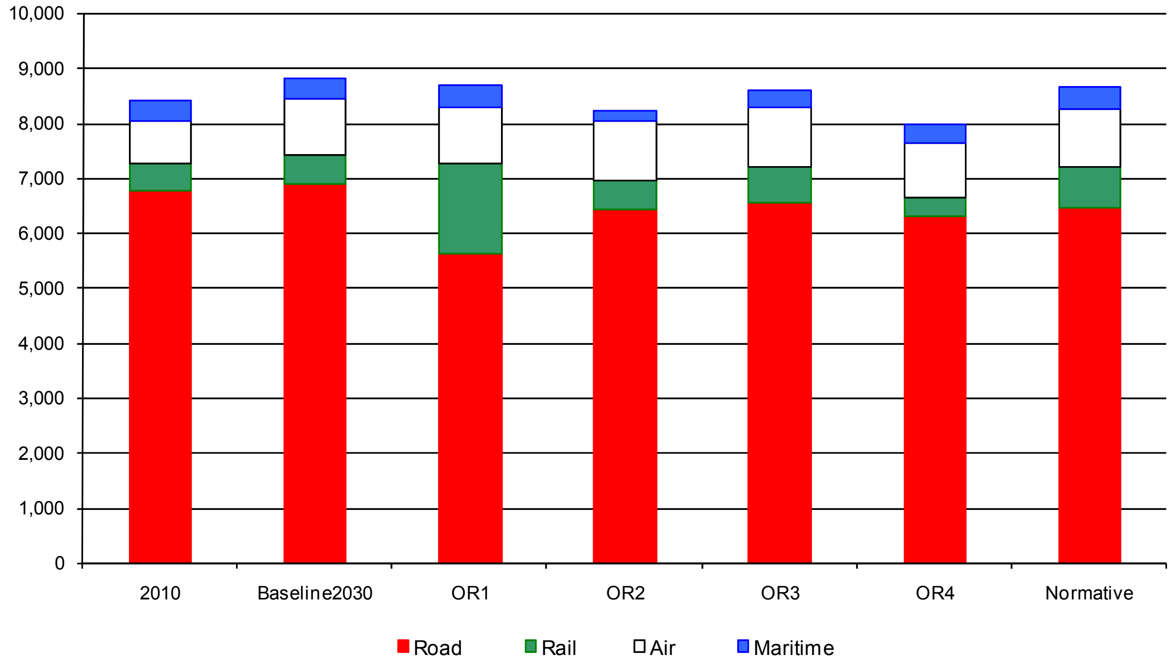


Figure 4-9 Hours spent travelling in each mode

Total travel time increases in Baseline 2030 by 4.9% against Baseline 2010, about three times less than the increase in total trip kilometres (12.7%). This implies that the overall transport system is faster in 2030 than in 2010.

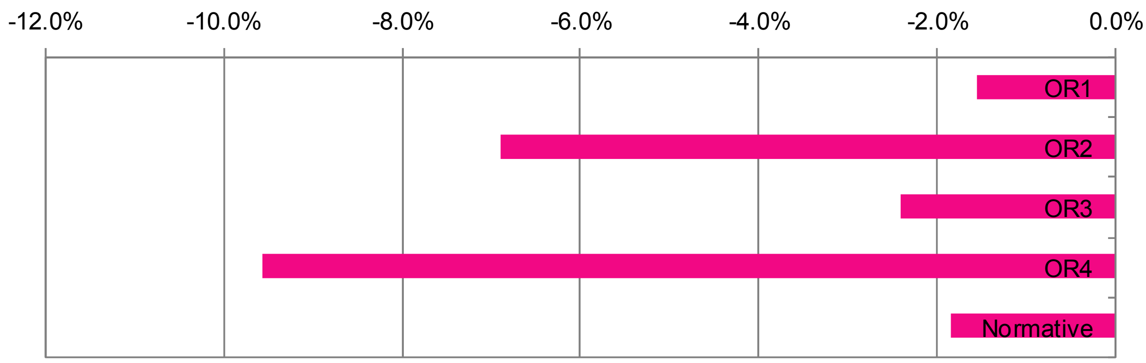


Figure 4-10 Change in long-distance travel time in relation to Baseline 2030 (based on hours), all modes and trip purposes included

The longest time spent travelling is to be found in the Baseline 2030 scenario; the exploratory and the Normative scenarios all improve on that (see also Figure 4-10). What is particularly notable from Table 4-3 and Figure 4-9 is that the Baseline has the highest number of hours spent on roads, while in the other scenarios either the number of kilometres spent on the road is reduced (OR1, OR2, OR3 and Normative) or travelling on the road becomes faster as is the case in OR4 where travel time decreases in spite of it having the highest road mileage of all scenarios.

Rail speed increases in OR3, OR4 and the Normative, while in OR1 and OR2 rail speed remains the same as in Baseline 2030, where in turn it is slightly faster than in 2010. Accordingly, as it stands out in Figure 4-9, travel time by rail is by far the largest in OR1, which also has by far the largest rail pax km. OR3 has with +15% the highest increase in rail speed, but this is not enough to bring the overall travel time down in its ranking, since OR3 has both the third highest rail passenger mileage and the third highest rail travel time, but only helped to increase the distance to OR1 and the Normative scenario for rail travel time.

For flights, OR3 is also the one with the highest reduction in flight travel time with -10 minutes per flight, and the rail and air travel time reduction combine to overtake the Normative scenario slightly in the total overall travel time for all modes. The influence of the travel time reduction per flight is not as large as could be expected on first glance since OR3 has a higher share of short-haul flights than other scenarios, which increases the average flight duration through the higher weight of times for starts and landings. Furthermore, a higher share of connecting flights means more transfer times, which contribute considerably to a longer overall flight time.

More generally, scenarios with higher shares of air travel have higher global travel time savings, reflecting the fact that air travel is still faster than other modes despite delays inherent to the air mode (formalities, security, access/egress to airports, transit). High speed rail is only competitive for some medium length trip ranges when compared to air.

An exception is scenario OR4, which has a lower share in air travel, but still has the largest decrease in travel time. The reason for this is that road speed is increased by 15% (e.g. from 120 to 140km/h in motorways), and this shows that sensitivity to improvements in roads is particularly large. Such speed increases are allowed in OR4 through the increase in road safety due to the implementation of fully or semi-autonomous vehicles (adaptive cruise control devices implemented in most vehicles, road platooning as proposed by Volvo in SARTRE FP7 project, autonomous vehicles such as Google's or Audi's).

Travel time on unimodal and multimodal trips

Table 4-4 shows the average time spent on unimodal and multimodal trips in each scenarios.

Table 4-4 Travel time for unimodal and multimodal trips

	Travel time (hours / trip)						
	2010	Base2030	OR1	OR2	OR3	OR4	Normative
Unimodal	1.16	1.16	1.10	1.19	1.13	1.05	1.14
Multimodal	5.27	5.06	3.71	2.62	4.59	5.61	4.35

The differences between unimodal and multimodal trips are marked with an average of 1.05 to 1.19 hours for unimodal trips and 2.6 to 5.6 hours for multimodal trips. It is also striking that the differences between scenarios are negligible for unimodal trips while large for multimodal ones.

Unimodal trips are in most cases short and simple trips. 1.1 or 1.2 hours as average would clearly be too short, if it covered trips ranging from at least 100km, defined in general as the minimum for a long-distance trip in ORIGAMI, from air travel across Europe including transfers between connecting flights. However, what needs to be remembered in this context is that the modelling covers all travel between NUTS3 zones and that these vary considerably in size. While in the north of Finland a NUTS3 zone is very large, for instance in Germany or Benelux it is typically very small, and since the largest number of trips originate in the more densely populated areas, the average trip length in this modelling exercise is under 150 km. So the 1.1 or 1.2 hour average is a result of the combination of trips with short distances and longer flights with high speeds.

For multimodal trips, the travel time decreases slightly from 2010 to 2030 due to increased efficiency. It is highest in OR4, the scenario with the lowest rail and highest car travel, and that although road speed is increased by 15%. This is due to the fact that, although the total pax km for multimodal trips are the same as in the Baseline 2030, there are fewer multimodal trips and those that remain are longer and make less use of the road, since there are now more pure road trips.

In contrast, OR2 has by far the lowest travel time for multimodal trips, but nevertheless also by far the lowest level of multimodality of all scenarios. The extensive use of the air mode in OR2 makes it possible to have more unimodal long-distance air trips, which is why the average time in those is the highest of all scenarios – even if only by a small amount in absolute terms. On the other side, there are much fewer long-distance multimodal trips, and thus their average travelling time is smaller.

4.1.3 Transport Costs

Table 4-5 lists the generalised global costs for transport by mode and in total for each scenario and Figure 4-11 visualises this.

Table 4-5 Global generalised transport costs

	Transport costs (million € / a)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	146,479	146,859	123,350	137,667	135,208	154,675	144,877
Rail	14,401	16,404	54,113	15,698	23,107	7,997	24,455
Air	18,319	22,606	23,636	23,041	22,611	20,609	24,129
Maritime	12,615	13,205	13,899	5,822	13,467	12,146	14,138
Total	**191,815**	**199,074**	**214,998**	**182,229**	**194,394**	**195,427**	**207,598**

Transport generalised costs in the ORIGAMI 2030 scenarios include the cost required to run transport vessels on the network to fulfil mobility requirements, and the value of time spent by European citizens travelling along the continent[39]. Transport generalised costs do not include in this analysis infrastructure investments nor technology development costs (e.g. cost to develop electric vehicles).

The total change between 2030 and 2010 is smaller than for travel time and considerably smaller than for pax km. Pax km increase because trip numbers increase, but the network becomes more efficient and therefore travel times do not increase at the same rate. Furthermore, new infrastructure allows taking faster and cheaper routes.

For changes between the 2030 scenarios it is the other way round. Since the number of trips undertaken is the same for all of them, pax km only vary due to different routes being taken. But travel times are affected by the trip lengths as well as the differences in the infrastructure provision and therefore vary more strongly. What varies most in the input parameters are the costs for the various modes due to both different degrees of market liberalisation and pricing and taxation regimes and hence differences between costs are largest between scenarios.

[39] For further references on costs in the MOSAIC model, see Ulied A, Biosca O, Català R, Franco N, Larrea E, Rodrigo R, "Modelling module for interconnectivity" Deliverable D5.3 of INTERCONNECT, Cofunded by FP7. TRI, Edinburgh Napier University, Edinburgh, May 2011.

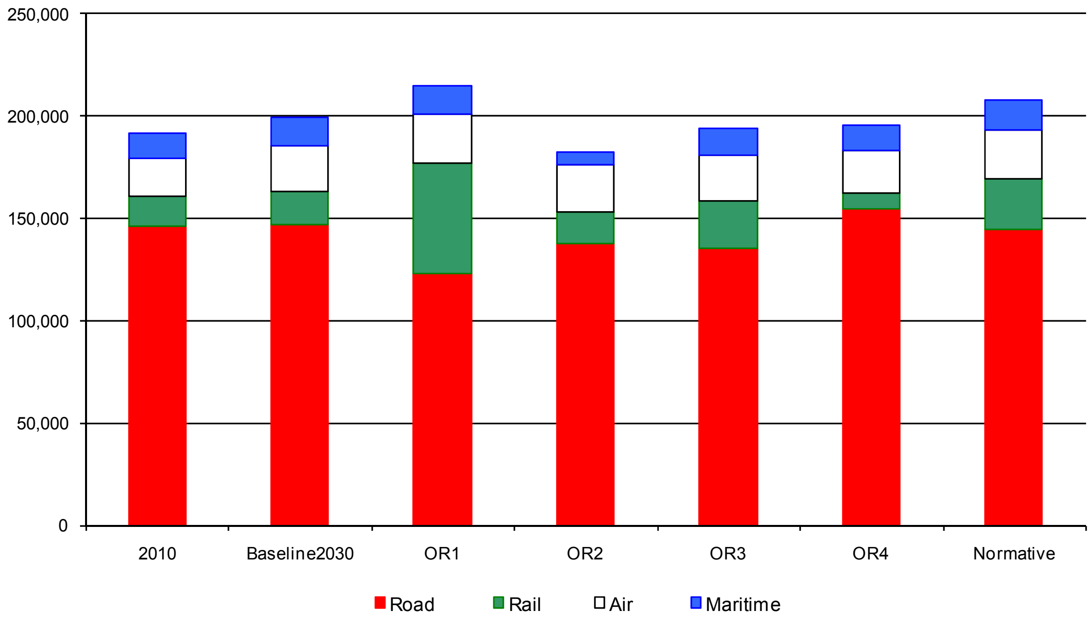


Figure 4-11 Global generalised transport costs

In contrast to travel times (Figure 4-10), which are in all scenarios lower than in Baseline 2030, Figure 4-12 shows that for costs some scenarios are higher and others lower than the Baseline.

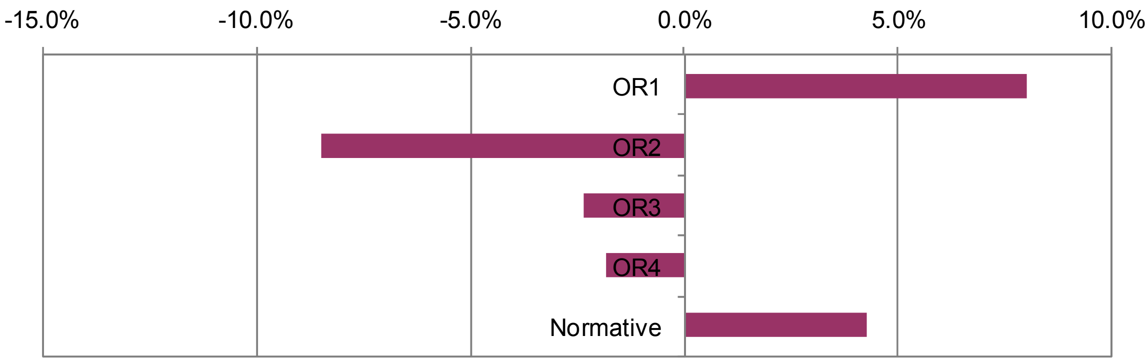


Figure 4-12 Change in long-distance travel generalised cost in relation to Baseline 2030 (based on euros), all modes and trip purposes included

Table 4-6 lists the costs as costs per passenger kilometres, and Figure 4-13 illustrates this. This allows, in conjunction with the total mileage per mode in each scenario from Table 4-1, a better analysis of which modes have contributed most to each change.

Table 4-6 Average generalised transport costs per 1000 passenger kilometres

	Transport costs (€ / 1000 pax km)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	216	213	232	215	207	213	224
Rail	238	231	238	238	239	201	240
Air	71	62	65	59	60	58	65
Maritime	990	984	977	965	981	978	978
Total	**190**	**175**	**189**	**165**	**171**	**173**	**183**

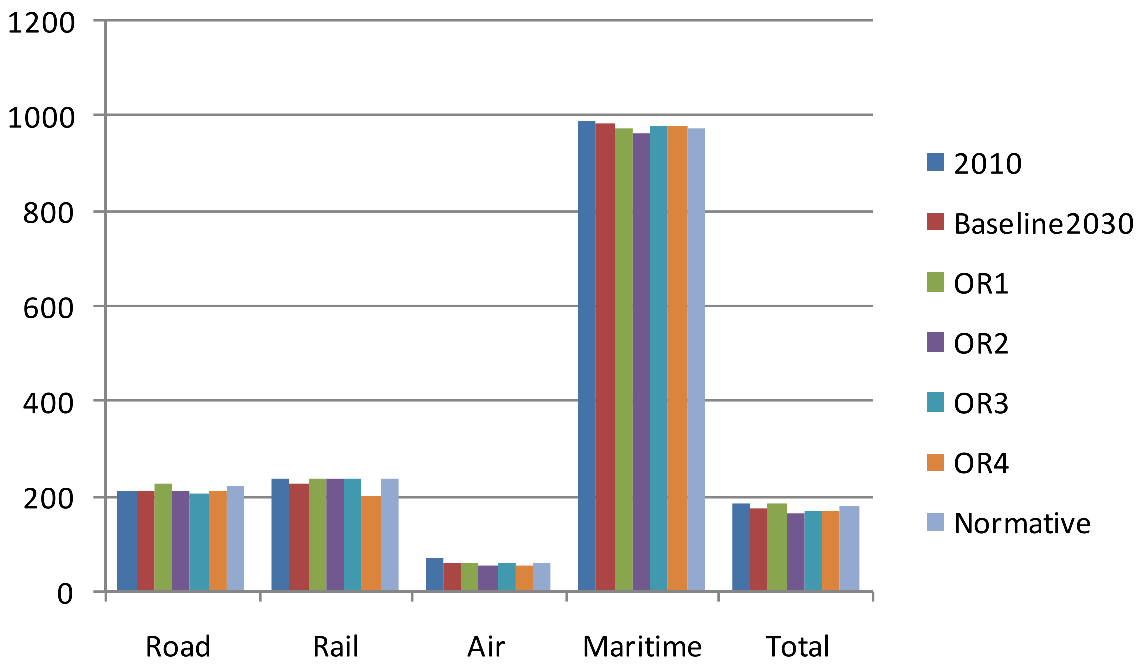


Figure 4-13 Average generalised transport costs in € per 1000 passenger kilometres

The first thing to note for all scenarios is that the average costs for road and rail are on a similar level, while the costs for air are just between a third and a quarter of these and, on the other end, costs for maritime transport soar. Having the cost of travel time a major contribution to total travel cost, it is logic that the air mode has lower generalised costs per kilometre than others as the mode is much faster, and therefore the cost of time per kilometre is very low. In contrast to air, the ferry mode being very slow is a heavy time consumer, increasing its generalised cost per kilometre.

OR2 is the scenario with the lowest cost per pax km and the lowest global costs. The cost for car travel is even marginally higher than in the Baseline 2030 in spite of the increased car occupancy, which is in some part due to the fact that the model applies variations to the value of time and operative costs across the different countries and thus the average generalised cost of road per kilometre could change as road is more or less used in different regions. Another effect to take into account is the cost of accessing the cities, which is fixed and does not depend on the length of trip. If road trips become shorter in the scenario, as in OR2, the cost of accessing the cities makes the average road cost go up.

In scenario OR3, better management of the transport network results in the lowest operational costs per km in each mode. However, it is only the second lowest in terms of global transport cost because the low specific operational costs are combined with the second largest number of pax km.

In scenario OR4 the cost per pax km are the same or lower than the Baseline for each transport mode, and the resulting cost across modes is also slightly lower. OR4 has by far the highest pax km for road, the most expensive mode apart from maritime, and a move away from rail and air, the cheaper modes. This happens although the price for road usage in OR4 is the same as in the Baseline, because an increase in road pricing is offset by a price reduction through liberalisation. However, it is the 15% increase in road speed that appears to be the overriding factor in attracting users to the road use. Furthermore, the availability of cleaner cars with much reduced emissions should also contribute to making the use of cars a more attractive proposition, although the model does not allow for environmental consciousness. In spite of this move, global generalised transport costs decrease thanks to a reduction in air transport operation costs due to liberalisation and cheaper rail operating costs.

OR2 is the scenario with the lowest cost per pax km and the lowest global costs. The cost for car travel is even marginally higher than in the Baseline 2030 in spite of the increased car occupancy,

which is in some part due to the fact that the model applies variations to the value of time and operative costs across the different countries and thus the average generalised cost of road per kilometre could change as road is more or less used in different regions. Another effect to take into account is the cost of accessing the cities, which is fixed and does not depend on the length of trip. If road trips become shorter in the scenario, as in OR2, the cost of accessing the cities makes the average road cost go up.

As stated earlier, fewer investments in new road and rail infrastructures, with unchanged operating costs for all modes, lead in OR2 to the increase of flights, which is by far cheaper than road and rail and therefore brings the overall costs in OR2.

Highest are the global costs in OR1, and here it also goes together with the highest cost per pax km for all 2030 scenarios. Air travel is, together with the Normative scenario, most expensive here, and particularly influential is the high cost of rail travel combined with by far the largest amount of rail travel in this scenario. The generalised cost of rail travel is high in spite of the 10% reduction in ticket prices, because there are many more rail trips, specifically more short trips as they are now quite competitive by comparison to the road, and a higher degree of multimodality. The access/egress to rail is relatively high in cost (and time) when the trip is short (similar to what happens in maritime and air modes). Clearly, although cost is a strong factor in choosing a particular mode the overriding factor in making rail so attractive in this scenario is the large extension of the rail network.

Finally, the Normative scenario has higher costs per pax km than the Baseline and also higher global costs. This is in part due to the fact that the overall mileage is larger than in the Base, but even more so due to the move to rail travel, which is more expensive here than in any other scenario, due again, like in OR1, to shorter rail trips with higher access/egress costs. So again, in spite of the high cost, rail is attractive due to a combination of factors including the increased price of road travel, the increased rail speed, the increase of the rail network and the better accessibility of rail stations.

Travel costs for unimodal and multimodal trips

Table 4-7 lists the costs for unimodal and multimodal trips. As for the travel time before, multimodal trips are between two and five times more expensive than unimodal trips, and again also differences are very small between different scenarios for the unimodal trips, but very significant for the multimodal ones.

Table 4-7 Transport costs for unimodal and multimodal trips

	Transport costs (€ / trip)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Unimodal	27	26	27	27	23	27	25
Multimodal	120	114	92	58	96	143	95

For the multimodal trips, differences between scenarios are much the same as for the travel time, not only with OR2 being lowest and OR4 being highest, but even also with the ranking of each one between them, even though not exactly with the same proportional differences.

4.2 Environmental Indicators

4.2.1 Energy Consumption

Energy consumption in the ORIGAMI 2030 scenarios is proportional to trip length and travel speed under consideration of the emission factors, which are different for different modes in different scenarios. Passenger long-distance rail is assumed to be electricity-powered all over the continent by 2030.

Fossil Fuel Consumption

Table 4-8 lists the fossil fuel consumption for road, air and maritime traffic and Figure 4-14 illustrates this.

Table 4-8 Fossil fuel consumption

	Fossil fuel consumption (million tons / a)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	19.9	14.8	9.9	5.8	12.8	13.5	10.1
Rail	-	-	-	-	-	-	-
Air	10.6	8.0	7.6	6.9	7.4	7.8	7.4
Maritime	0.6	0.4	0.4	0.2	0.4	0.4	0.4
Total	**31.1**	**23.3**	**17.9**	**12.9**	**20.6**	**21.7**	**18.0**

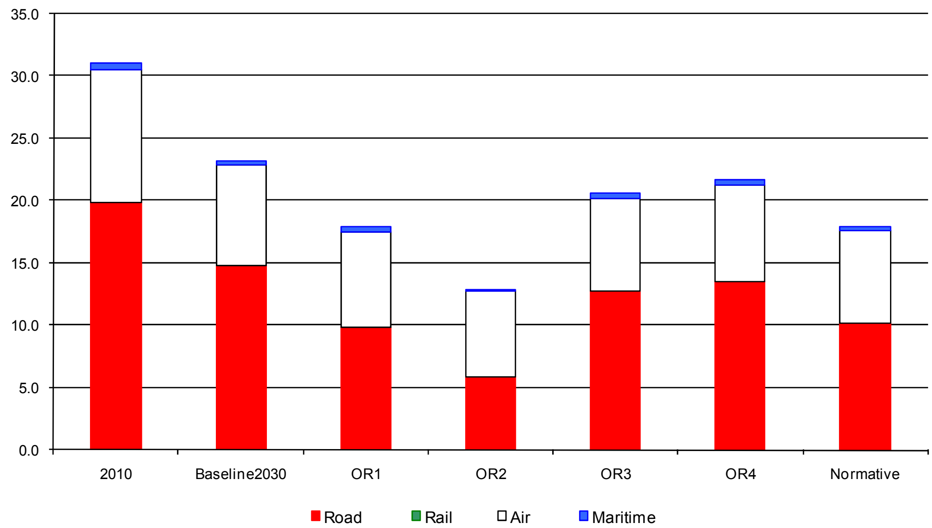


Figure 4-14 Distribution of fossil fuel consumption

The Baseline 2030 has a lower fuel consumption than the Baseline 2010 for all modes in spite of the increase in traffic volumes, because vehicles of all modes have become more energy efficient. However, all 2030 scenarios improve on that even further, albeit to very different degrees.

Differences for maritime traffic are large in relative terms due to the halving of ferry traffic in OR2, but in absolute terms the contribution of ferry traffic to the overall fuel consumption is marginal. Values for air travel range from 6.9 million tons / a for OR2 with its emphasis on clean engines to 8.0 for the Baseline. The other scenarios lie in between and a range from 7.4 to 7.8 million tons / a does not contribute very much to the overall picture.

The overriding effect comes from road traffic, as Figure 4-14 clearly demonstrates. There are four factors that lead to the differences between scenarios. The first one is the car occupancy, which is 1.5 in most 2030 scenarios, but 1.65 in OR3 and 2.0 in OR2, the second one are the cleaner technologies in general, and the third one the use of electric cars in particular. The fourth of course is the traffic volume in each mode and overall. In the Baseline and in OR3, average emissions are 135 g / veh km, while in OR1 they are 10% lower, in OR4 and the Normative 15% and in OR3 35%, and, while this has not been spelt out specifically, the reduction in emissions is largely related to a reduction in fuel consumption even if the use of biofuels also plays a role in some scenarios. On top of that there are 20% electric cars in the Baseline, OR1 and OR4, 22% in OR1, 25% in OR4 and the Normative, but 30% in OR2.

These three factors combine to make OR2 by far the scenario with the lowest consumption of fossil fuels with a reduction of 60% against the Baseline for road travel and 45% overall.

In OR3, the car occupancy rate, even if only 10% higher than in the Baseline, has a stronger effect on the reduction of fuel consumption than the cleaner cars and the electric vehicles in OR4, since the total consumption is lower in OR3 in spite of the higher mileage.

In OR1, there is a lower reduction in car emissions as well as a lower increase in electrics cars than in OR4 and no increase in car occupancy at all, but the fuel consumption is for road traffic 33% lower simply because in OR1 much more trips are made by rail and this scenario has the lowest car use of all scenarios.

The Normative scenario has nearly the same reduction for road traffic as OR1 and overall also 23%, but this scenario achieves this in spite of the higher traffic volumes on the road and in the air, through a stronger reduction of the specific emissions / fuel consumption in all modes and the increase in the number of electric cars.

Electricity Consumption

Table 4-9 and Figure 4-15 show the electricity consumption in the different scenarios. Only rail and road use electricity as a source of energy. In the case of road the share of electric vehicles (EV) is almost negligible in 2010 and increases in the future more or less depending on the scenario, about twentyfold in the Baseline 2030. Electric aviation and maritime transport are not considered.

Table 4-9 Total electricity consumption

	Total electricity consumption (million kWh / a)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	0.05	1.0	0.7	0.6	0.9	1.2	0.9
Rail	3.3	2.3	7.0	1.7	3.2	1.3	3.0
Air	-	-	-	-	-	-	-
Maritime	-	-	-	-	-	-	-
Total	**3.45**	**3.3**	**7.8**	**2.3**	**4.0**	**2.5**	**3.9**

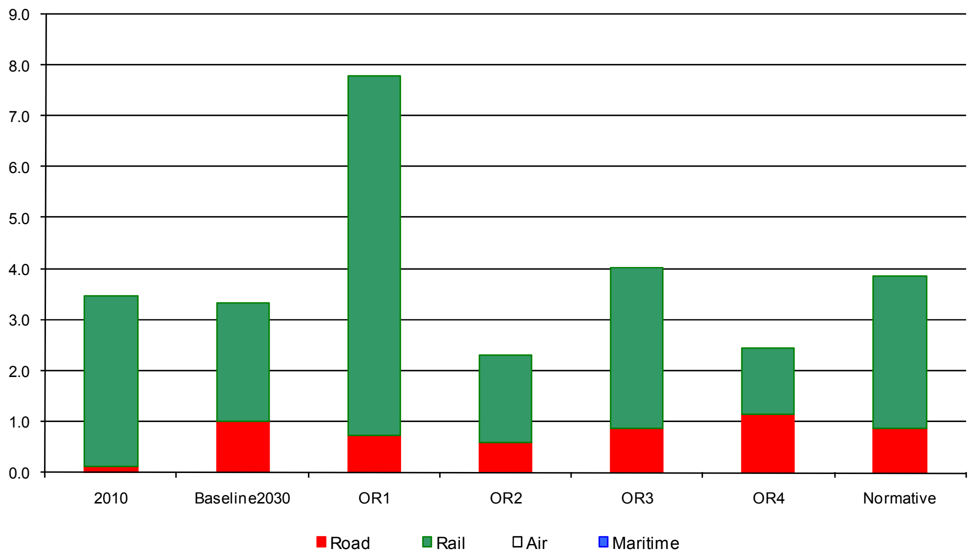


Figure 4-15 Distribution of total electricity consumption in million kWh / a

In OR2, there are 50% more electric cars than in the Baseline and just 7% less road traffic, so one could expect an increase in electricity consumption. However, the 50% increase only means that the share of electric cars rises from 20% to 30%, and this is not only counterbalanced by the reduced road passenger mileage, but more importantly by the increased car occupancy from 1.5 to 2.0, which means the same mileage is done with 25% fewer cars in total. Hence overall OR2 is not only the scenario with the lowest road fuel consumption but also, with – 40%, the lowest electricity consumption on the road.

In OR4 the road electricity consumption goes even up on the Baseline, because there are both more electric cars and a much higher road mileage. The other scenarios, with their mix of policies, lie somewhere in between.

For rail, the differences between the scenarios are much larger than for road both in absolute and relative terms. As could be expected, by far the largest consumption is in OR1 with its large expansion of the rail network and the extremely high passenger numbers. In contrast, OR2 is also very low here due to the low pax km on rail, but even lower is in this case OR4, again directly related to the fact that OR4 has the lowest rail pax km of all scenarios.

Fuel Efficiency

Fuel efficiency is defined as the average amount of fuel required to transport a passenger for one kilometre. It is obtained by dividing the total energy consumption of a mode by the total passenger kilometres for that specific mode. For homogenisation purposes all fuels are transformed to toe (tons of oil equivalent). Table 4-10 and Figure 4-16 show the results.

Table 4-10 Fuel efficiency per passenger and kilometre

	Fuel efficiency (toe / million passenger km)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	30	22	19	9	20	19	16
Rail	6	4	4	3	4	4	3
Air	47	25	24	20	23	25	23
Maritime	42	29	27	23	26	29	26
Total	**33**	**22**	**17**	**13**	**19**	**20**	**17**

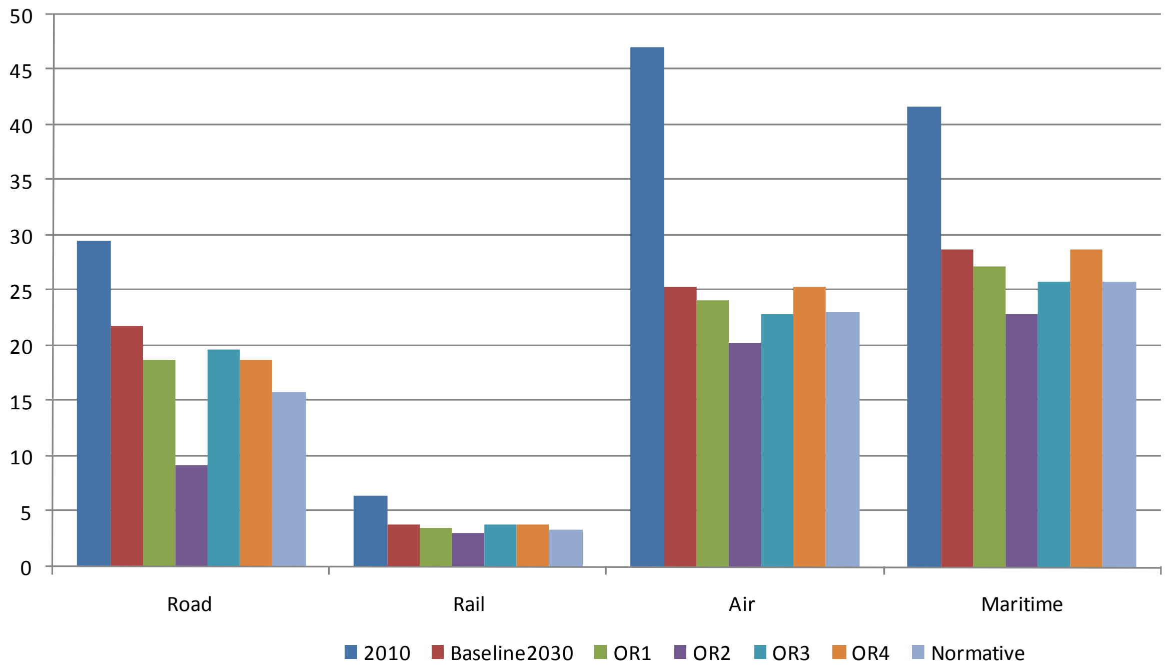


Figure 4-16 Fuel efficiency in toe (tons of oil equivalent) per million passenger kilometre

Fuel efficiency improves between 2010 and 2030, by 25% for road, 40% for rail, 45% for air and 30% for the maritime mode. This is due to three reasons:

- ➢ Specific technological improvements in the vehicles lead to less energy consumption per kilometre;
- ➢ In the case of road the increased share of electric cars; and

- Increase in vehicle occupation and load factors, implying that more passengers are being transport with nearly the same amount of energy.

All 2030 scenarios improve further on the Baseline 2030, implying that each of the scenarios has more optimistic hypotheses in terms of technology and/or vehicle occupancy and load factors than the Baseline.

OR2 is the scenario focussed on obtaining as much value as possible from vehicle technologies. Hence efficiency improves dramatically in scenario OR2, with the effects of much cleaner vehicles and the occupancy factor combining to a 60% improvement for the road when comparing to the 2030 Baseline, and still 40% overall.

OR3 and OR4 are the scenarios with the smallest improvement, while both OR1 and the Normative scenario show a 23 % overall increase of fuel efficiency. This happens although the Normative scenarios shows lower values than O1 for every single mode, because the Normative scenarios has a much lower share in rail travel, the most energy efficient mode.

Greenhouse Gas Emissions

Greenhouse Gas (GHG) Emissions are mostly CO2 gas released from fossil fuel engines in vehicles; the emissions from energy generation are much lower, hence the very low values for rail even in OR2, where rail passenger mileage is over 40% of the road mileage and over 60% of that for air passengers (Table 4-11 and Figure 4-17).

Table 4-11 Greenhouse gas emissions

	Greenhouse gas emissions (million tons / a)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	63.0	47.0	31.3	18.5	40.4	42.9	32.1
Rail	1.3	0.9	2.8	0.7	1.3	0.5	1.2
Air	33.6	25.3	24.2	21.9	23.6	24.7	23.6
Maritime	1.8	1.3	1.4	0.5	1.2	1.2	1.3
Total	**99.8**	**74.6**	**59.6**	**41.5**	**64.5**	**69.3**	**56.5**

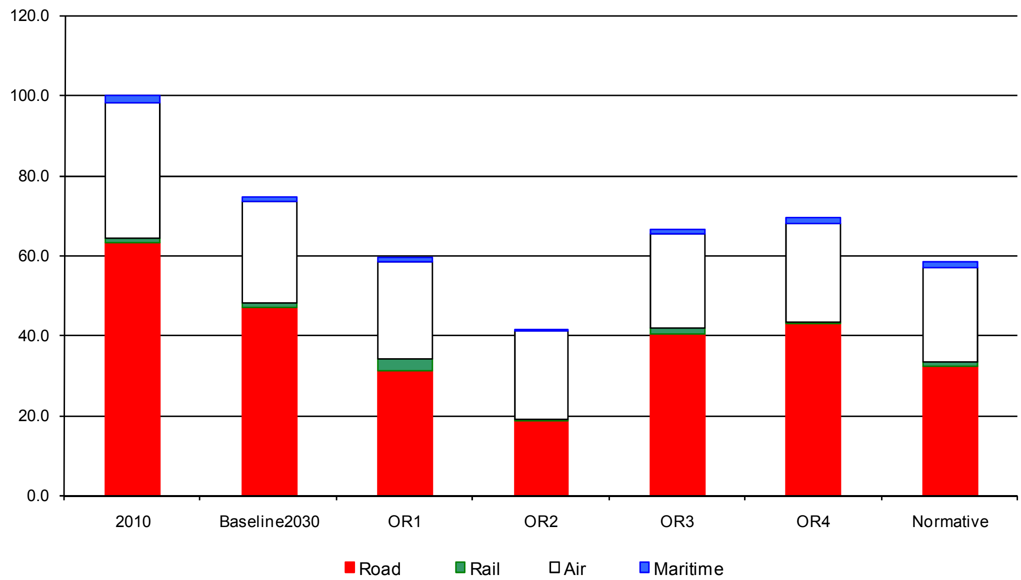


Figure 4-17 Distribution of greenhouse gas emissions in million tons / a

The overall picture is very similar to that for fossil fuel consumption (Figure 4-14), which is no surprise given that fossil fuels are the main generator of GHG emissions. Figure 4-18 directly relates the changes in fuel consumption and CO2 emissions as well as Nox and PM10. Again it confirms how closely fuel consumption and CO2 emissions are interlinked.

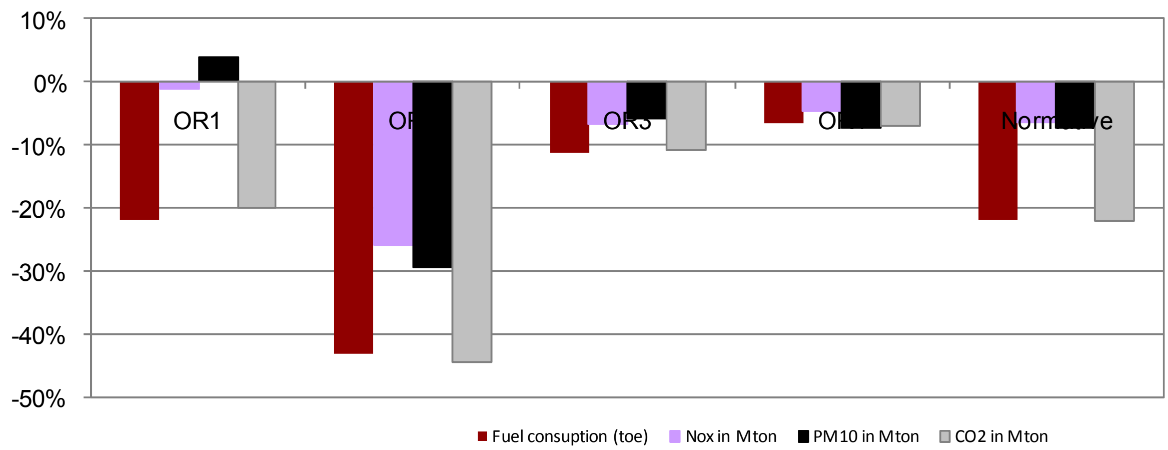


Figure 4-18 Change in energy consumption and emissions of long-distance travel in relation to Baseline 2030, all modes and trip purposes included

Table 4-12 filters out the influence of the mileage for each mode, so that here only the total is influenced by the relative share of each mode, while all mode specific numbers only depend on the underlying technologies used. For some scenarios this shows differences to the previous table. For road it is notable that the specific emissions are lower in OR3 than in OR4, while the total emissions are higher, due to the higher mileage. For rail, differences are very small between all 2030 scenarios, with the total of course is highest in OR2 due to the high rail mileage and lowest in OR4 due to the high mileage. For air the specific reduction in Baseline 2030 compared to Baseline 2010 is 46%, while overall, due to the increase in air travel, it is only 25%.

What the totals in Table 4-12 shows however, is that the relative positions of the different scenarios are the same as for the overall figures, indicating that the influence of the mileage is not as large as the influence of the technological differences.

Table 4-12 Green house gas emissions per passenger kilometre

	Greenhouse gas emissions (tons / million pax km)						
	2010	**Base2030**	**OR1**	**OR2**	**OR3**	**OR4**	**Normative**
Road	92	68	59	29	62	59	50
Rail	22	13	12	11	13	13	12
Air	129	70	66	56	63	70	63
Maritime	145	100	98	83	87	100	90
Total	**99**	**66**	**52**	**38**	**57**	**61**	**50**

Both in overall emissions (Table 4-11) and in emissions per pax km with (Table 4-12) OR2 has with over minus 40% the highest reductions in GHG emissions, consistent with the fact that it also had the lowest fuel consumption due to cleaner vehicles in all modes. This strategy is coherent with the 2011 Transport White Paper approach, favouring technological development and innovation.

The Normative scenario has a reduction of more than 20% in CO2 emissions, complying with the White Paper target for 2030. This scenario responds to a more balanced approach, with policies targeting both behaviour and technology development, as well as infrastructure investment and management strategies.

4.2.2 Particulate Emissions

Particulate emissions in transport are mostly released from the engines of vehicles. It is mostly PMx and NOx. They are responsible for causing health problems in the human body and in the fauna.

Table 4-13 Particulate emissions

	Particulate emissions (million tons / a)						
	2010	Base2030	OR1	OR2	OR3	OR4	Normative
Road	0.41	0.31	0.21	0.12	0.27	0.26	0.21
Rail	0.19	0.13	0.39	0.10	0.18	0.07	0.17
Air	2.12	1.60	1.53	1.38	1.49	1.56	1.49
Maritime	0.64	0.47	0.47	0.17	0.43	0.43	0.45
Total	**3.36**	**2.50**	**2.60**	**1.76**	**2.36**	**2.32**	**2.32**

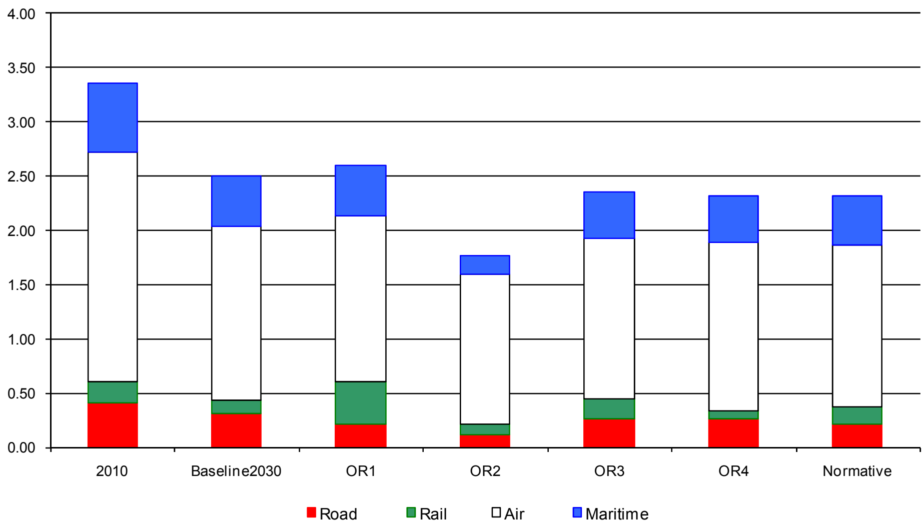


Figure 4-19 Distribution of particulate emissions

As Table 4-13 and Figure 4-19 show, the by far largest share of particulate emissions comes from air traffic, by far bigger than its share in passenger km and even more so than its share in vehicle km. What is also very noticeable is that maritime transport is the mode that emits by far the most particulates per pax km or by veh km. Table 4-14 shows for the Baseline 2030 as an example how large the differences between particulate emissions for the different modes are: very large per pax km and huge per veh km, which is why Figure 4-19 looks very different from all those shown for mileage, fuel consumption and GHG emissions before.

Table 4-14 Particulate emissions for each mode in Baseline 2030

	Particulate emissions	
	Tons / m pax km	Tons / m veh km
Road	0.45	0.68
Rail	1.83	457.75
Air	4.40	748.36
Maritime	35.01	7,343.75
Total	**2.20**	**5.42**

OR4, although it has the lowest pax km for air and also the lowest veh km, has the second highest particulate emissions for air as in the scenario there is no technological improvement on the airplane engines (it remains as in the Baseline), while in the other scenarios there is always a reduction in fuel consumption and all the emissions for the air (with more or less intensity depending on the scenario).

Overall, there is a significant improvement from the Baseline 2010 to 2030, and particulate emissions decrease further in all but one scenarios with respect to the 2030 Baseline, in line with the reductions of energy consumption. The exception is OR1, where particulate emissions increase due to the high growth of rail traffic (generation of electricity with coal and increasingly gas lead to indirect emissions of PM10 which are relatively high).

OR2 has, again, the lowest particulate emissions from all scenarios, since engines here have become the cleanest of all scenarios in all modes. But the differences between the other 2030 scenarios are smaller than those for GHG emissions, because GHG emissions decrease faster with technological improvements than NOx or particulate matter.

4.3 EFFICIENCY OF THE TRANSPORT SYSTEM

The level of use of the infrastructure system has been measured as a ratio between the total number of travellers and the total length of infrastructure available. Higher values indicate more saturated infrastructures, meaning a better use of the resources but also the possibility of congestion, although real congestion problems should be analysed at a level of detail that the MOSAIC model does not allow.

Table 4-15 Exploitation of infrastructure

	Exploitation of infrastructure (passenger km travelled / a / km infrastructure in service)						
	2010	Base2030	OR1	OR2	OR3	OR4	Normative
Road	1,469	1,702	1,435	1,568	1,634	1,770	1,628
Rail	327	405	1,231	371	551	241	578

The use of road infrastructure grows from 2010 to 2030 by 16%. In the other 2030 scenarios the use varies, with the strongest reduction in OR1 with its large shift to rail travel and the largest increase in OR4 with the highest investment in road infrastructure (Table 4-15). More generally, the usage of roads is fully in line with the pax km in each scenario so that the relative ranking between them remains the same.

However, the differences in road usage between scenarios are much smaller than the differences in rail usage. This grows by 24% from 2010 to 2030, but in most scenarios stays considerably lower than the road usage. In OR4, with the rail investment even lower than in the Baseline 2030, it even goes down to a level lower than 2010 and just 14% of the road usage. In contrast, the huge rail investment in OR1 pays off and the rail usage approaches that of the road. In the Normative scenario the rail investment is close to that of OR1, but rail usage is less than half of OR1, mainly because also road investment is particularly strong in this scenario, which makes rail relatively less attractive.

4.4 SOCIAL WELFARE

The maps in this section evaluate social welfare in the different scenarios by measuring accessibility on all transport modes (Figure 4-20 and Figure 4-21). Accessibility of a region is calculated as population that can be reached from this region weighed by required travel time for it to be reached. High accessibility can therefore be the result of several factors:

- There are good connections to the long-distance network and distant destinations are more accessible as for instance in France. Connectivity is the main factor for most of the regions.
- Where the population density is high, accessibility is higher because more destinations are in easy reach, as for instance in Turkey.

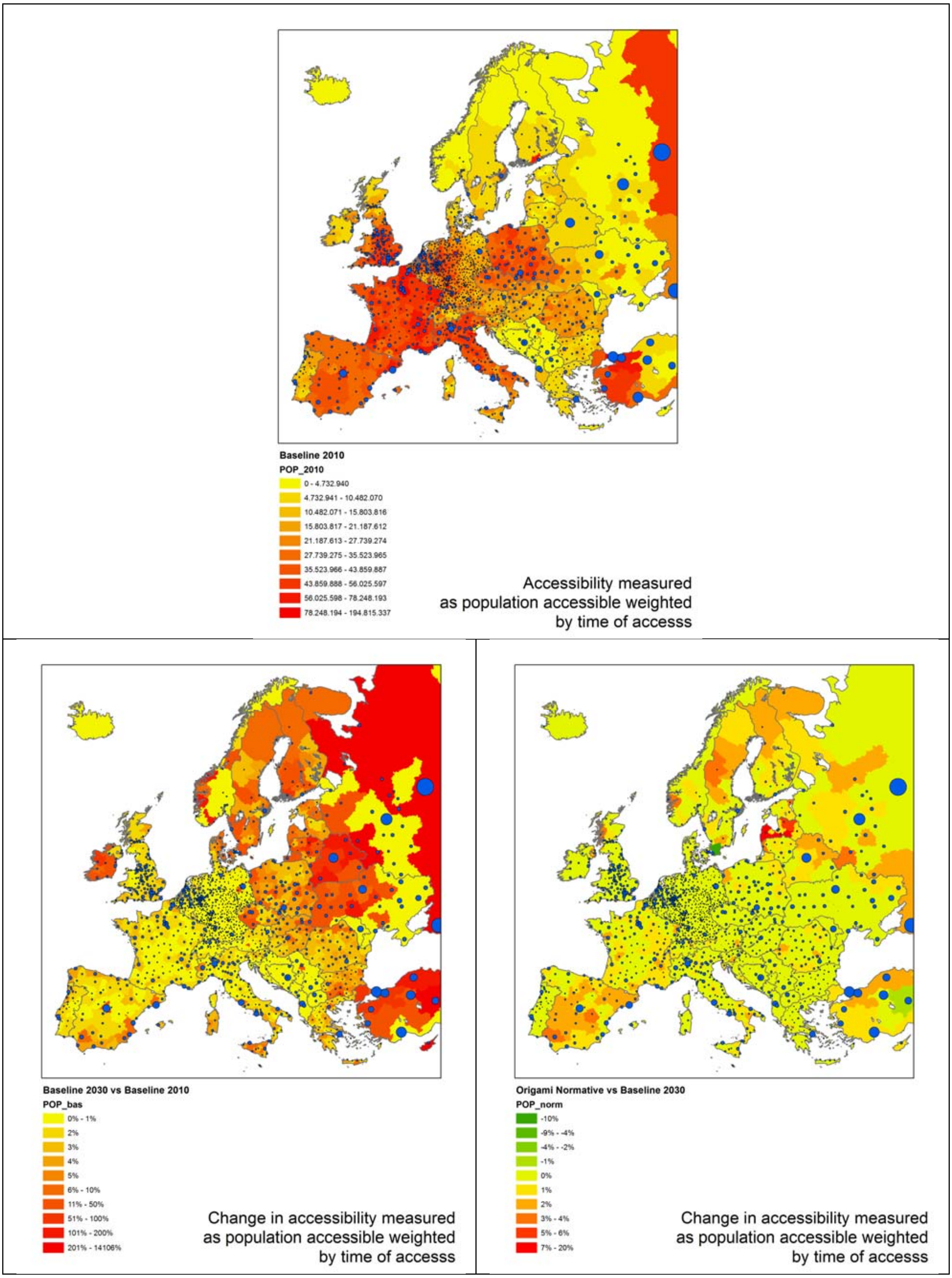


Figure 4-20 Levels of accessibility in European regions in 2010 and relative changes for Baseline 2030 and the Normative scenario

- The case of Russia is different. The regions are so big that all the population is concentrated in a single point in the model, thus accessibility boosts because of the region's own population. This would be very different if the real distribution of the population would be available to subdivide some of these outer regions into a lower level (similar to NUTS3).

The last two factors lead to some distortions in the map for 2010, not just for Turkey and Russia, but for instance also for the stark contrast between Spain and Portugal. However, for the comparison between scenarios, and the relative change between them, these distortions cancel each other out.

The main finding for the Baseline 2010 is that the highest accessibility is generally given on a corridor from Rome across Northern Italy and France through to Southern England. Accessibility is also generally high in Spain, Western Germany and Poland, the latter through a mix of large regions with high population and good flight connections to Western Europe. Accessibility is generally, as was to be expected, lower in the more peripheral regions, but also in Switzerland, Austria and Bavaria, largely due to the Alps making connections less direct, and Eastern Germany with a lower population density.

The map comparing the Baseline 2030 against 2010 shows, not surprisingly, that the main increase in accessibility occurs in the peripheral regions, with some unexplained gaps in the Ukraine and western Russia. Another peripheral area with no significant increase in accessibility is Southern Turkey, but this was already relatively well connected as a touristic area in 2010. For most of central and western Europe any increase in accessibility is small, but there is no area with a decrease in accessibility.

Given that the population distribution remains constant across the different 2030 scenarios, variation of accessibility depends here only on changes in the available transport modes (new infrastructure, upgrading of existing infrastructure, transport cost variation).

For the Normative scenario, there is no change in accessibility against the Baseline 2030 for most parts of Europe, and where there is a change, it is in most cases very small. Two pockets with a larger decrease are in central Turkey and in the area around Stockholm, and larger increases are to be found in Spain, the west of Scotland Scandinavia, Estonia and Latvia, Western Russia and Belarus, and Northern Turkey. All these areas benefit from the higher rail and road investment in the Normative scenario.

The four exploratory scenarios show very different trends. OR1 shows the largest decreases in accessibility of all scenarios. Most parts of central and Eastern Europe show no change to the Baseline, but there are decreases in particular in large parts of Russia and the Ukraine, due to the increase in costs of all modes except rail, which becomes particularly relevant when long distances have to be bridged in areas with low population density. In contrast, accessibility increases in Spain and France, largely due to the large increase in rail links and in particular High Speed Rail links. The reason for the accessibility increases in parts of Scandinavia and Western Scotland is similarly that these areas have got improved rail links in OR1.

In OR2, where there is less new infrastructure for road and rail than in the Baseline, there is nevertheless no notable change in accessibility for most of Europe and there are more areas with an increase than a decrease. For some of the most peripheral areas there is even a strong increase in accessibility, since the little new investment there is, is mainly focussed on increasing accessibility into Europe rather than within.

OR3 is the scenarios with the least dramatic changes in spite of a level of investment similarly low as OR2. The only zone with a darker green is the one around Stockholm and the only red zones are in Latvia. The majority of areas in Western and Northern Europe have a slight increase in accessibility due to reduced costs in all modes, particularly for air travel, and increased travel speeds in all modes except road. As the investments aim less at territorial cohesion when compared to OR2, they tend to concentrate more on the already better equipped regions.

OR4 is the scenario with the largest increases in accessibility and, moreover, these increases are to be found in all but a very few pockets. The increase is smallest in Germany and generally getting larger the further the region is away from the centre. The main reasons behind this are the large increase in road and rail infrastructure, which opens up much more direct connections, in combination with the increased speed both for road and rail.

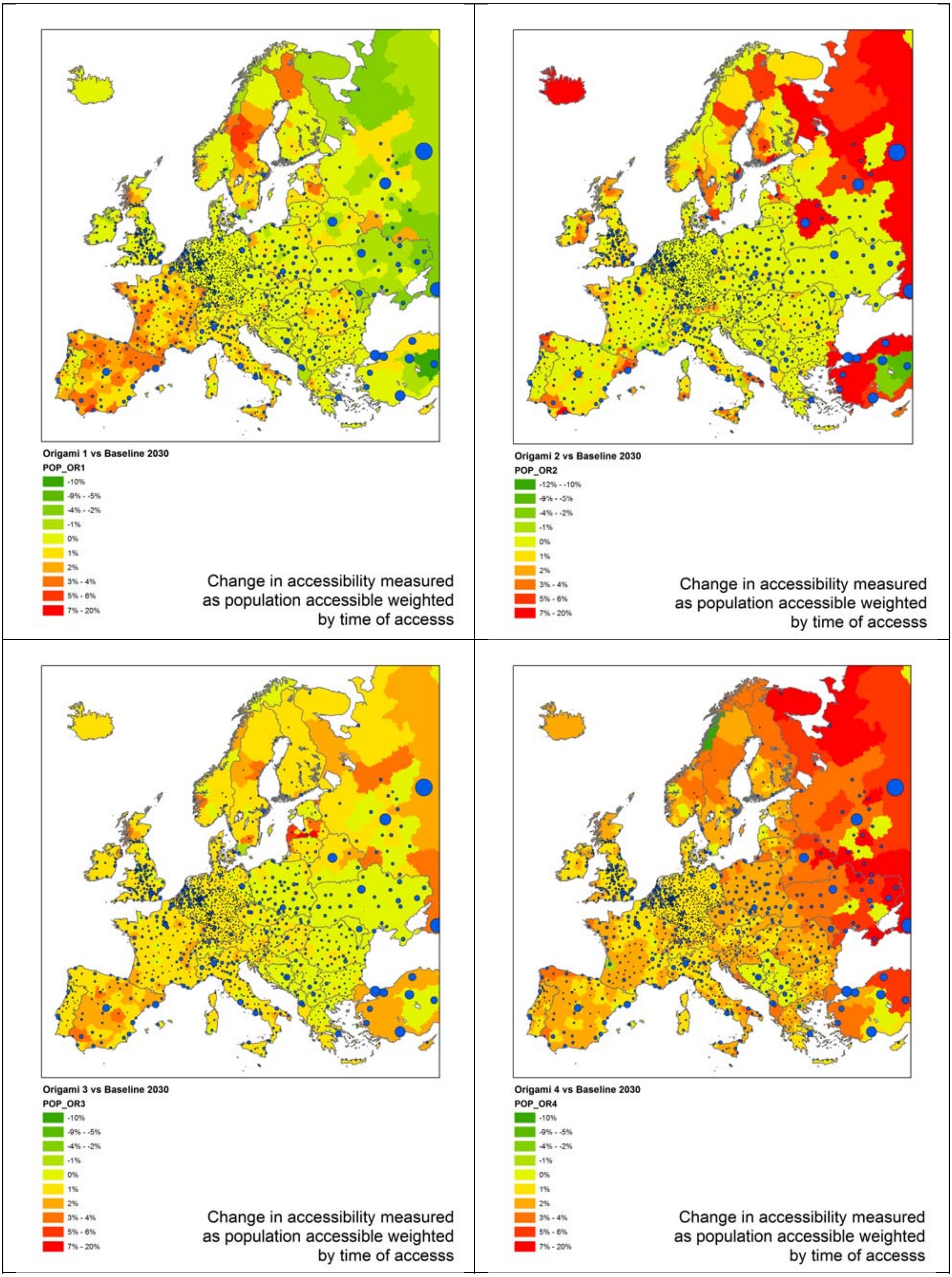


Figure 4-21 Relative change of accessibility in European regions between OR1 to O4 scenarios against Baseline 2030

5 LUNA MODEL DESCRIPTION

5.1 INTRODUCTION

The main scope of the model LUNA (Simulating the demand for Long-distance travel Using a Non-OD-matrix based Approach) is to assess long term effects of changes in socio-demography, economy, technology and transport policy. Hence the time horizon of the model reaches up to 2050, LUNA currently covers the EU27 Member States plus Norway and Switzerland. The scope of LUNA are holiday and business trips involving overnight stays. The model is subdivided into the following sub-modules:

- A population cohort model;
- A household formation model;
- A car ownership model;
- A non-OD-matrix based transport demand model;
- An aggregate transport supply model; and
- An evaluation indicator module.

From a technical point of view LUNA is based on the principles of Systems Dynamics and was programmed utilising the System Dynamics software Vensim(r)[i] while Microsoft Excel(r) is used as the data interface. In Vensim(r) there exists a simple way to provide a user friendly model version for users/clients without allowing them to change the basic model structure. Models can be converted into the file format “vpm” which stands for Vensim Packaged Model. These models can be run with the software “Vensim Model Reader” which can be downloaded from the Vensim(r) homepage for free. Vensim Packaged Models allow the user to choose policies from a pre-defined set of policy instruments, to choose and define background scenarios, to run the model and to calculate the effects of the selected policies and scenarios. The user is able to investigate all the underlying cause-effect relations in a qualitative way. The “Document” function of the Model Reader furthermore enables the user to investigate all underlying mathematical equations and parameters. Hence this type of model is fully transparent (“White box” in contrast to a “Black box” model). A Vensim Packaged Model of LUNA will be published on the internet (www.origami-project.eu). Interested readers are referred to this model, if they want to investigate all the qualitative and quantitative relations in full detail.

5.2 POPULATION COHORT MODEL

The population is subdivided into 18 age groups in five year time steps from 0-4 years up to 85 and more years. Figure 5-1 and Figure 5-2 show screenshots from the population cohort model as programmed in Vensim(r). The ageing of the population is modelled using a typical stock-flow-model (see Figure 5-1). Red elements indicate base year values which are imported from Excel(r) data files as constants. The term “T=0” in general points to base year values. The extension “xls” in general signals constants or data which are imported from Excel(r) data files. Blue elements mark time series data which are imported from Excel(r) scenario definition files. The calculation of the population in each time step is described in Equation 5-1. Figure 5-2 illustrates how this equation is defined in the Vensim(r) environment.

$$P_{r,k}(t) = P_{r,k}(t-1) + A_{r,k-1}(t) - A_{r,k}(t) + B_{r,k0}(t) - D_{r,k(t)} + M_{r,k(t)}$$

Equation 5-1 Population by age group

Legend:

$P_{r,k}(t)$ .... Population of age group k in region r (where regions are countries) in year t
$P_{r,k}(t-1)$ .... Population of age group k in region r in year t-1
$A_{r,k-1}(t)$ .... Ageing population leaving age group k-1 and transferring into age group k in region r in year t (zero for age group 0 to 4 years)
$A_{r,k}(t)$ .... Ageing population leaving age group k and transferring into age group k+1 in region r in year t (zero for age group 85 and more years)
$B_{r,k0}(t)$ .... Number of live births entering age group k0 (0 to 4 years) in region r in year t
$D_{r,k}(t)$ .... Number of deaths in age group k in region r in year t
$M_{r,k}(t)$ .... Net migration of population of age group k into region r in year t

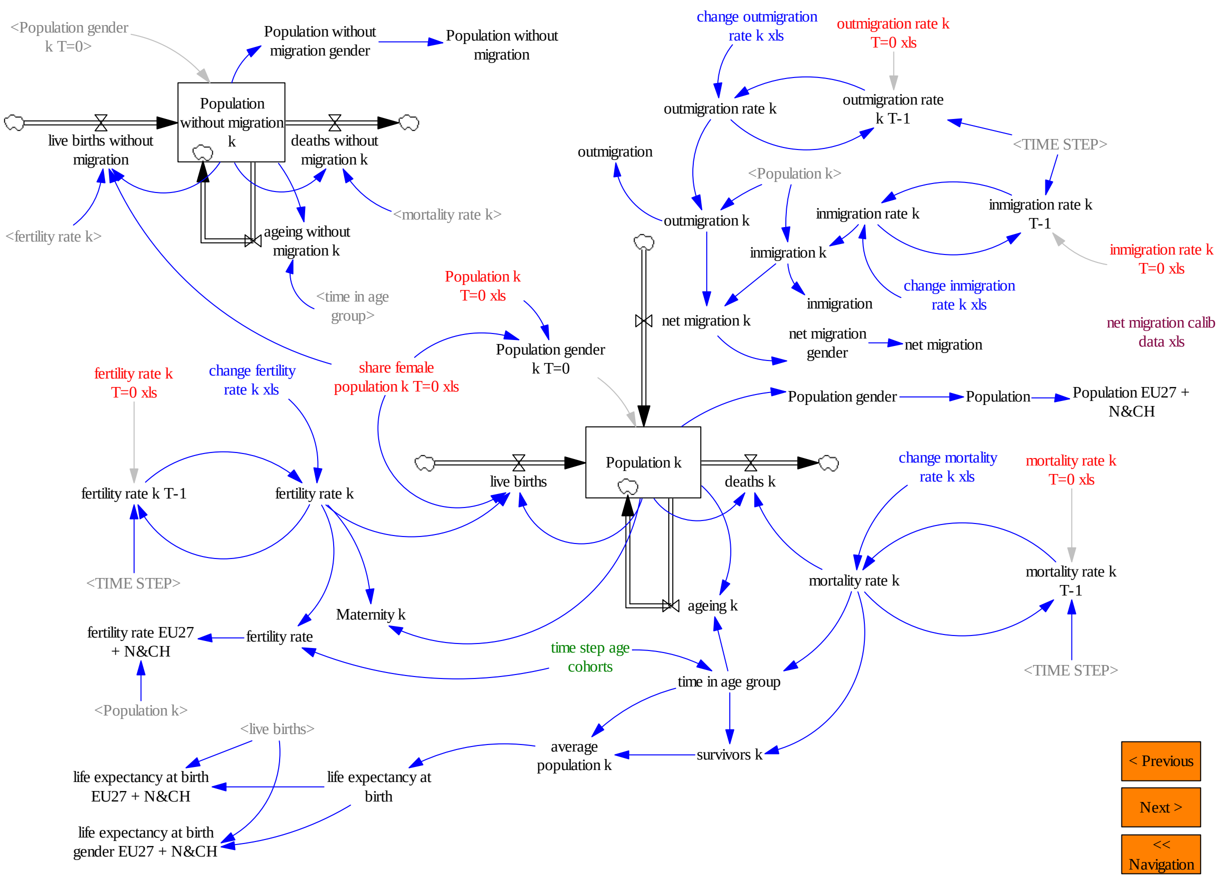


Figure 5-1 Screenshot LUNA population cohort model in Vensim(r)

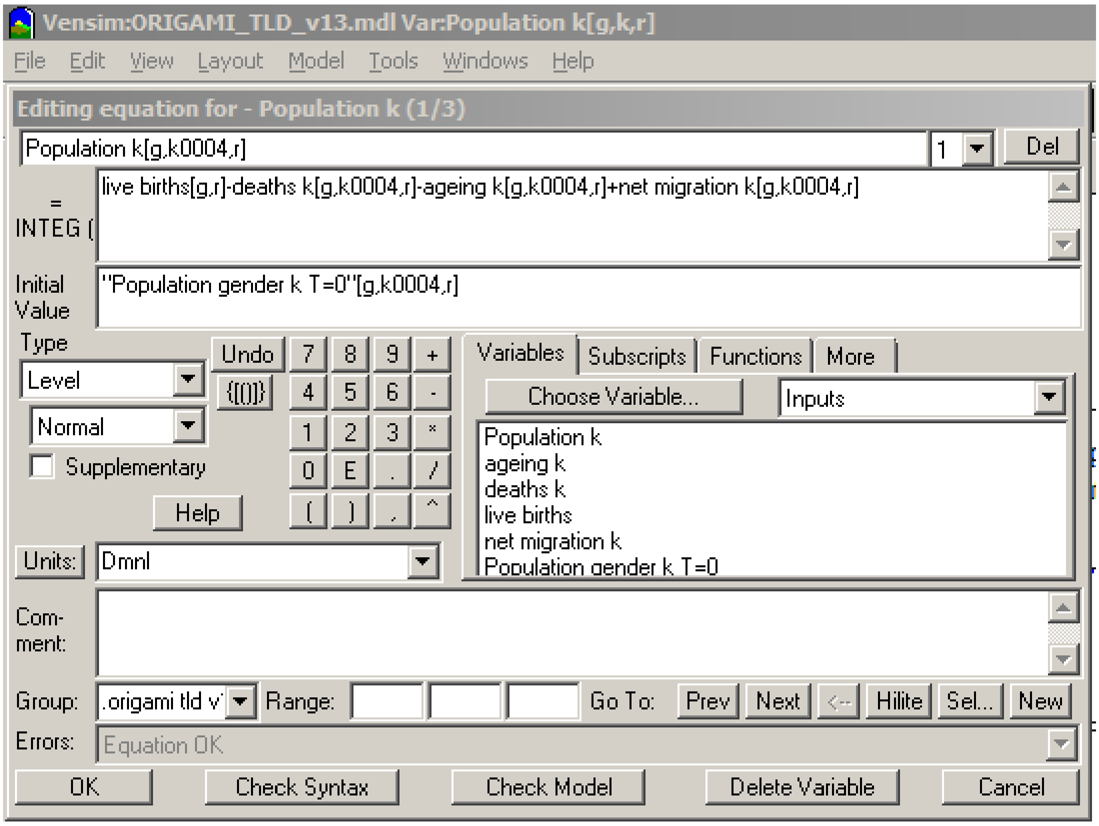


Figure 5-2 Screenshot Vensim(r) equations tool – calculation of population by gender, age cohort and region

5.3 HOUSEHOLD FORMATION MODEL

The LUNA household formation sub-model assigns the population of the different age groups to the different household types and income groups. Household types have been defined corresponding to the Eurostat database (single person household 20 to 59 years, two persons household 20 to 59 years, family household with one child, family household with two children, family household with three or more children, single parent HH with children, three or more adults, three or more adults with children, two persons household 60 years and older and single person household 60 years and older). Some of the household types have a clearly defined household size; for instance a single household always consists of one person. However, the four household types family household with three or more children, single parent HH with children, three or more adults and three or more adults with children do not have a clearly defined household size. The constraints of their minimum size and data about the national average household size have been used to calculate the household size of these household types (Table 5-1). The number of persons per household type and the share of households by household type (Eurostat 2011d) are used to calculate the number of households by type. Finally the number of persons per age cohort is allocated to the household types utilising the information about household size and number of households by type (Figure 5-3) which shows the view from Vensim(r) with all intermediate variables. The underlying equations may be viewed in the published model.

Table 5-1 Persons per household type and region

Household type	Single person HH young	Two persons HH young	Family HH one child	Family HH two children	Family HH three and more	Single parent HH with child	Three or more adults	Three or more adults with children	Two persons HH mature	Single person HH mature
Belgium	1	2	3	4	5.5	2.7	3.5	4.6	2	1
Bulgaria	1	2	3	4	5.3	2.5	3.7	5.0	2	1
Czech Republic	1	2	3	4	5.3	2.4	3.3	4.5	2	1
Denmark	1	2	3	4	5.5	2.8	3.3	4.6	2	1
Germany	1	2	3	4	5.1	2.0	3.0	4.3	2	1
Estonia	1	2	3	4	5.4	2.6	3.6	4.7	2	1
Ireland	1	2	3	4	5.5	2.6	3.4	4.7	2	1
Greece	1	2	3	4	5.3	2.4	3.6	4.6	2	1
Spain	1	2	3	4	5.3	2.4	3.5	4.6	2	1
France	1	2	3	4	5.2	2.4	3.2	4.5	2	1
Italy	1	2	3	4	5.3	2.4	3.4	4.6	2	1
Cyprus	1	2	3	4	5.3	2.5	3.6	4.7	2	1
Latvia	1	2	3	4	5.3	2.6	3.7	4.9	2	1
Lithuania	1	2	3	4	5.4	2.7	3.6	4.9	2	1
Luxembourg	1	2	3	4	5.4	2.5	3.4	4.6	2	1
Hungary	1	2	3	4	5.4	2.5	3.5	4.7	2	1
Malta	1	2	3	4	5.4	2.5	3.7	4.8	2	1
Netherlands	1	2	3	4	5.2	2.3	3.1	4.4	2	1
Austria	1	2	3	4	5.4	2.5	3.6	4.7	2	1
Poland	1	2	3	4	5.4	2.5	3.7	5.0	2	1
Portugal	1	2	3	4	5.3	2.5	3.5	4.7	2	1
Romania	1	2	3	4	5.4	2.5	3.7	5.1	2	1
Slovenia	1	2	3	4	5.7	2.9	4.6	5.4	2	1
Slovakia	1	2	3	4	5.3	2.5	3.6	4.8	2	1
Finland	1	2	3	4	5.6	2.7	3.3	4.6	2	1
Sweden	1	2	3	4	5.0	2.0	3.0	4.0	2	1
United Kingdom	1	2	3	4	5.6	2.9	3.8	4.8	2	1
Norway	1	2	3	4	5.3	2.5	3.2	4.5	2	1
Switzerland	1	2	3	4	5.5	2.6	3.7	4.8	2	1

Source: (Eurostat 2011d, a), own calculations

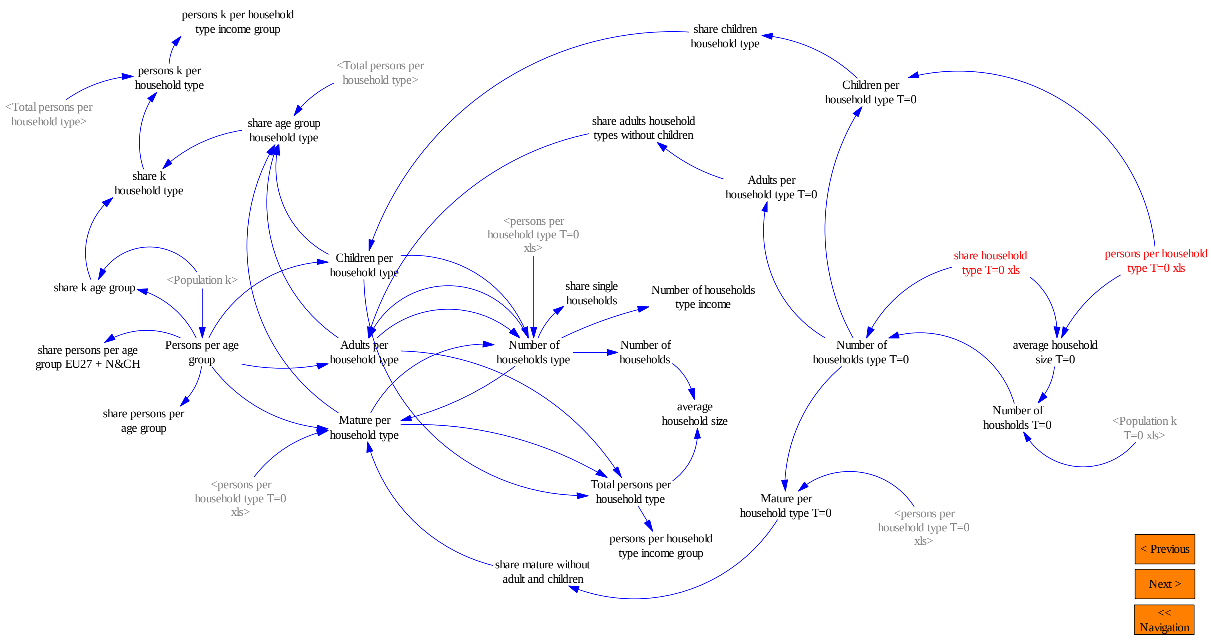


Figure 5-3 LUNA household formation model in Vensim(r)

The development of regional[40] household income is calculated from the scenario assumptions concerning regional GDP development. Three different income groups are taken into account in LUNA:

- Households in the three lowest income deciles;
- Households in the four middle income deciles; and
- Households in the three highest income deciles.

The base year median annual household income (Eurostat 2011b) is used to calculate the base year median income per person and hour by household type (Figure 5-4).

[40] In the current application, regions correspond to a country level (EU27 countries plus Norway and Switzerland). Nevertheless the model architecture is open in this aspect and future applications might use different regional definitions (e.g. NUTS2).

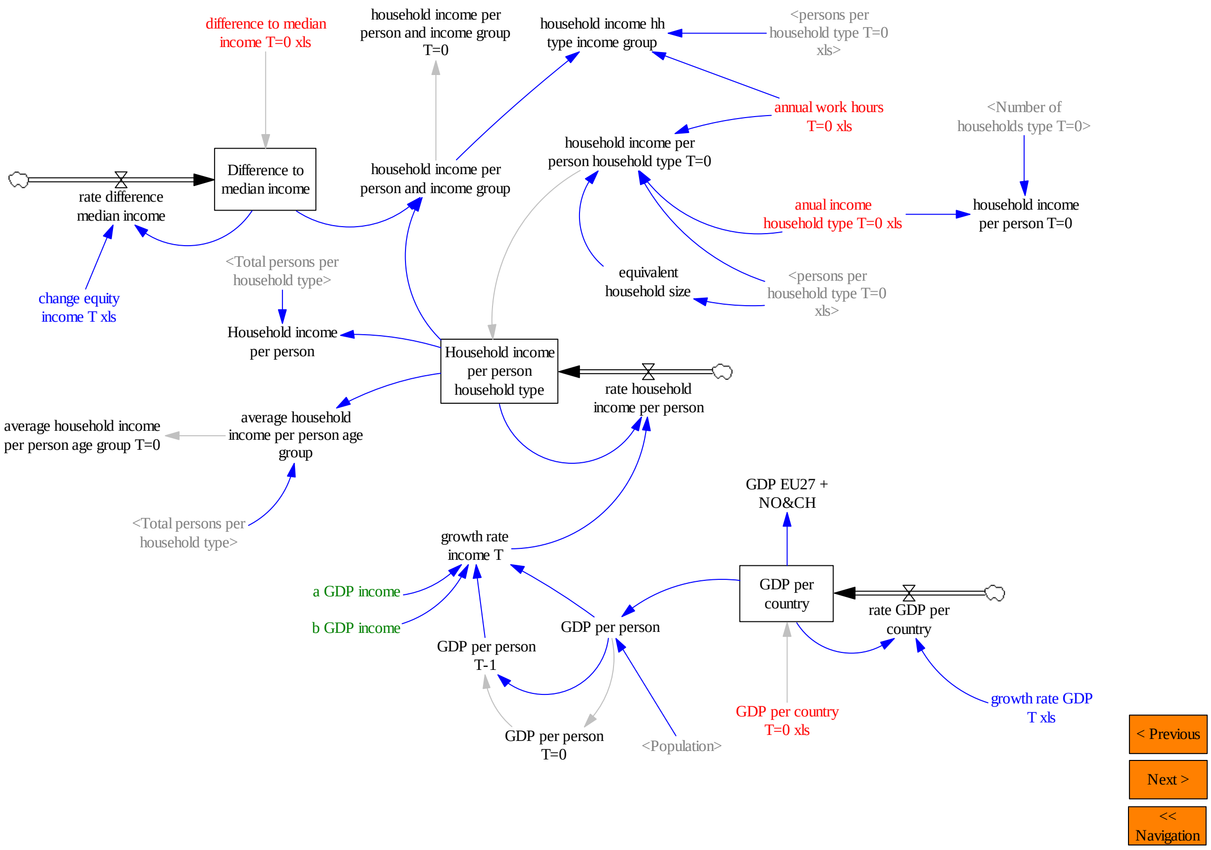


Figure 5-4 LUNA household income per person per household type and income group

The development of the household income for later years correlates with the GDP development (Equation 5-2).

$$I_r = a + b * GDP_r$$

Equation 5-2 Correlation between household income and GDP per person

Legend:
I_r..................Household income in region r (€/a)
a..................Parameter regression analysis (=1558.5; data source: Eurostat database)
b..................Parameter regression analysis (=0.4814; data source: Eurostat database)
GDP_r ....Gross domestic product per person in region r (€/a)

5.4 Car Ownership Model

Car availability depends on the household type and the household income (Equation 5-3). Figure 5-5 shows a screenshot of the car availability sub-model as programmed in Vensim(r). Figure 5-6 shows a screenshot of the equation tool in Vensim(r).

$$P_{h,r}^{no\ car} = a + b * S_r + c * I_{h,r}$$

Equation 5-3 Share of households without access to a car

Legend:
$P_{h,r}^{no\ car}$ .... Percentage of households of type h without a car in region r
a .... Regression coefficient (= 0.3077; data source: (Dargay et al. 2008) and Eurostat database)
b .... Regression coefficient (= 0.4380; data source: (Dargay et al. 2008) and Eurostat database)
S_r .... Dummy variable (1 if single household else 0)
c .... Regression coefficient (= -0.0230; data source: (Dargay et al. 2008) and Eurostat database)
$I_{h,r}$ .... Household income per person household type h in region r

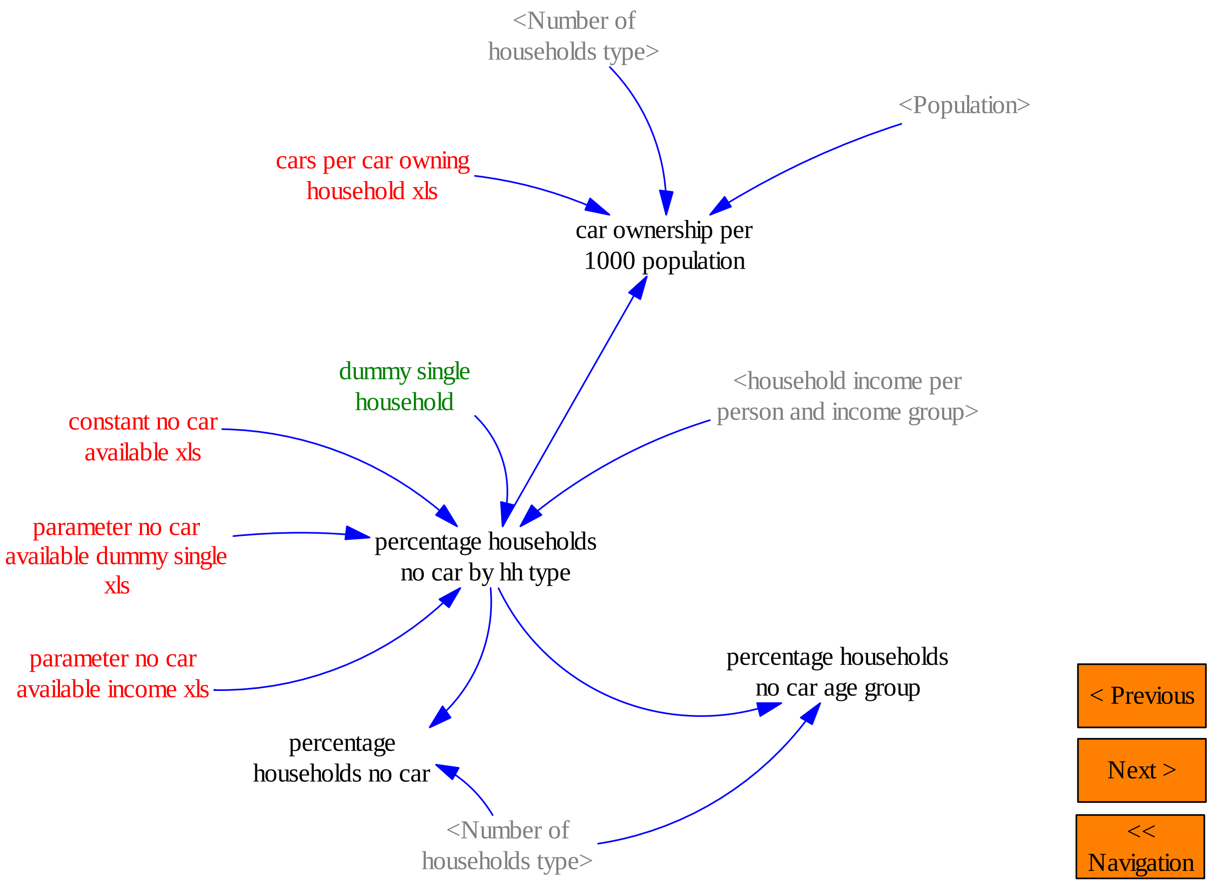


Figure 5-5 LUNA car availability sub-model in Vensim(r)

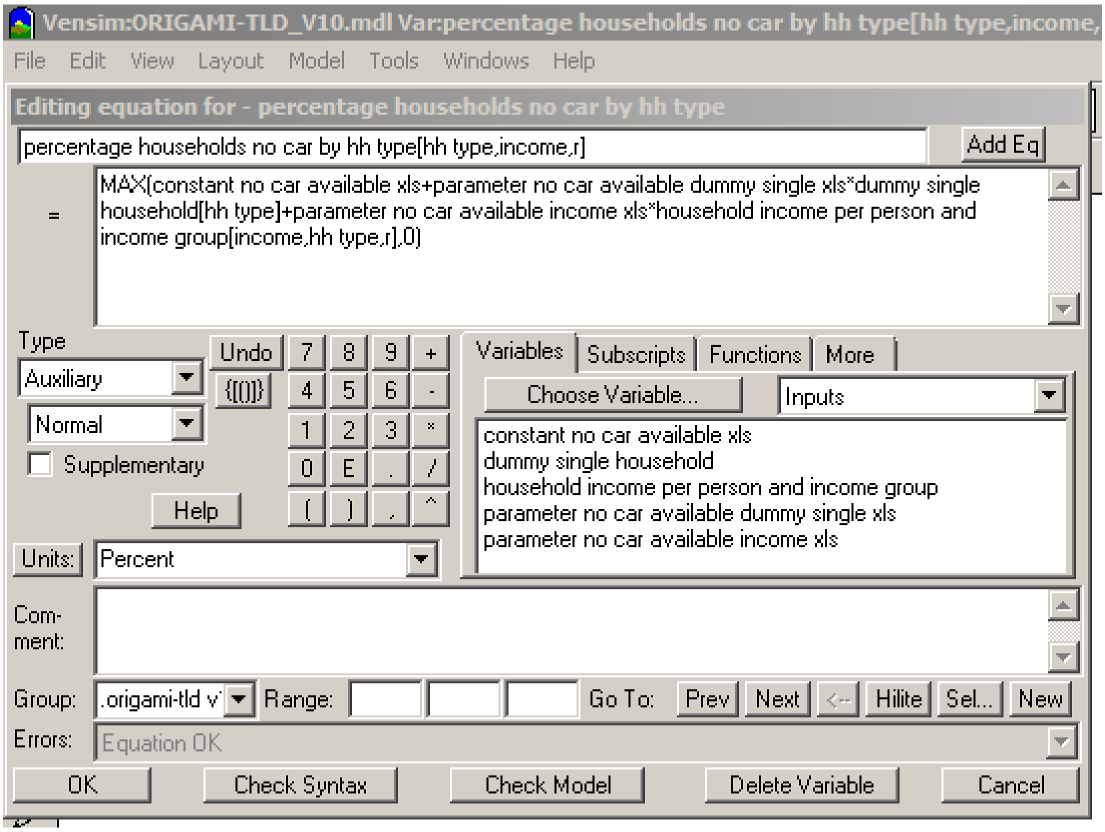


Figure 5-6 Screenshot calculation share of households without access to a car

5.5 TRANSPORT DEMAND MODEL

The LUNA transport demand model consists of the following sub-models:

- A car availability model;
- A trip rate model; and
- A distance class and mode choice model.

The following five different modes of transport are available in LUNA: private car, bus and coach, railway, air and maritime. Regional car availability of households is calculated from household type and income. Holiday trip rates are a function of household income and car availability. Business trip rates are a function of GDP per employed. The distance class and mode choice sub-model uses so called friction factors to distribute the total demand for holiday trips to the different distance bands and modes of transport. Friction factors are indicators to measure the subjectively perceived effort in terms of time and money which is necessary to carry out a journey. Friction factors can be interpreted as a kind of generalised cost although measured in time rather than money. The concept of friction factors with subjective weighting factors for different parts of a journey stems from (Walther et al. 1997).

Figure 5-7 shows a screenshot of the trip rate model as programmed in Vensim(r). Trip rates vary with household income and car availability.

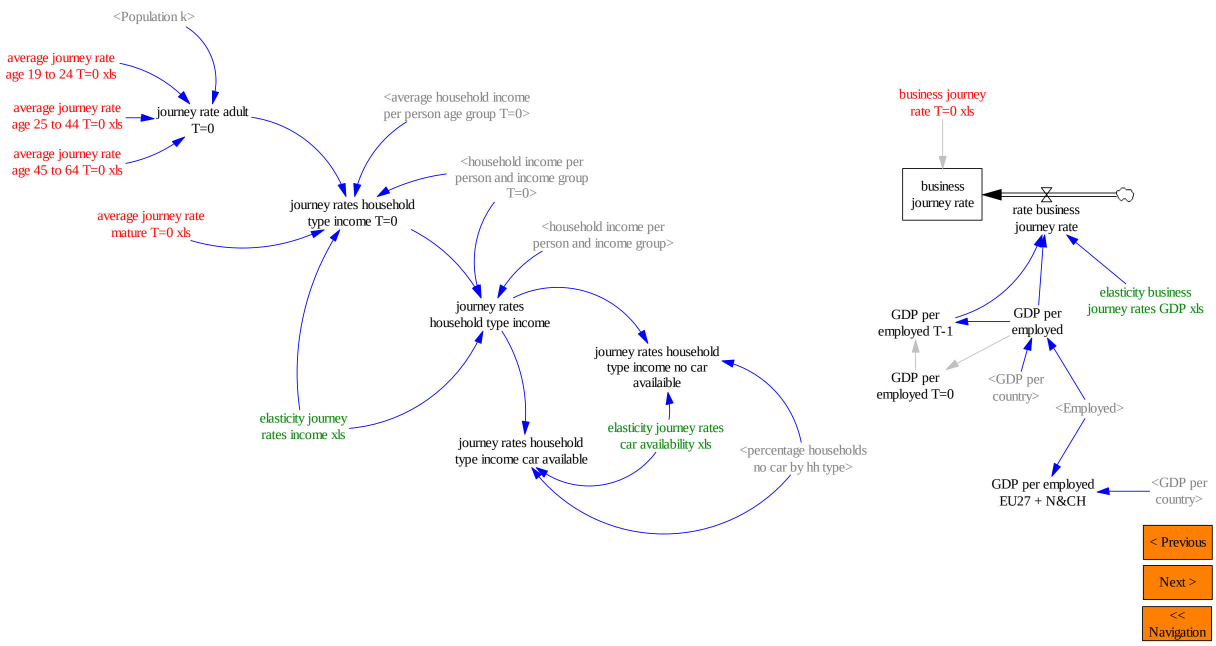


Figure 5-7 LUNA trip rate model in Vensim(r)

Equation 5-4 shows the general definition of the friction factors.

$$f_{d,r}^{m} = \sum_{n} SW_{d,r}^{m,n} * t_{d,r}^{m,n} + \sum_{n} \frac{c_{d,r}^{m,n}}{\alpha_{r}^{m,n} * I_{r} * o_{d,r}^{m}}$$

Equation 5-4 Friction factor definition

Legend:
$f_{d,r}^{m}$ ....Friction factor for a holiday trip with mode m in distance band d originating in region r (h)
$SW_{d,r}^{m,n}$.........Subjective weighting factor for part n of a holiday trip with mode m in distance band d originating in region r (-)
$t_{d,r}^{m,n}$.............Time of part n of a holiday trip with mode m in distance band d originating in region r (h)
$c_{d,r}^{m,n}$ ....Costs for part n of a holiday trip with mode m in distance band d originating in region r (€)
$\alpha_{r}^{m,n}$..............Parameter for willingness to pay for part n of a holiday trip with mode m originating in region r (-)
I_r..................Household income per person in region r (€/h)
$o_{d,r}^{m}$ ....Occupancy rate of a private vehicle on a holiday trip with mode m in distance band d originating in region r (-), 1 if a public mode is used

Equation 5-5 shows the general form of the subjective weighting factors. The parameters a, b, c and α have been estimated by (Walther et al. 1997) for regional travel. The parameters for long-distance travel have been estimated by the developers of LUNA based on expert judgement and comparison with observed data about modal split and distance band shares.

$$SW_{d,r}^{m,n} = a + b * e^{c * t_{d,r}^{m,n}}$$

Equation 5-5 Subjective weighting factor definition

Legend:
$SW_{d,r}^{m,n}$.........Subjective weighting factor for part n of a holiday trip with mode m in distance band d originating in region r (-)
$t_{d,r}^{m,n}$.............Time of part n of a holiday trip with mode m in distance band d originating in region r (h)
a, b, c...........Parameters

Figure 5-8 shows a screenshot of the friction factor calculation for the air mode as an example. In general a journey consists of the access to the entrance point to the main mode (parking place, bus terminal, railway station, airport, harbour), waiting, check-in and security procedures, in-vehicle time, changing and egress from the main mode.

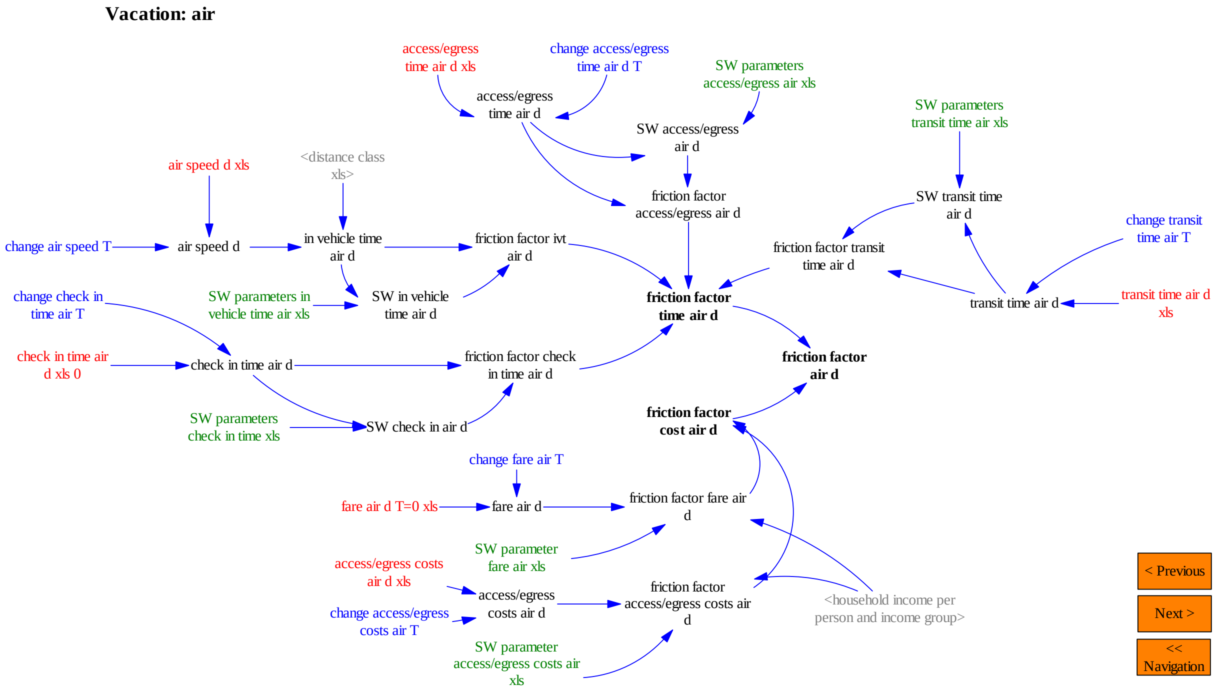


Figure 5-8 LUNA friction factor calculation mode air in Vensim(r)

Equation 5-6 and Figure 5-9 show the calculation of the number of holiday trips by mode, distance band and region.

$$T_{d,r}^{m} = P_r^{car}\,\frac{\frac{a_{d,r}^{m}}{f_{d,r}^{m}}}{\sum_{d,m}\frac{a_{d,r}^{m}}{f_{d,r}^{m}}} + P_r^{no\ car}\,\frac{\frac{a_{d,r}^{m\prime}}{f_{d,r}^{m\prime}}}{\sum_{d,m\prime}\frac{a_{d,r}^{m\prime}}{f_{d,r}^{m\prime}}}$$

Equation 5-6 Distance band and mode choice

Legend:
$T_{d,r}{}^{m}$ ....Holiday trips with mode m in distance band d originating in region r (trips/a)
$P_r{}^{car}$..............Potential holiday trips originating in region r households with access to a car (trips/a)
$P_r{}^{no\ car}$...........Potential holiday trips originating in region r households without access to a car (trips/a)
$a_{d,r}{}^{m}$ ....Availability of mode m in distance band d originating in region r (-)
$f_{d,r}{}^{m}$ ....Friction factor for a holiday trip with mode m in distance band d originating in region r (h)
m'................Subset of modes available in households without access to a car (coach, rail, air, maritime)

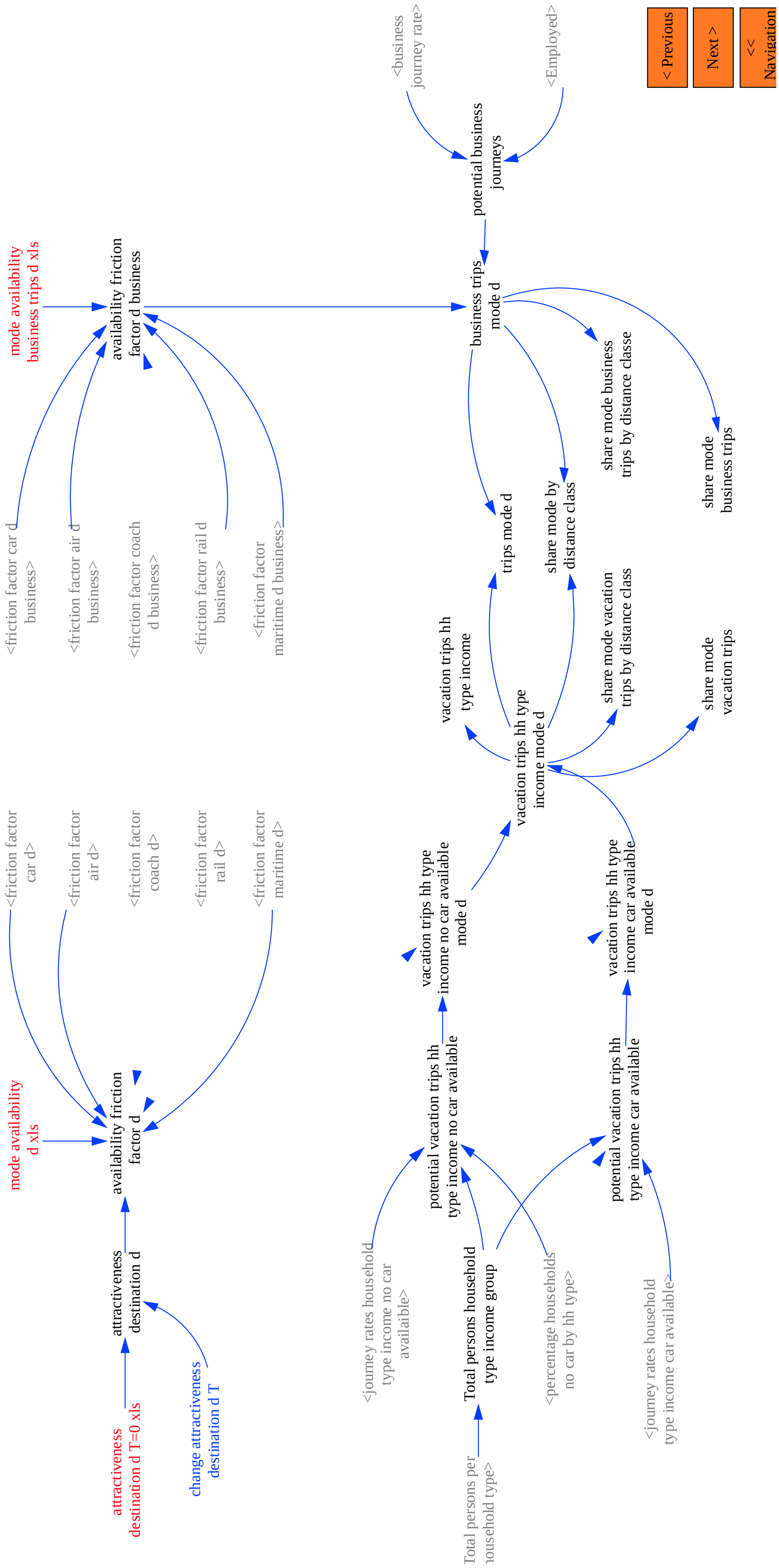


Figure 5-9 LUNA distance class and mode choice model in Vensim(r)

5.6 AGGREGATED TRANSPORT SUPPLY MODEL

It is unrealistic for the collective modes (bus, rail, air, maritime) to calculate emissions by multiplying emission factors per person kilometre by person kilometres travelled. Emissions will only change significantly if supply is changed. Hence an aggregated transport supply model was integrated in LUNA (Figure 5-10). Assumptions about base year load factors and base year transport demand are used to calculate base year seats and seat kilometres (Equation 5-7). Subsequently the load factor is calculated in each iteration by dividing the number of passengers by the number of seats (Equation 5-8). The number of seats is adjusted by a user defined increment if the load factor reaches a user defined threshold (Equation 5-9). Vehicle kilometres are calculated by dividing passenger kilometres by load factors and specific vehicle capacities (Equation 5-10).

$$S_r^c(T_0) = \frac{P_r^c(T_0)}{LF_r^c(T_0)}$$

Equation 5-7 Seat capacity collective modes base year

Legend:
$S_r^c(T_0)$ .... Seats collective mode c originating in region r base year T_0
$P_r^c(T_0)$ .... Number of passengers collective mode c originating in region r base year T_0
$LF_r^c(T_0)$ .... Load factor collective mode c originating in region r base year T_0 (%)

$$LF_r^c(t) = \frac{P_r^c(t)}{S_r^c(t)}$$

Equation 5-8 Load factor collective modes

Legend:
$LF_r^c(t)$ .... Load factor collective mode c originating in region r year t (%)
$P_r^c(t)$ .... Number of passengers collective mode c originating in region r year t
$S_r^c(t)$ .... Seats collective mode c originating in region r year t

$$If\ LF_r^c(t) > LF_r^c(max)\ then\ S_r^c(t) = (1 + i_r^c) * S_r^c(t-1)\ else\ S_r^c(t) = S_r^c(t-1)$$

Equation 5-9 Seat capacity collective modes year t

Legend:
$LF_r^c(t)$ .... Load factor collective mode c originating in region r year t (%)
$LF_r^c(max)$ ..... Threshold load factor collective mode c originating in region r (%)
$S_r^c(t)$ .... Seats collective mode c originating in region r year t
$S_r^c(t-1)$ .... Seats collective mode c originating in region r year t-1
i_r^c .... Increment seat supply adaptation collective mode c originating in region (%)

$$d_r^{c,veh}(t) = \frac{d_r^{c,pass}(t)}{LF_r^c(t) * s_r^c(t)}$$

Equation 5-10 Seat capacity collective modes base year

Legend:
$d_r^{c,veh}(t)$ .... Vehicle kilometres collective mode c originating in region r year t (veh km/a)
$d_r^{c,pass}(t)$ .... Passenger kilometres collective mode c originating in region r year t (veh km/a)
$LF_r^c(t)$ .... Load factor collective mode c originating in region r year t (%)
$s_r^c(t)$ .... Seat capacity per vehicle collective mode c originating in region r year t (-)

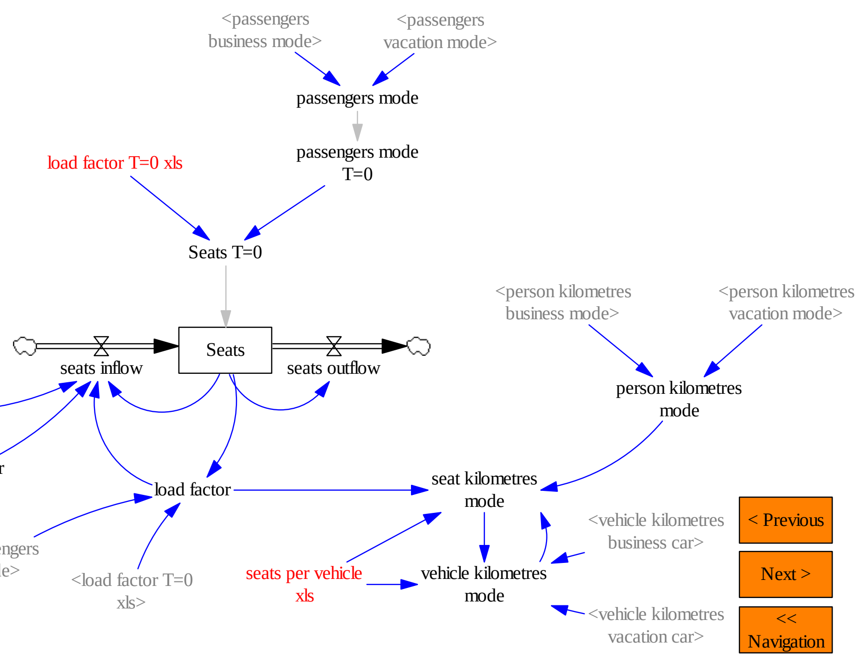


Figure 5-10 LUNA aggregated transport supply model in Vensim(r)

5.7 Evaluation Indicator Module

An extensive set of indicators for the scenario evaluation has been defined in ORIGAMI. These indicators are calculated in LUNA in a separate view (Figure 5-11).

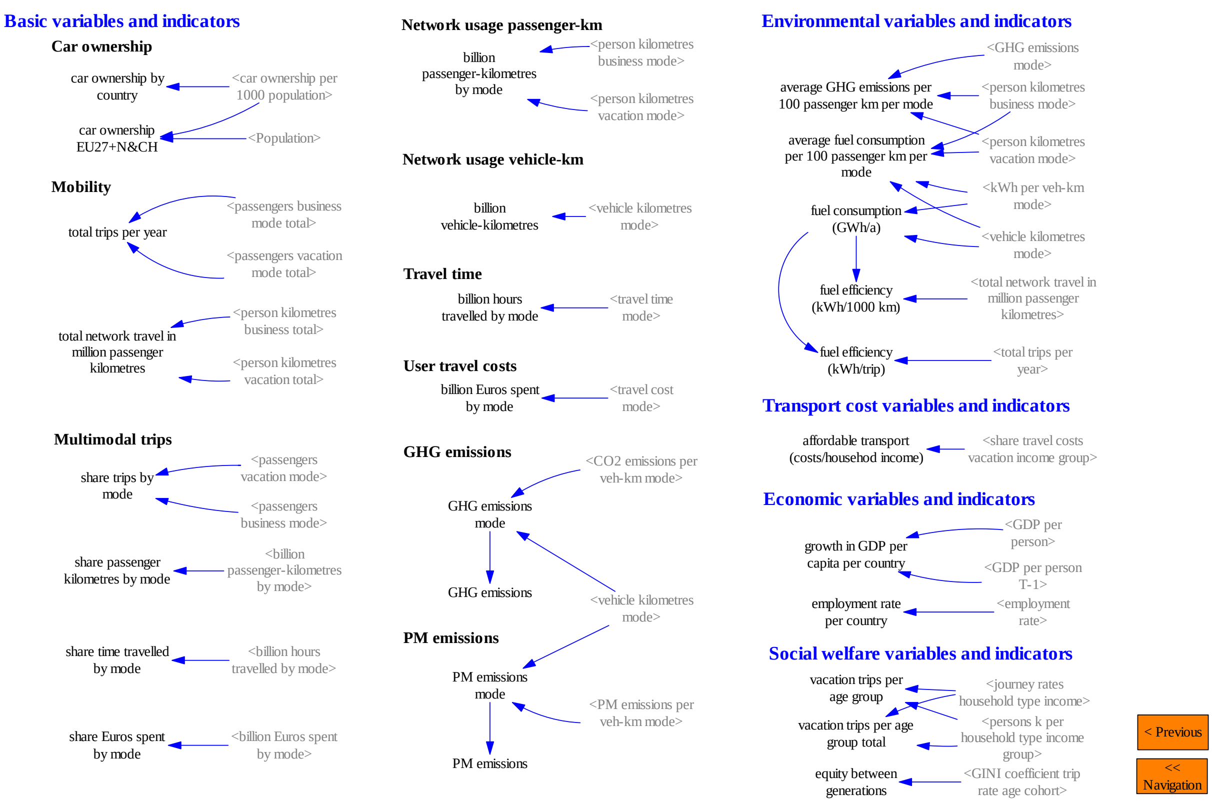


Figure 5-11 LUNA evaluation indicator calculation in Vensim(r)

5.8 Model Calibration

5.8.1 Available Data

A comparison of different outcome indicators of the model LUNA with observed data from different sources has been carried out in order to estimate model parameters.

Three main data sources for the calibration and testing of the long-distance travel model LUNA have been identified in an extensive literature and project review:

- The Eurostat tourism demand database (Eurostat 2011c);
- A household survey from the project DATELINE - Design and Application of a Travel Survey for European Long-distance Trips based on an International Network of Expertise (DATELINE Consortium 2004); and
- Different National Travel Surveys (Ministry of Transport and Communications Finland et al. 2006; Ministerio de Fomento 2007; Swedish Institute for Transport and Communications Analysis (SIKA) 2007; infas Institut für angewandte Sozialwissenschaft GmbH 2010; Ministère de l'Ecologie du Développement durable des Transports et du Logement 2010; Department for Transport 2011).

(Eurostat 2011c) defines tourism as *activity of persons travelling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes*. Strictly speaking the data are not exactly about long-distance travel. Rather than by distance, data are reported by duration of stay (one night and more and four nights and more). Nevertheless it seems appropriate to assume that journeys with four or more overnight stays are mainly long-distance trips. The Eurostat database distinguishes between the journey purposes holiday, visiting friends and family and business. Eurostat tourism data are available for all EU27 countries plus Norway and Switzerland. Nevertheless some data are missing for some countries and years, for instance there are no data available from the Netherlands about business trips with a duration of one night and over.

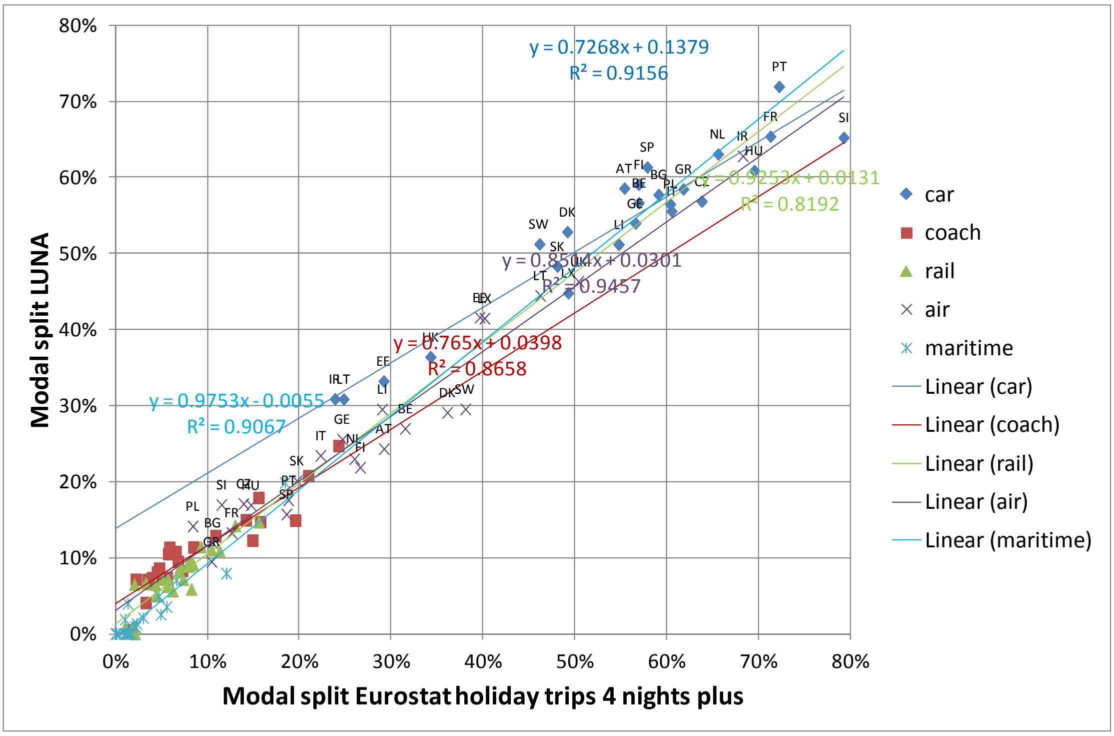
A household and person level survey on long-distance travel of 86,000 residents in the EU 15 countries plus Switzerland has been carried out in DATELINE (DATELINE Consortium 2003, 2004). The survey took place from October 2001 through to October 2002. The dataset contains travel date, destination, duration, travel mode and distance bands. Residents aged 15 years and over reported long-distance travel of over 100 km crow-fly distance for the purposes holiday, private, business and commuting.

Data about long-distance travel are available from national travel surveys in Finland, France, Germany, Spain, Sweden and the United Kingdom. The disadvantage of this set of data is that the definitions of distance bands are not consistent.

A comprehensive summary of the relevant data from the three sources can be found in (Lemmerer and Pfaffenbichler 2012).

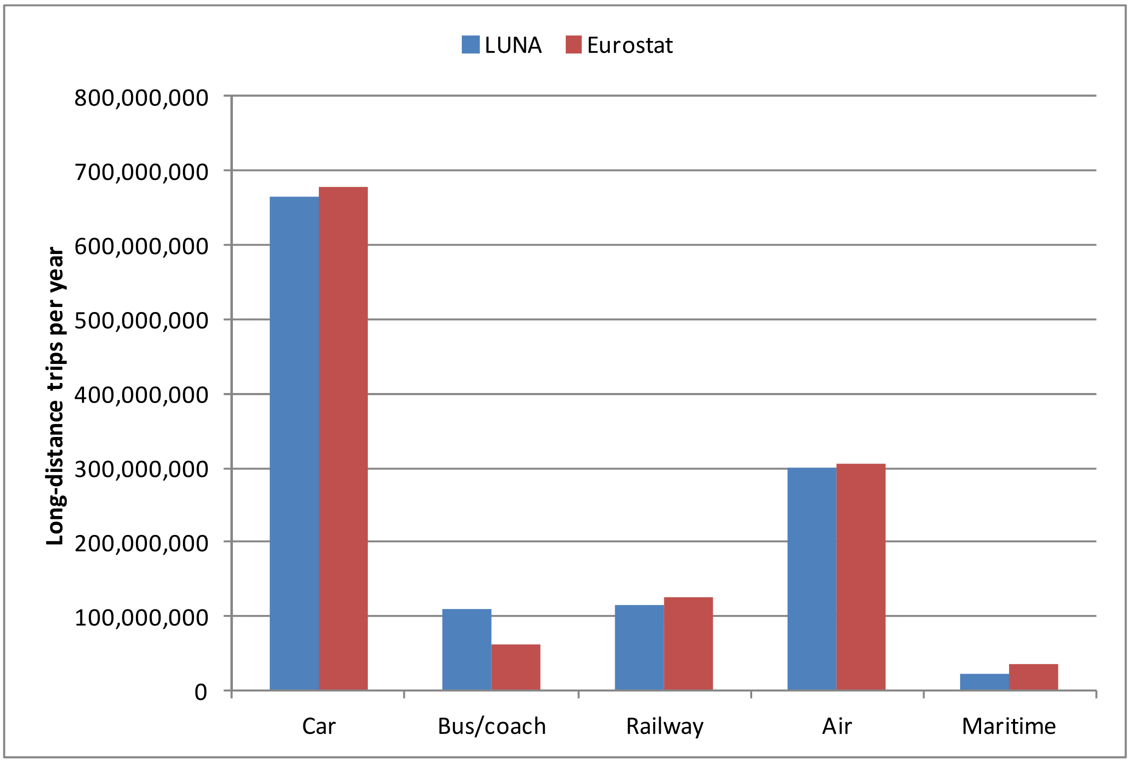
5.8.2 Calibration

In a first step the model LUNA was calibrated to fit mode split calculated from Eurostat data for holiday trips of four nights and more ((Data *source: Eurostat 2011c)*
Figure 5-12) and the total number of trips by mode for the purposes holiday and visiting friends and family ((Data *source: Eurostat 2011c)*
Figure 5-13). The mode splits show a reasonable fit by country with all R-squared values above 0.81. The total trips show a good fit apart from coach/bus where LUNA overestimates these totals as compared to the data. The fit for the main modes of car, air and rail is however very good.



(Data source: Eurostat 2011c)

Figure 5-12 Comparison of base year modal split by country LUNA holiday trips – Eurostat holiday trips four nights and more

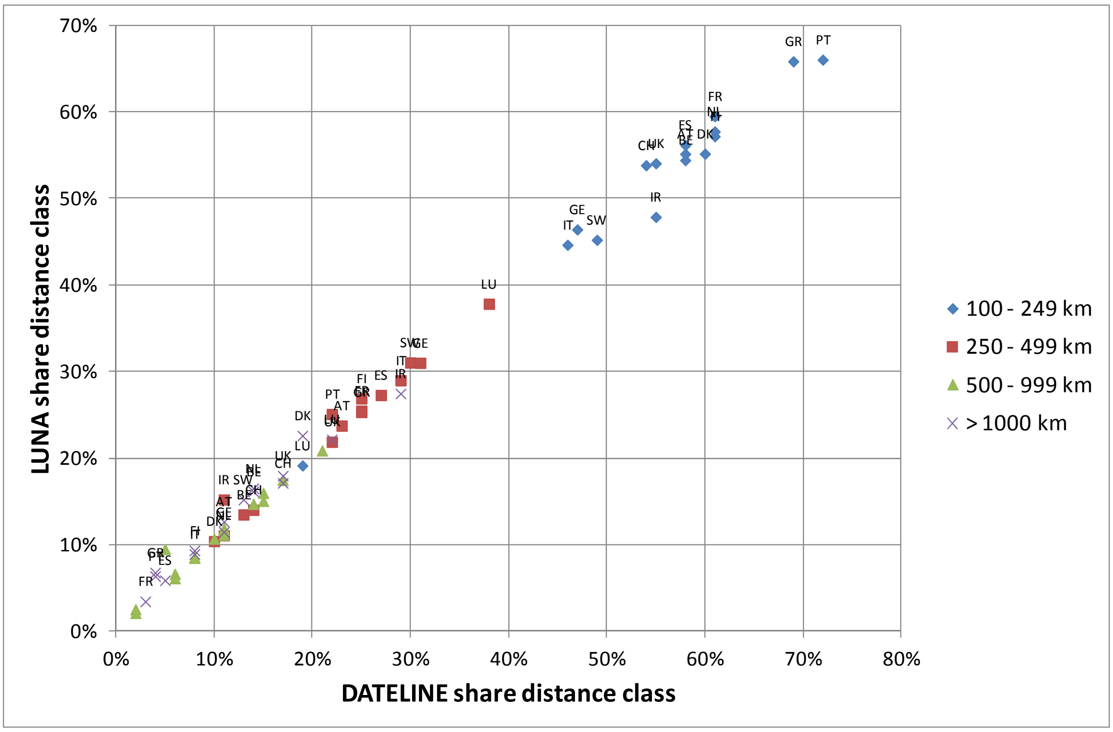


(Data source: Eurostat 2011c)

Figure 5-13 Comparison of total trips by mode base year LUNA holiday trips – Eurostat holiday and visiting friends and family trips four nights and more

In a second step parameters were varied in order to fit the distribution of trips by distance band from DATELINE (Data *source: DATELINE Consortium 2004)*

Figure 5-14). As can be seen the model fits the distance class data quite well at the country level with only a few outliers such as Ireland and Portugal (due to it being more difficult to model the peripheral countries where even a short long-distance trip may involve maritime or air).



(Data source: DATELINE Consortium 2004)

Figure 5-14 Comparison of LUNA base year share of distance class by country – DATELINE share of distance class

6 DESCRIPTION OF THE SCENARIOS FOR 2050

6.1 LUNA BASELINE SCENARIO DEVELOPMENT

LUNA is a country level model and consequently there will be a lower level of spatial detail required when setting scenarios and policies. Nevertheless it has to be mentioned that the dynamic nature of LUNA adds the time dimension to the scenario definition, i.e. it is necessary / possible to define 40 different values for each scenario variable. In combination with the spatial dimension, i.e. the 29 countries represented in LUNA, this gives a total of 1,160 potential values for each single scenario variable.

Table 6-1 describes the assumptions and data sources used for each dimension (social, demographic etc) in the development of the Baseline scenario for the 2050 model LUNA. In particular this compares the model development with what has been suggested in the ORIGAMI description of work.

Table 6-1 LUNA Baseline Scenario development

Description of work	LUNA
• Demography	
o Stable in demographic terms	o Source: (Eurostat 2012) o Fertility rate: The fertility rate of EU27 plus Norway and Switzerland increases from 1.593 in 2010 to 1.694 in 2050 (+6%) o Life expectancy at birth: increasing in the EU27 plus Norway and Switzerland from 79.5 years in 2010 to 86.0 years in 2050 (+8%)
o Ageing population	o The share of residents 60 years and older is increasing from 23.1% in 2010 to 33.6% in 2050 (+45%)
• Social	
o Increasing migration from northern countries to southern countries	o This hypothesis could not be confirmed by the available data from the Eurostat database. o Net migration is negative in Bulgaria, Estonia, Ireland, Latvia, Lithuania, Malta, Poland and Romania in the early years of the forecast period. The trend is reversed later and all countries have a positive net migration in the later years. Source: (Eurostat 2012)
o Maintaining social welfare and social inclusiveness	o The GINI coefficient of the welfare distribution between countries is lightly improving from 0.21 in 2010 to 0.20 in 2050. o In the base year intra-zonal equity is decreasing in Denmark, Germany, Spain, France, Cyprus, Latvia, Lithuania, Luxembourg, Malta, Austria, Slovenia, Slovakia and Sweden. It is assumed that between 2020 and 2030 intra-zonal equity improves in all countries and is constant afterwards.
o Multicultural	o Not within the scope of the model
o Economy	o
o Moderate economic growth	o Source for growth rates by country: (European Commission 2009) o Total GDP of EU27 plus Norway and Switzerland is assumed to grow by about 3% p.a. in 2010. The yearly growth rate declines continuously to about 1.5% in 2050.
o Increasing productivity	o Source for growth rates by country: (European Commission 2009) o GDP per employee in the EU27 plus Norway and Switzerland increases from about 58,000 €/a in 2010 to about 127,000 €/a (+120%)
o Growing exponentially in terms of information exchange	o Not within the scope of the model
• Technology	
o Shift towards a post-carbon technologies	o The technology shift was defined in line with the Baseline scenario of GHG-TransPoRD.
o Shift towards nanotechnology, biomedicine	o Not within the scope of the model
• Spatial development	
o More urbanised, with more or less diffused structures	o This level of spatial detail is not available in LUNA.

• Governance	
o Public sector staying at its current size, or being marginally reduced	o Not within the scope of the model.
o Growing pensions, health care and other public services	o In the base scenario it is assumed that there are no cuts of pensions, i.e. income of mature households grows in line with the income of the other household types. o Improvements in health care are reflected in the increasing life expectancy at birth. See section Demography.
o Making larger infrastructure and research investments	o Part of the transport supply side scenarios. Aligned with the respective MOSAIC base line assumptions.
o Internal EU policy reforms towards more open markets	o Not within the scope of the model
• Politics	
o Peaceful; democratic; enlarged, integrating many neighbouring countries in the East, and South	o Is reflected in the positive net migration. See topic Social.
o More closely connected to North African countries	o Is reflected in the positive net migration. See topic Social.

6.2 BUILDING BLOCKS FOR THE POLICY SCENARIOS

6.2.1 Background

The socio-demographic and economic scenarios are defined by the elements total fertility, life expectancy at birth, in and out migration, employment and GDP. Furthermore LUNA allows the definition of different scenarios concerning developments in propulsion technology and transport policy. Scenarios for LUNA can then be defined by a combination of the different assumptions concerning the different socio-demographic, economic and transport sub models. Table 6-2 gives a descriptive overview of the sub-scenario assumptions defined. These sub-scenarios are combined to define six ORIGAMI scenarios for 2050 (see section 6.3).

Table 6-2 LUNA sub models and scenario dimensions

Sub model	Scenario assumptions
Total fertility	Baseline, High growth, Low growth
Life expectancy	Baseline, High growth, Low growth
Migration	Baseline, Concentration towards central Europe
Employment	Baseline
GDP	Baseline, Concentration towards central Europe, Dispersion into the periphery, Uniform high growth, Uniform low growth
Propulsion technology	Baseline, Low emission, Very Low Emission
Transport policy	Baseline, Normative reference, Regulation & high infrastructure investment, Regulation & low infrastructure investment, Liberalisation & low infrastructure investment, Liberalisation & low infrastructure investment

6.2.2 Socio-Demography and Economy

Total fertility rate

Fertility rates are defined as follows:
Total fertility rate: The mean number of children that would be born alive to a woman during her lifetime if she were to pass through her childbearing years conforming to the fertility rates by age of a given year[41].

[41] Source: Eurostat metadata Fertility, http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/demo_fer_esms.htm, accessed: 06/07/2012

Three different potential future scenarios have been defined concerning total fertility rate: Baseline, low growth and high growth. The Baseline fertility rate for the 2050 scenarios is consistent with the EUROPOP2010 convergence scenario (Eurostat 2012). The total fertility rate of the EU27 plus Norway and Switzerland in the Baseline is slightly increasing from 1.6 in 2010 to 1.7 in 2050. Approximately in line with (Lanzieri 2006) a high fertility rate scenario is assumed where the fertility rate increases to about 2.0 in 2050 and a low fertility rate scenario where the fertility rate decreases to about 1.4 in 2050 (see Figure 6-1).

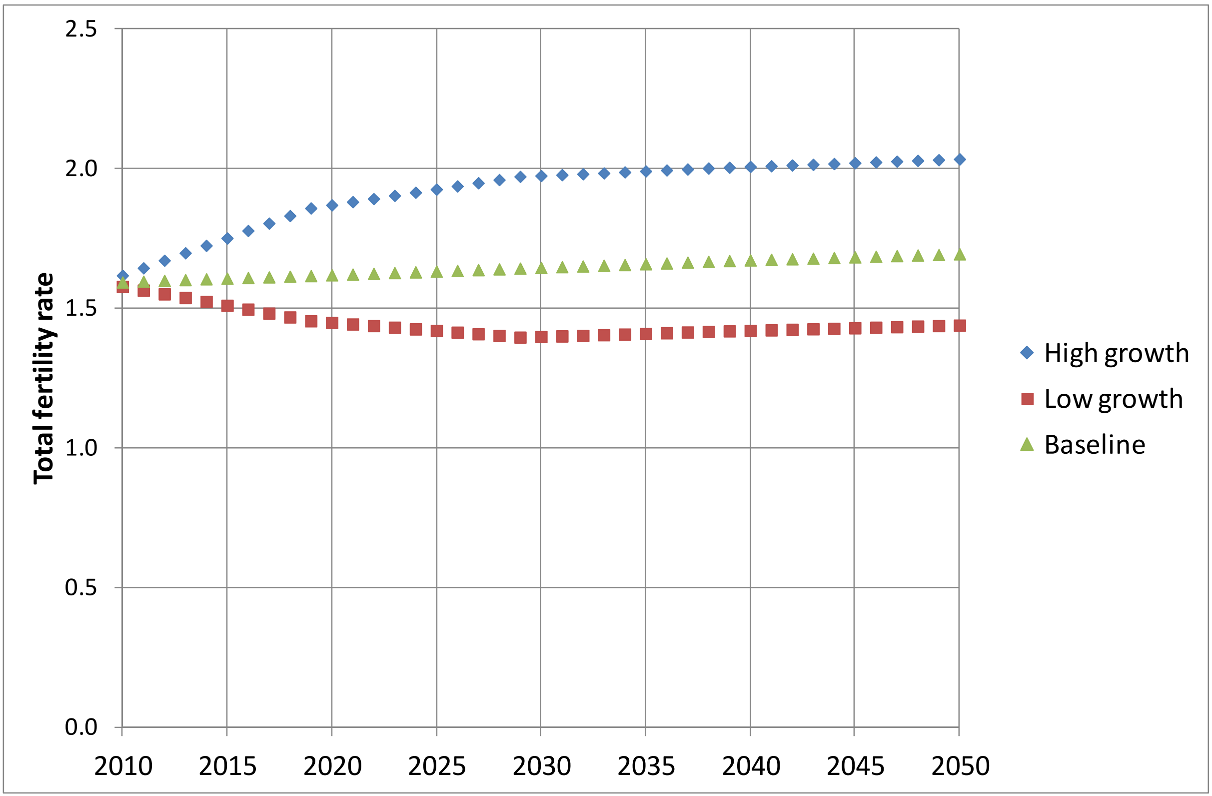


Figure 6-1 Total fertility rate EU27 + NO & CH by sub-scenario

Figure 6-2 to Figure 6-4 show the development of the total fertility rate by country. In the base year Ireland has the highest fertility rate (about 2.1) while Latvia and Portugal have the lowest fertility rates (about 1.3). In 2050 in all three scenarios Ireland still has the highest birth rate (1.7, 2.0 and 2.4 respectively), but now Portugal has the lowest birth rate (1.3, 1.5 and 1.8 respectively). Overall fertility rates have a converging trend in all three scenarios. The difference between the highest and the lowest fertility rate decreases from 0.8 in 2010 to 0.4 (low fertility), 0.5 (Baseline) and 0.6 (high fertility) in 2050.

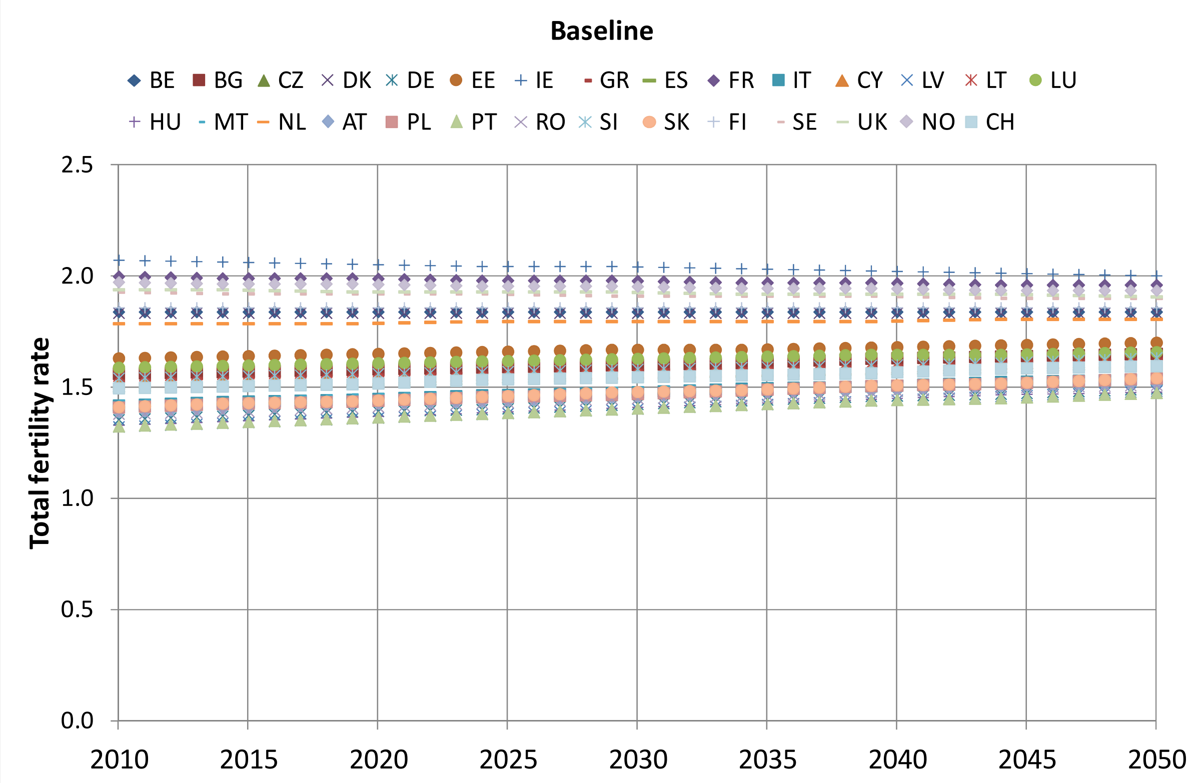


Figure 6-2 Total fertility rate by country – Baseline sub-scenario

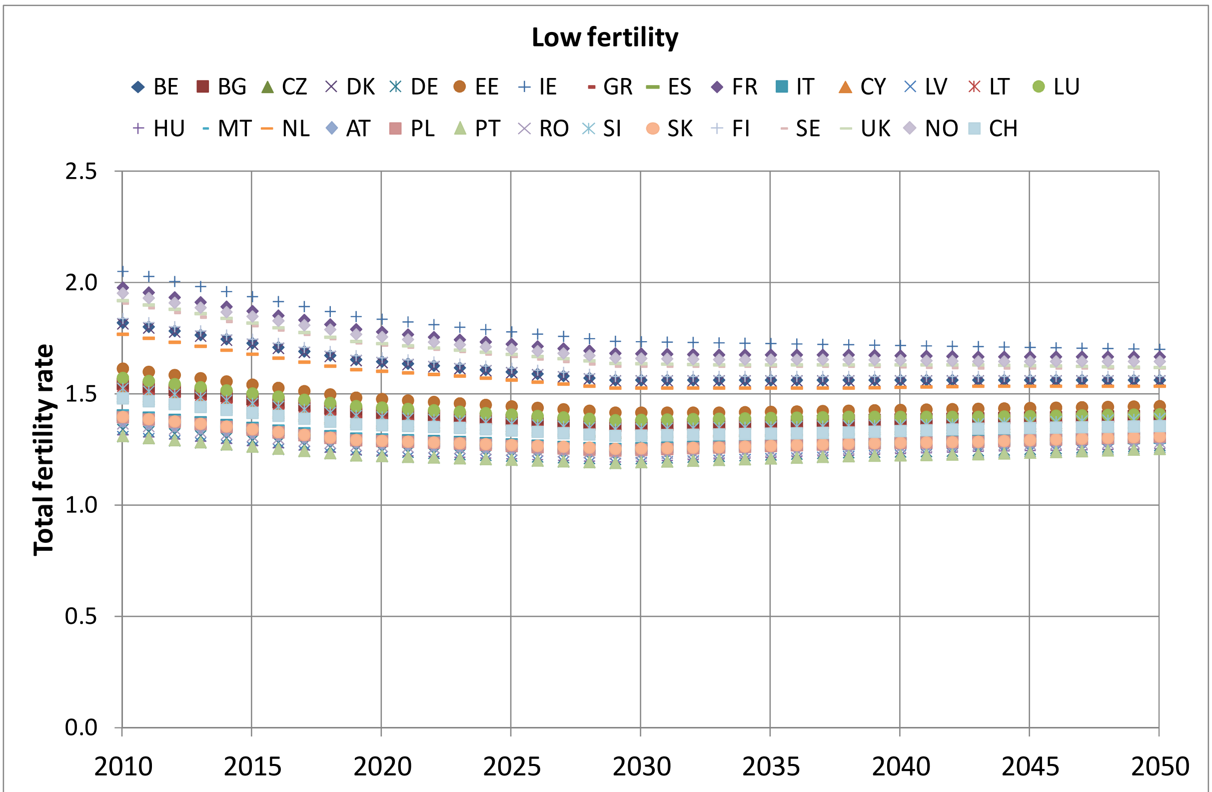


Figure 6-3 Total fertility rate by country – low growth sub-scenario

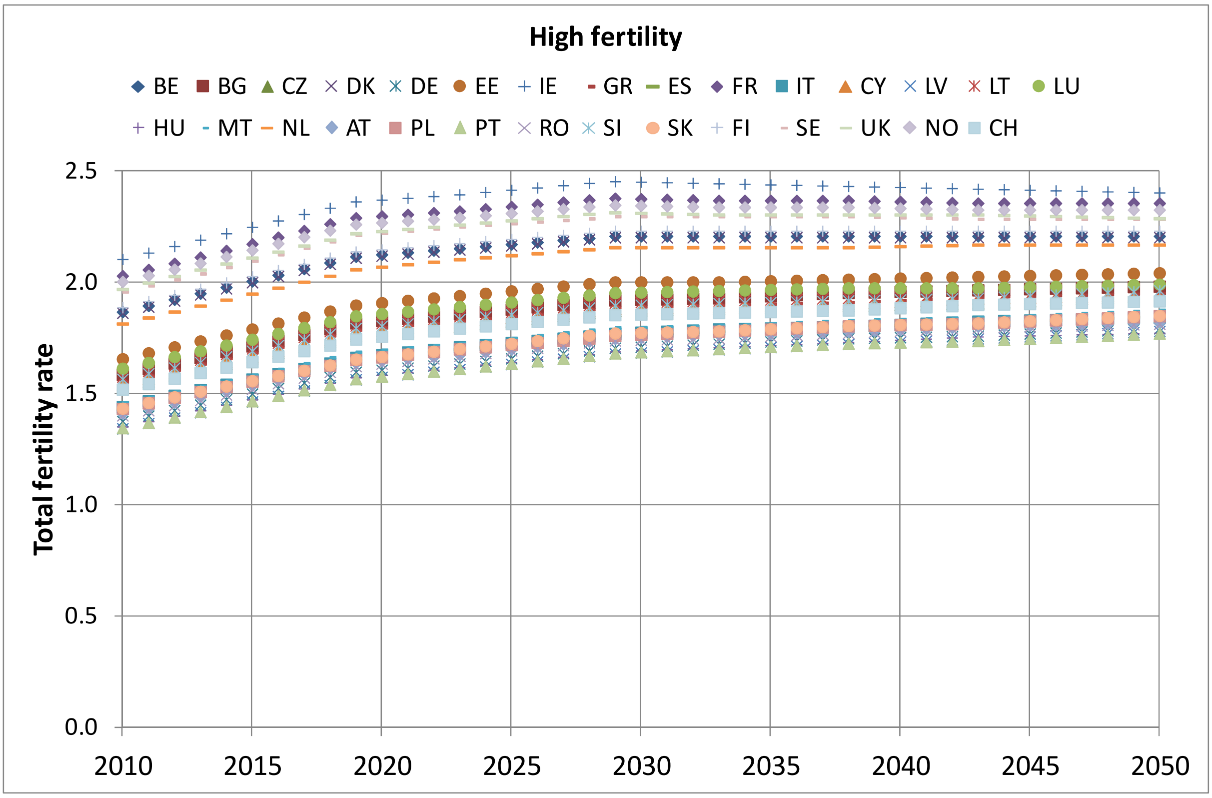


Figure 6-4 Total fertility rate by country – high growth sub-scenario

Life expectancy

Three different potential future scenarios have been defined concerning life expectancy at birth: Baseline, low growth and high growth. As for total fertility rates the scenario definitions are based on (Eurostat 2012) and (Lanzieri 2006). Life expectancy at birth increases from about 79.5 years in 2010 to about 86.0 in 2050 (Figure 6-5) in the Baseline scenario. For the low scenario the rates of change of mortality are decreased by 30% and 25% for male and female respectively over the period to 2050. For the high life expectancy scenario the rates of change of mortality are increased by 35% and 30% for male and females respectively. These assumptions result in the gender specific development of life expectancy at birth as shown in Figure 6-6. Average life expectancy of the female population of the EU27 plus Norway and Switzerland increases from about 83 years in 2010 to about 88 years (low growth), 89 years (Baseline) and 90 years (high growth) in 2050. Average life expectancy of the male population of the EU27 plus Norway and Switzerland increases from about 76 years in 2010 to about 82 years (low growth), 84 years (Baseline) and 85 years (high growth) in 2050.

Figure 6-7 to Figure 6-9 show the development of the average life expectancy at birth by country. In the base year Switzerland has the highest life expectancy at birth (about 82 years) while Latvia has the lowest one (about 73 years). In 2050 in all three scenarios Latvia still has the lowest life expectancy at birth (79, 80 and 81 years respectively). In the high growth scenario Ireland has the highest life expectancy at birth (about 89 years), while Switzerland has the highest one in the Baseline and low growth scenario (88 and 87 years respectively). Overall life expectancy at birth shows a converging trend in all three scenarios. The difference between the highest and the lowest value decreases from about 9 years in 2010 to about 7 years in 2050 for all other scenarios.

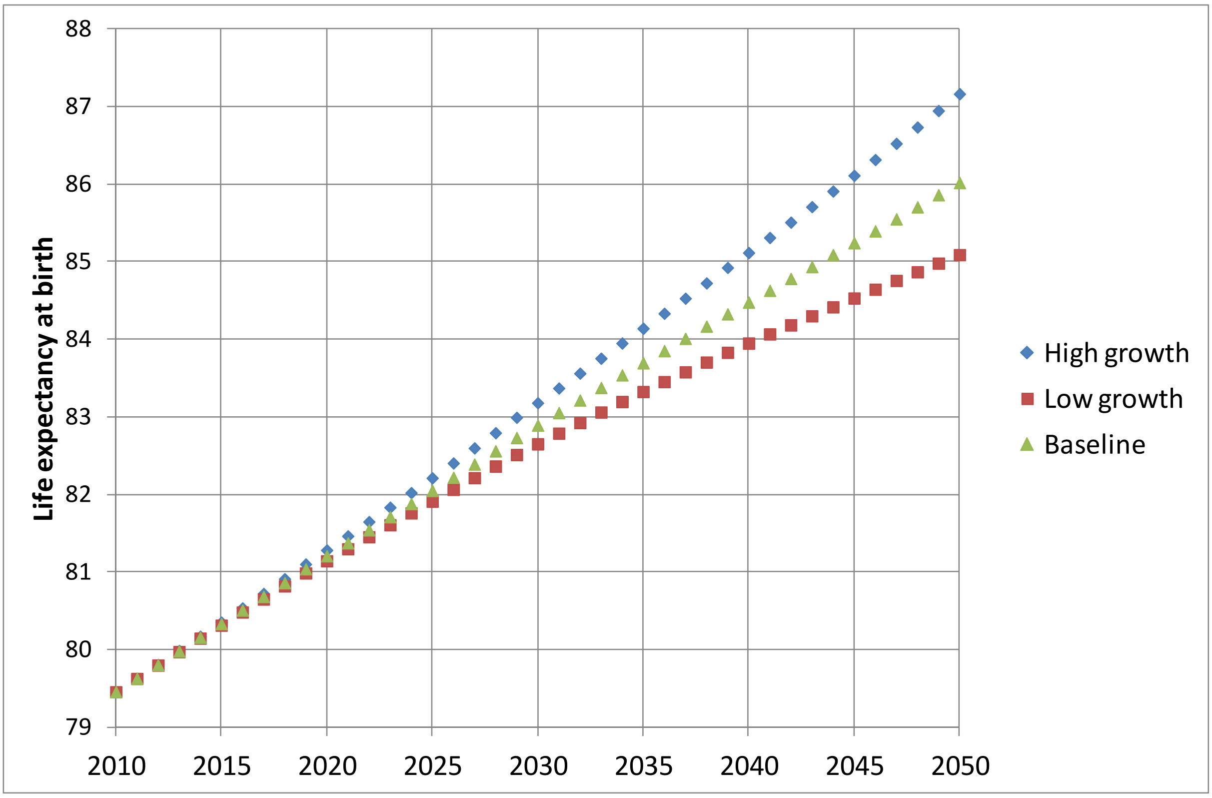


Figure 6-5 Life expectancy at birth EU27 + NO & CH by sub-scenario

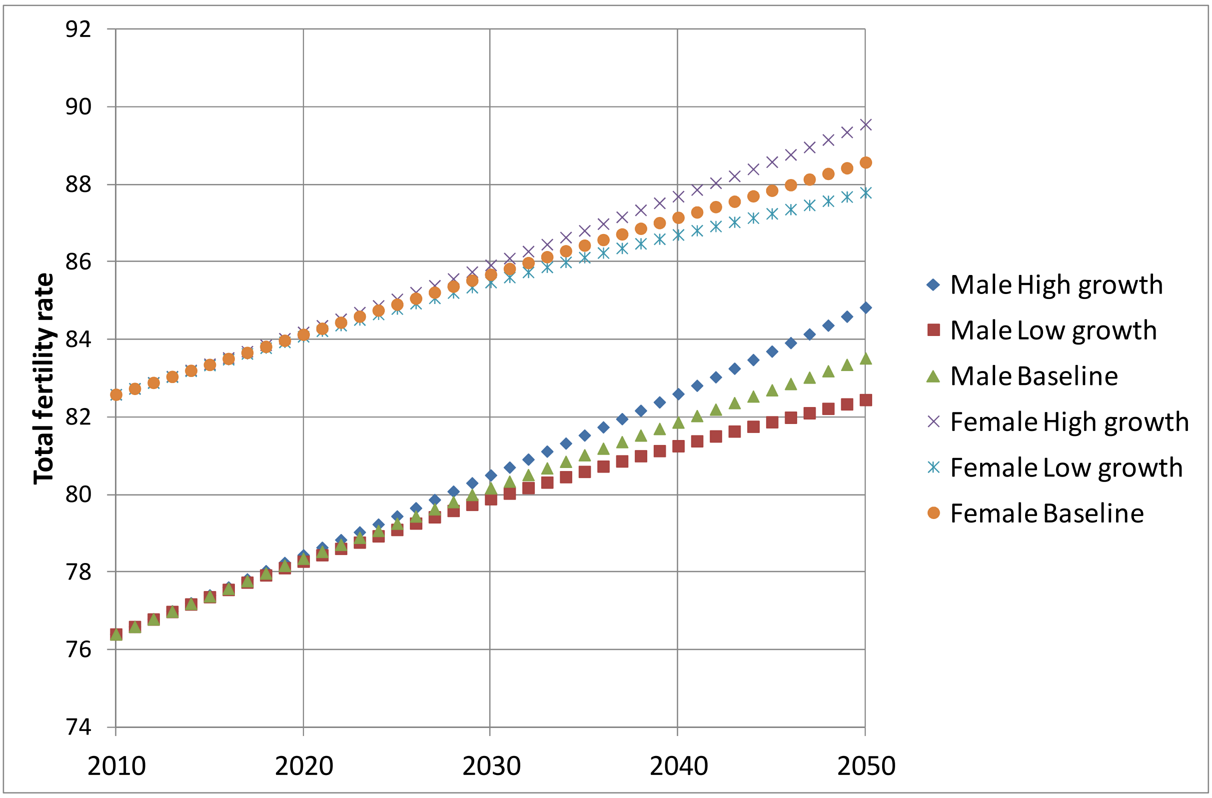


Figure 6-6 Life expectancy at birth by gender EU27 + NO & CH by sub-scenario

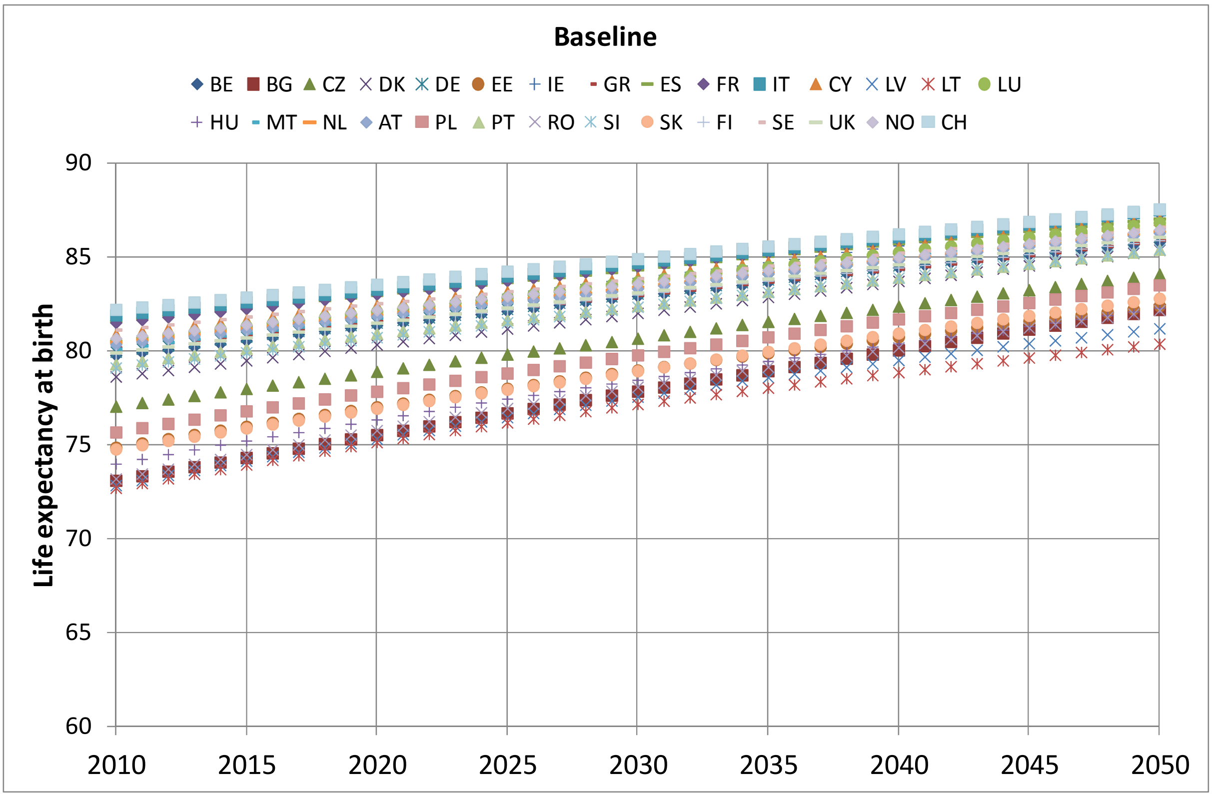


Figure 6-7 Life expectancy at birth by country – Baseline sub-scenario

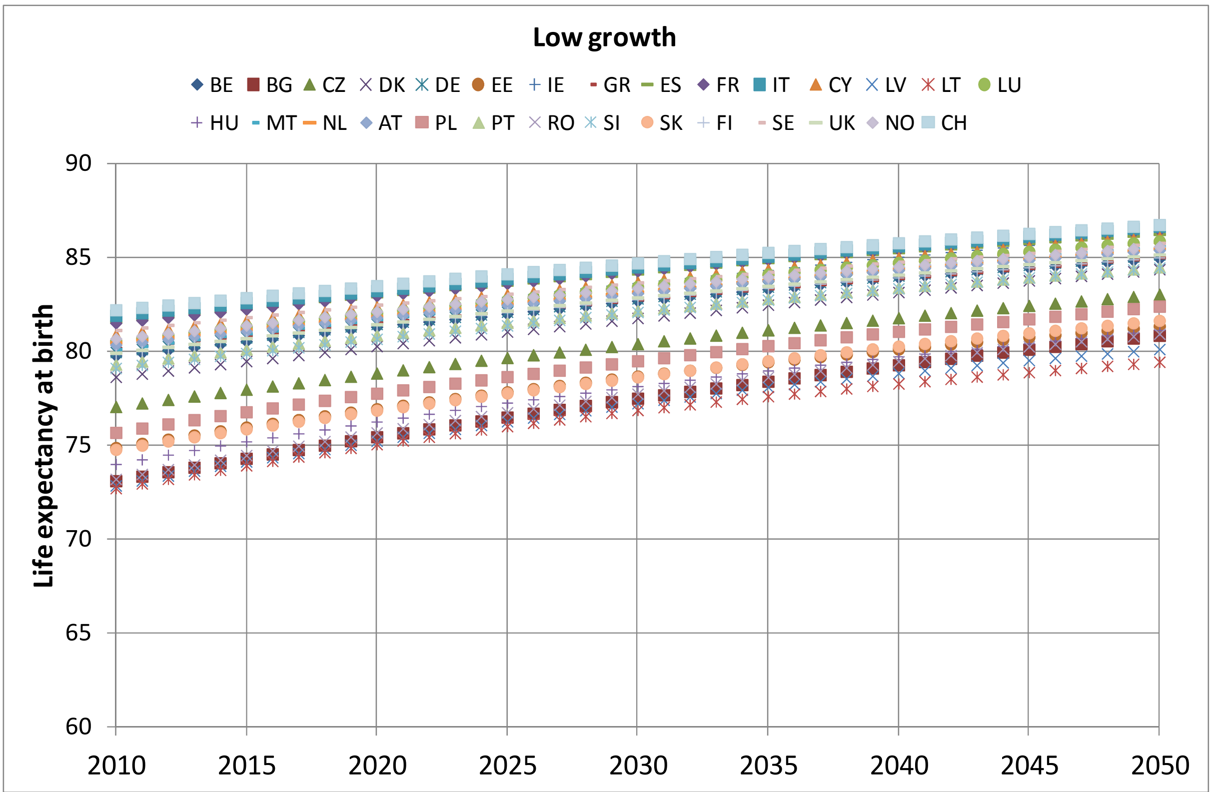


Figure 6-8 Life expectancy at birth by country – low growth sub-scenario

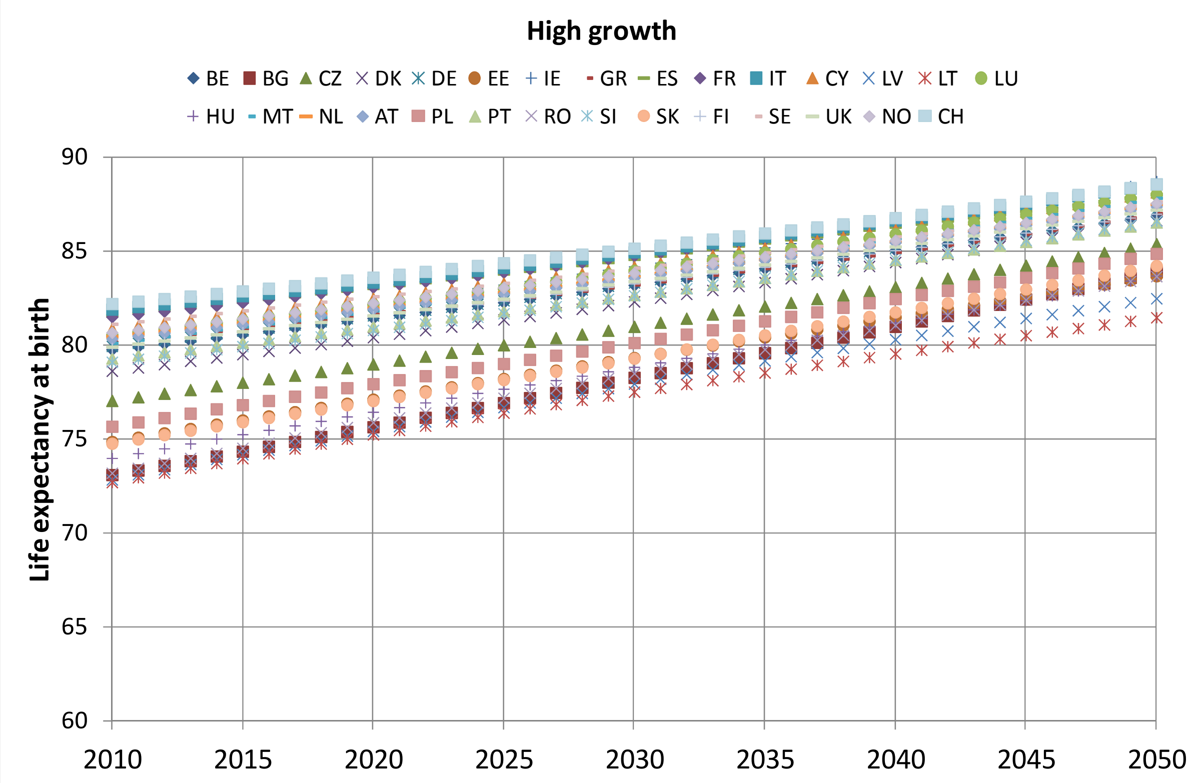


Figure 6-9 Life expectancy at birth by country – high growth sub-scenario

Migration

Migration can be defined by the combination of sub-scenarios for in and out migration[42]. Two different potential future scenarios have been defined concerning migration: Baseline and centralisation, i.e. a trend of net migration towards central Europe. The in and out migration rates in the Baseline scenario were validated to fit the forecasts from (Eurostat 2012). The concentration towards the central Europe scenario has been defined in way so that the total net migrating effect is approximately the same as in the Baseline scenario (Figure 6-10).

[42] Note: In the current version of LUNA no information about the origin of the in-migrating population and no information about the destination of the out-migrating population is available.

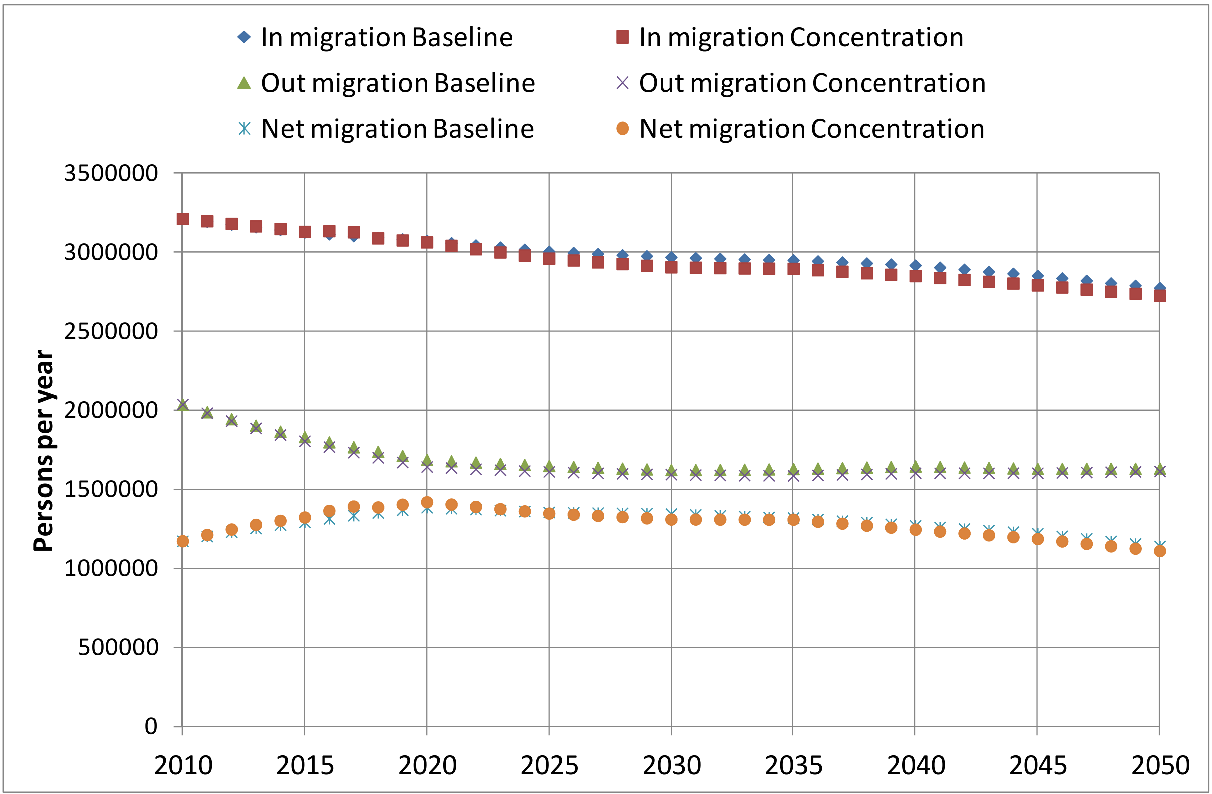


Figure 6-10 In, out and net migration EU27 plus Norway and Switzerland - sub-scenario Baseline and concentration towards central Europe

The total net migration up to 2050 is about 53 million persons. For the centralisation scenario the in-migration and out-migration rates were adjusted so that certain countries gain and lose in terms of net migration as shown in Table 6-3 and Table 6-4. These changes in migration rates result in a shift in population whilst maintaining the overall level in 2050 to be approximately similar to the Baseline scenario.

Table 6-3 Changes in in migration rates for the centralisation scenario relative to the Baseline scenario

Country	2010	2015	2020	2025	2030	2035	2040	2045	2050
Belgium	0%	10%	20%	22%	25%	25%	25%	25%	25%
Bulgaria	0%	-10%	-15%	-20%	-20%	-20%	-20%	-20%	-20%
Czech Republic	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Denmark	0%	-3%	-5%	-8%	-10%	-13%	-15%	-15%	-15%
Germany	0%	10%	20%	25%	30%	35%	35%	35%	35%
Estonia	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Ireland	0%	-10%	-15%	-20%	-20%	-20%	-20%	-20%	-20%
Greece	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Spain	0%	-5%	-10%	-15%	-20%	-20%	-20%	-20%	-20%
France	0%	10%	20%	25%	25%	30%	30%	30%	30%
Italy	0%	-5%	-10%	-15%	-15%	-15%	-15%	-15%	-15%
Cyprus	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Latvia	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Lithuania	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Luxembourg	0%	10%	20%	22%	25%	25%	25%	25%	25%
Hungary	0%	-10%	-15%	-20%	-20%	-20%	-20%	-20%	-20%
Malta	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Netherlands	0%	6%	13%	19%	25%	25%	25%	25%	25%
Austria	0%	10%	20%	25%	25%	25%	25%	25%	25%
Poland	0%	-5%	-10%	-15%	-20%	-20%	-20%	-20%	-20%
Portugal	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Romania	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Slovenia	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Slovakia	0%	-3%	-5%	-8%	-10%	-13%	-15%	-18%	-20%
Finland	0%	-5%	-10%	-15%	-15%	-15%	-15%	-15%	-15%
Sweden	0%	-5%	-10%	-15%	-15%	-15%	-15%	-15%	-15%
United Kingdom	0%	-3%	-5%	-8%	-10%	-10%	-10%	-10%	-10%
Norway	0%	-5%	-10%	-10%	-10%	-10%	-10%	-10%	-10%
Switzerland	0%	10%	15%	20%	25%	25%	25%	25%	25%

Table 6-4 Changes in out migration rates for the centralisation scenario relative to the Baseline scenario

Country	2010	2015	2020	2025	2030	2035	2040	2045	2050
Belgium	0%	-10%	-20%	-22%	-25%	-25%	-25%	-25%	-25%
Bulgaria	0%	10%	15%	20%	20%	20%	20%	20%	20%
Czech Republic	0%	3%	5%	8%	10%	13%	15%	18%	20%
Denmark	0%	3%	5%	8%	10%	13%	15%	15%	15%
Germany	0%	-10%	-20%	-25%	-30%	-35%	-35%	-35%	-35%
Estonia	0%	3%	5%	8%	10%	13%	15%	18%	20%
Ireland	0%	10%	15%	20%	20%	20%	20%	20%	20%
Greece	0%	3%	5%	8%	10%	13%	15%	18%	20%
Spain	0%	5%	10%	15%	20%	20%	20%	20%	20%
France	0%	-10%	-20%	-25%	-25%	-30%	-30%	-30%	-30%
Italy	0%	5%	10%	15%	15%	15%	15%	15%	15%
Cyprus	0%	3%	5%	8%	10%	13%	15%	18%	20%
Latvia	0%	3%	5%	8%	10%	13%	15%	18%	20%
Lithuania	0%	3%	5%	8%	10%	13%	15%	18%	20%
Luxembourg	0%	-10%	-20%	-22%	-25%	-25%	-25%	-25%	-25%
Hungary	0%	10%	15%	20%	20%	20%	20%	20%	20%
Malta	0%	3%	5%	8%	10%	13%	15%	18%	20%
Netherlands	0%	-6%	-13%	-19%	-25%	-25%	-25%	-25%	-25%
Austria	0%	-10%	-20%	-25%	-25%	-25%	-25%	-25%	-25%
Poland	0%	5%	10%	15%	20%	20%	20%	20%	20%
Portugal	0%	3%	5%	8%	10%	13%	15%	18%	20%
Romania	0%	3%	5%	8%	10%	13%	15%	18%	20%
Slovenia	0%	3%	5%	8%	10%	13%	15%	18%	20%
Slovakia	0%	3%	5%	8%	10%	13%	15%	18%	20%
Finland	0%	5%	10%	15%	15%	15%	15%	15%	15%
Sweden	0%	5%	10%	15%	15%	15%	15%	15%	15%
United Kingdom	0%	3%	5%	8%	10%	10%	10%	10%	10%
Norway	0%	5%	10%	10%	10%	10%	10%	10%	10%
Switzerland	0%	-10%	-15%	-20%	-25%	-25%	-25%	-25%	-25%

Figure 6-11 and Figure 6-12 show the development of net migration in persons per 1,000 residents by country and scenario. While net migration is converging in the Baseline scenario it is diverging in the centralisation scenario.

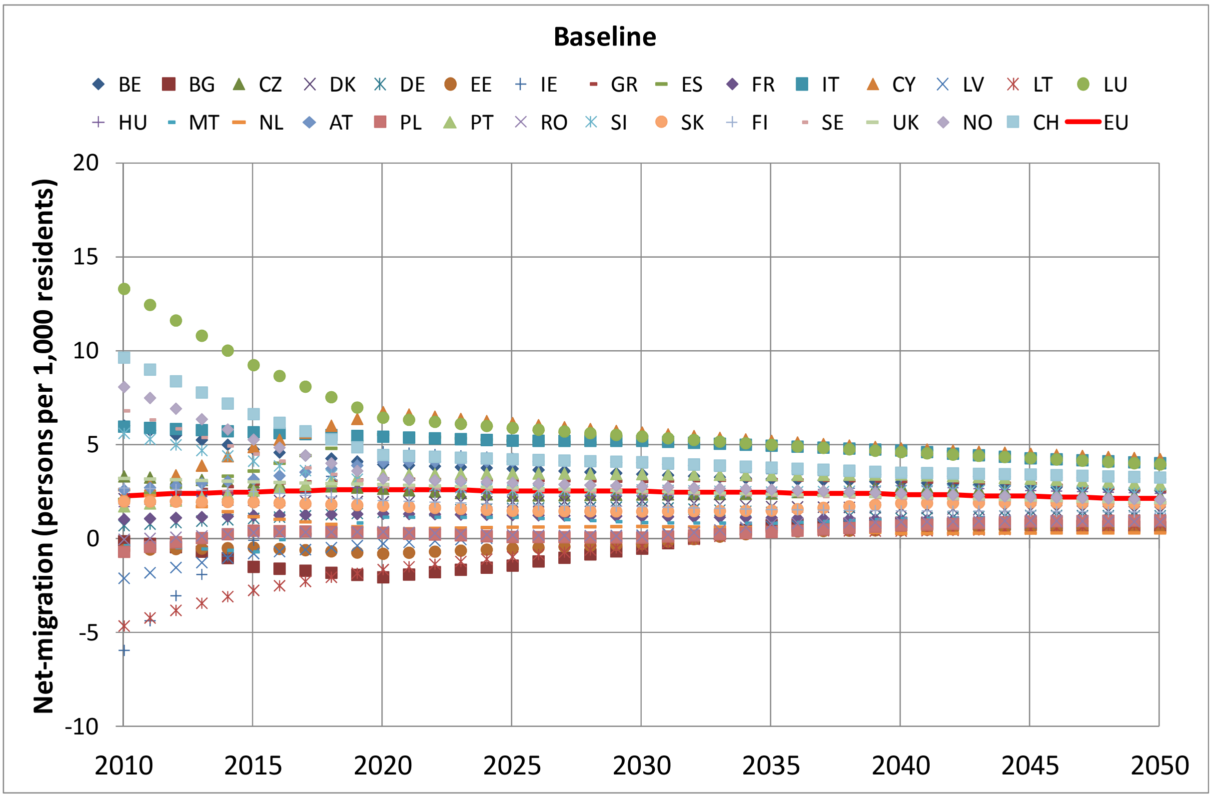


Figure 6-11 Net migration in persons per 1,000 residents by country – scenario Baseline

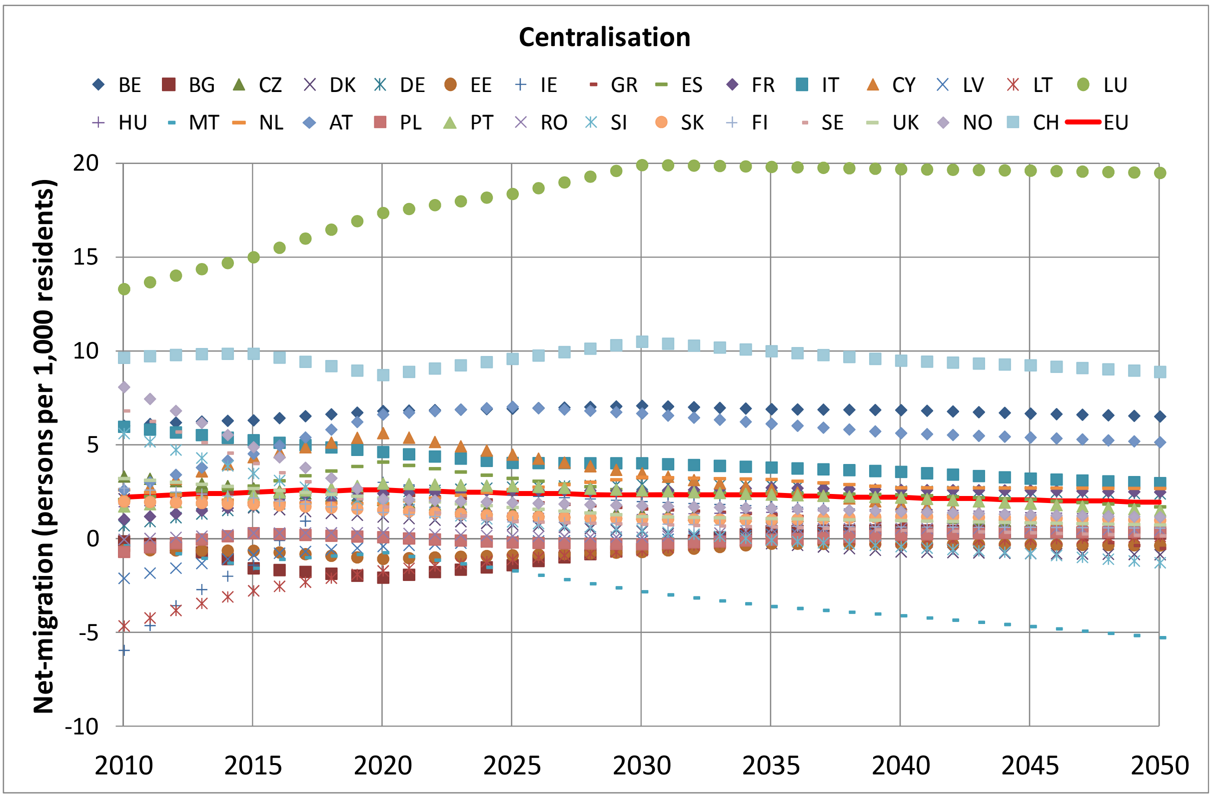


Figure 6-12 Net migration in persons per 1,000 residents by country – scenario centralisation

Figure 6-13 illustrates the spatial effect of the scenario concentration in comparison with the Baseline scenario.

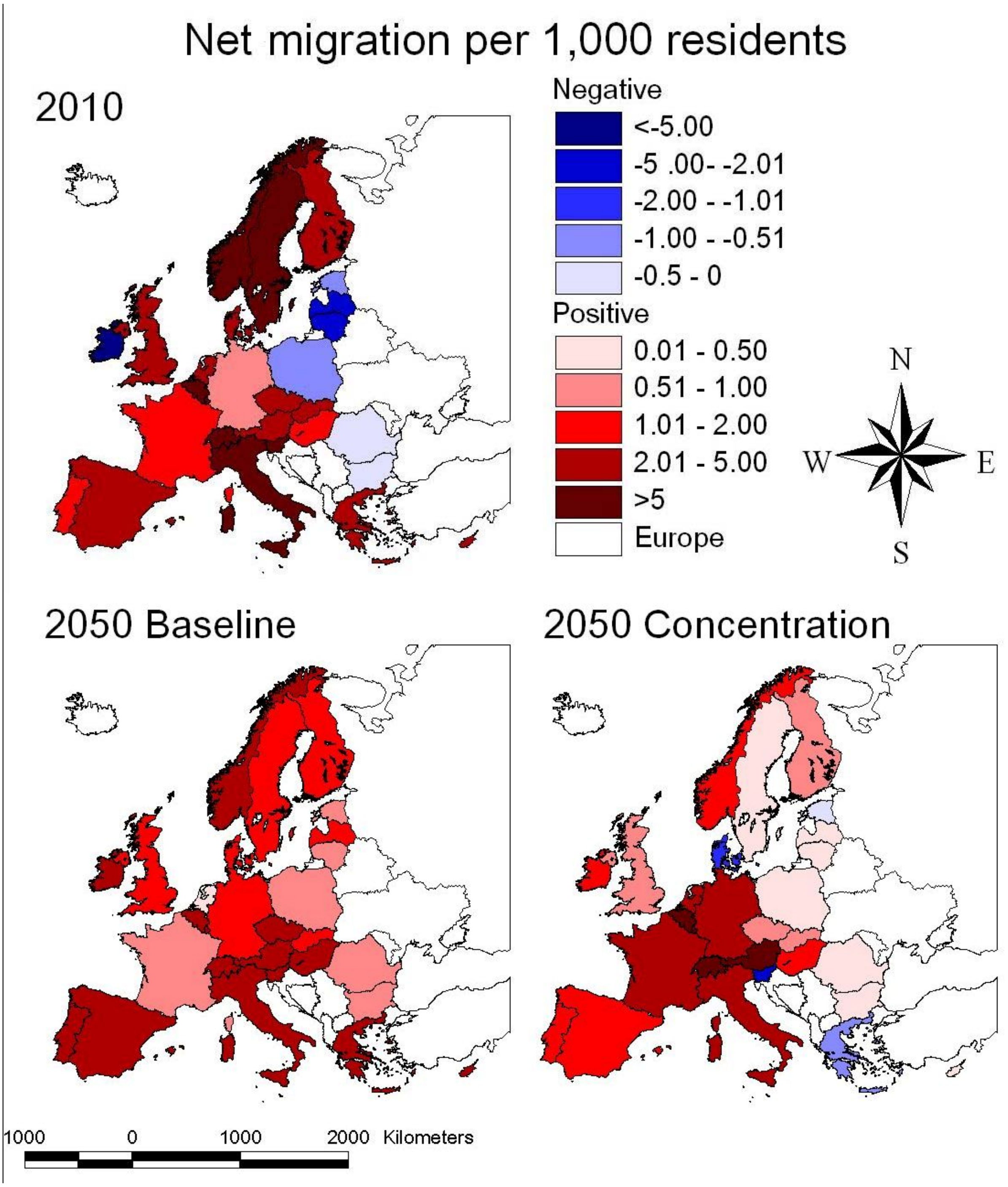


Figure 6-13 Net migration in persons per 1,000 residents by country

Employment

Only one scenario concerning employment has been defined. Changing rates of employment have been defined in line with (European Commission 2009). Total employment is increasing in the earlier years and peaking around 2020 at about +6 % relative to 2010 (Figure 6-14). Afterwards total employment is continuously decreasing and slightly below the 2010 value in 2050. In combination with socio-demographic Baseline assumptions total employment rate is slightly increasing from about 43 %

in 2010 to about 45 % around 2020, while in the later years it is decreasing continuously to about 41 % in 2050 (Figure 6-14 and Figure 6-15). Concerning the country level employment rates are diverging (Figure 6-15).

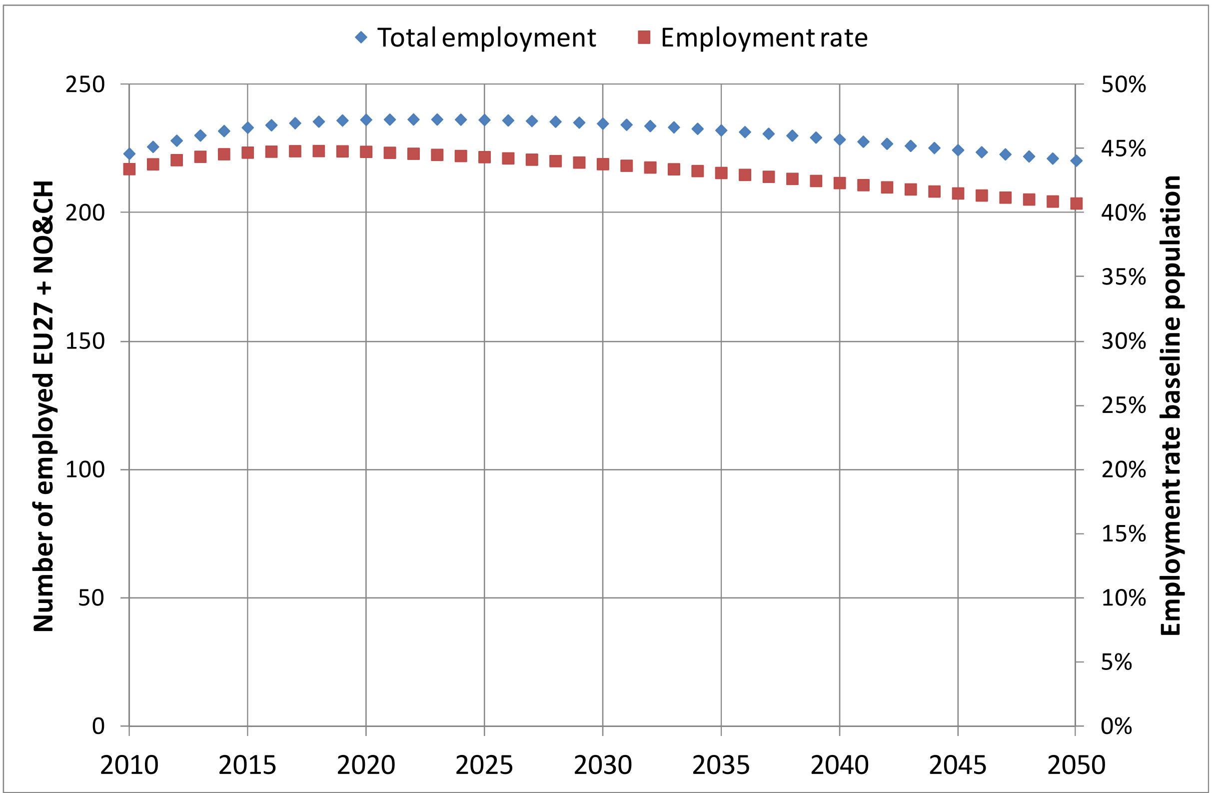


Figure 6-14 Total employment and employment rate Baseline

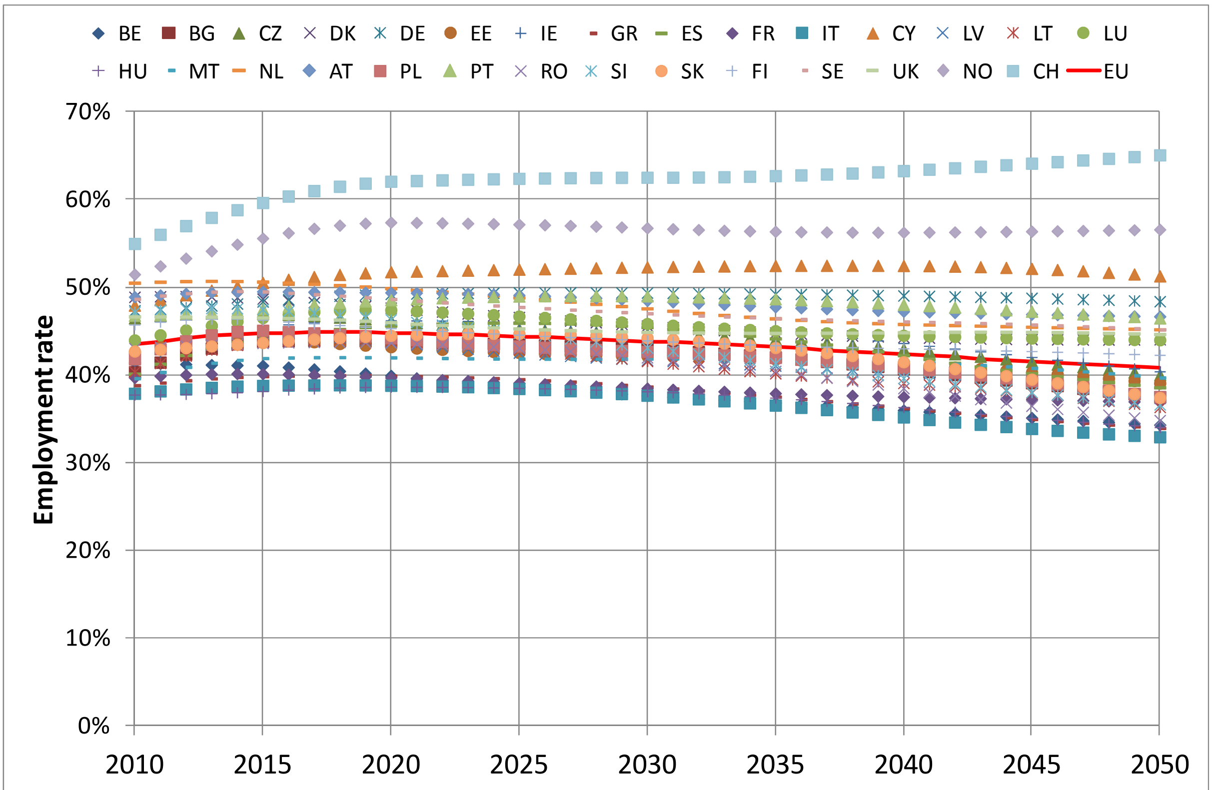


Figure 6-15 Employment rates by country – sub-scenario Baseline

GDP

The base growth rates for total GDP per country were taken in line with the ECFIN ageing report (European Commission 2009) and were set in line with EUROSTAT database for 2010. The rates of change in GDP per capita are shown in Table 6-5. Resulting GDP per capita is shown in Figure 6-16.

Table 6-5 Changes in GDP - Baseline

Country/Year	2010	2015	2020	2030	2040	2050
Belgium	3.8%	2.3%	1.9%	1.6%	1.8%	1.7%
Bulgaria	6.7%	3.0%	2.4%	1.7%	1.4%	0.3%
Czech Republic	3.8%	3.0%	2.5%	1.4%	0.9%	0.7%
Denmark	1.5%	1.7%	1.6%	1.5%	1.7%	1.9%
Germany	3.8%	1.9%	1.5%	1.3%	1.1%	1.0%
Estonia	11.7%	3.2%	2.6%	2.2%	1.0%	0.6%
Ireland	0.3%	3.4%	2.9%	2.3%	1.8%	1.6%
Greece	-5.4%	2.7%	2.9%	1.3%	1.0%	1.2%
Spain	2.1%	3.1%	3.4%	1.8%	0.9%	1.1%
France	3.1%	2.0%	1.9%	1.7%	1.8%	1.8%
Italy	1.7%	2.1%	1.9%	1.4%	1.0%	1.3%
Cyprus	2.5%	3.8%	3.9%	2.9%	2.3%	1.8%
Latvia	11.5%	3.0%	2.1%	1.8%	0.7%	-0.1%
Lithuania	11.5%	3.6%	2.5%	1.5%	0.8%	0.2%
Luxembourg	6.3%	4.0%	2.7%	2.1%	2.2%	2.2%
Hungary	3.5%	2.8%	2.4%	2.1%	1.1%	0.8%
Malta	4.4%	2.7%	2.7%	1.7%	1.2%	0.8%
Netherlands	2.3%	1.7%	1.5%	1.2%	1.5%	1.5%
Austria	4.9%	1.9%	1.9%	1.5%	1.5%	1.5%
Poland	4.4%	3.1%	2.5%	2.0%	0.5%	0.3%
Portugal	-1.0%	2.1%	2.1%	2.5%	1.8%	1.2%
Romania	10.0%	3.9%	2.9%	1.6%	1.1%	0.3%
Slovenia	0.6%	3.2%	2.6%	0.8%	0.7%	0.8%
Slovakia	5.0%	4.2%	3.4%	2.0%	0.5%	0.2%
Finland	6.6%	1.9%	1.7%	1.5%	1.6%	1.5%
Sweden	10.8%	2.2%	1.9%	1.7%	1.9%	1.7%
United Kingdom	2.2%	2.4%	2.0%	2.1%	2.1%	1.9%
Norway	8.7%	4.0%	2.7%	2.1%	2.2%	2.2%
Switzerland	10.7%	4.0%	2.7%	2.1%	2.2%	2.2%

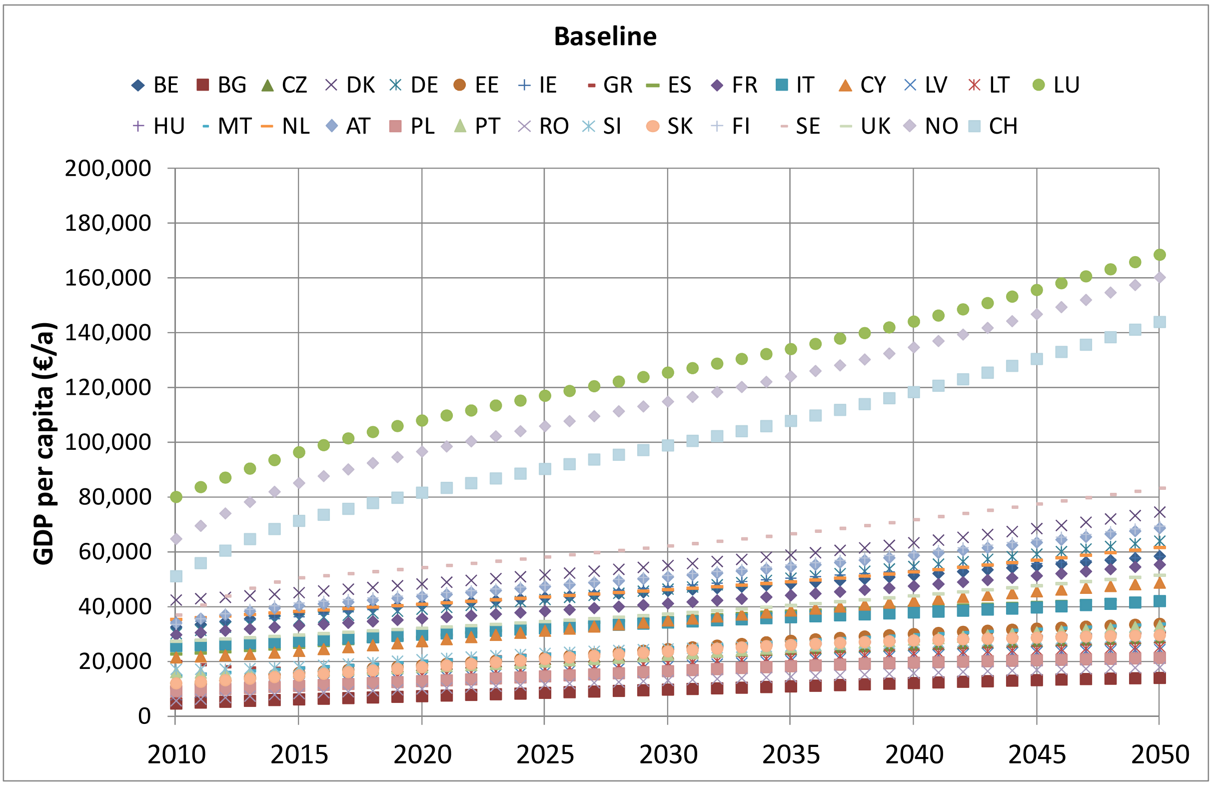


Figure 6-16 GDP per capita by country – scenario Baseline

Changes in GDP around these values were then based on uniform changes with a +/- 20% change in GDP per capita applied to the base patterns by the year 2050 for the high/low uniform cases (Figure 6-17 and Figure 6-18).

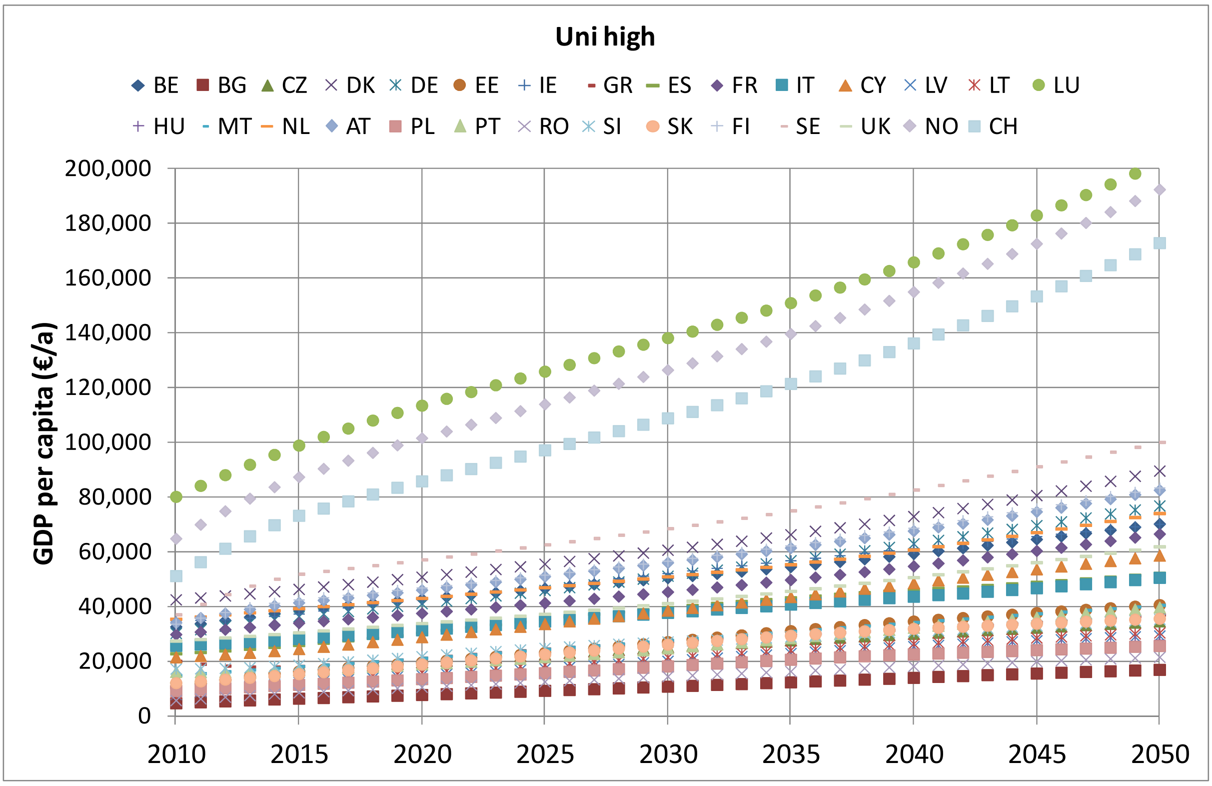


Figure 6-17 GDP per capita by country – scenario uniform high

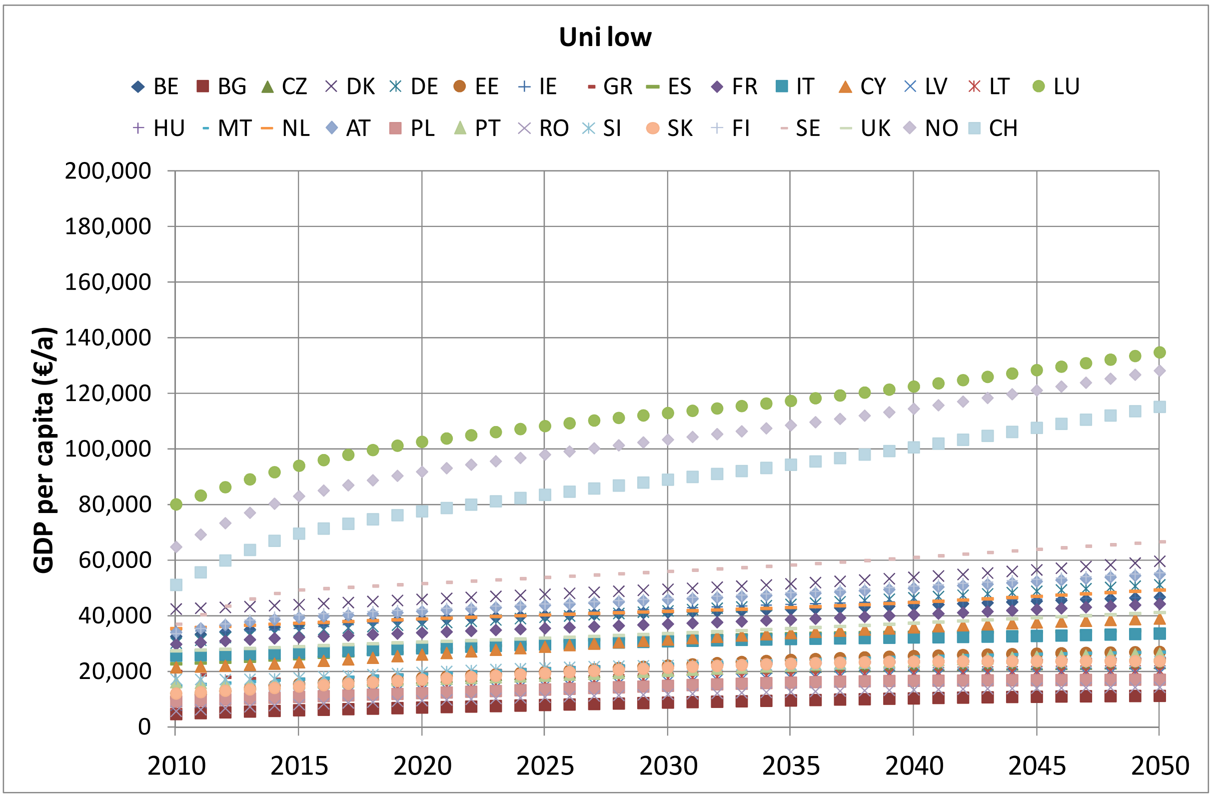


Figure 6-18 GDP per capita by country – scenario uniform low

6.2.3 Propulsion Technology

Three different scenarios concerning propulsion technology have been defined for the ORIGAMI 2050 scenarios: Baseline, low emission and very low emission. The Baseline and very low emission scenario are based on the Reference and Maximum Efficiency at Market conditions scenarios respectively (Fiorello et al. 2012). The low emission scenario is assumed to lie in the middle between these two scenarios.

Private car

For the Baseline scenario, the development of propulsion technology, emissions factors and fleet composition for the EU has been taken from the reference scenario included in the project GHG-TransPoRD (Fiorello et al. 2012). The GHG-TransPoRD reference Scenario is based on two main sources:

- Until 2030 the reference scenario is taken from PRIMES as defined in the document "EU energy trends to 2030 — UPDATE 2009" (EC, 2010). This reference scenario is the one used for assessment of the White Paper of the European Commission
- From 2030 to 2050 the reference scenario is extended using the ADAM reference scenario (Schade et al. 2009).

The GHG-TransPoRD reference scenario includes assumptions on the policy content. Measures implemented in the Member States by April 2009 and legislative provisions adopted by April 2009 that are defined in such a way that there is almost no uncertainty how they should be implemented in the future are within this scenario. As far as the transport sector is concerned, the main measures considered are:

- Regulation on CO2 from cars 2009/443/EC (binding CO2 emission targets for cars: 135 g CO2/km in 2015; 115 g CO2/km in 2020; 95 g CO2/km in 2025);
- Labelling regulation for tyres 2009/1222/EC;

- Regulation Euro VI for heavy duty vehicles 2009/595/EC;
- RES directive 2009/28/EC on the promotion of the use of energy from renewable sources; 10% target for renewables in transport is achieved for EU27.

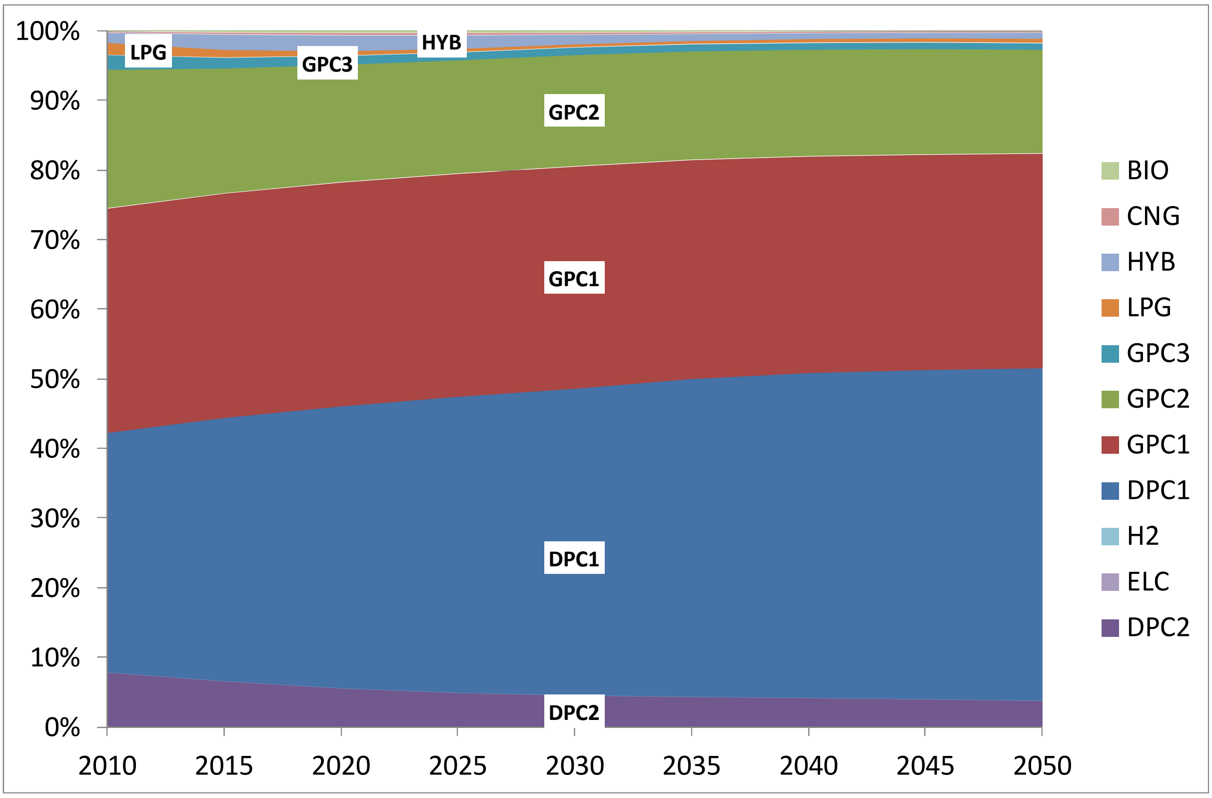
For the low emissions scenario the Maximum Efficiency at Market conditions scenario has been taken again from the GHG-TransPoRD Project. This Maximum Efficiency at Market conditions (MAX_E&M) scenario includes most of the technological measures for all modes detailed in (Fiorello et al. 2012), including both conventional and innovative cars. Neither the latter nor biofuels are supported by dedicated policy to promote their penetration in the market. Market diffusion thus depends on relative cost of different options and the cost development paths estimated with the learning curves.

Fuel and propulsion technologies taken into account in the ORIGAMI 2050 scenarios are summarised in Table 6-6. Figure 6-19 to Figure 6-21 show the development of the share of the different propulsion technologies in the different sub-scenarios. Figure 6-22 shows a comparison of the development of the share of non fossil fuel cars.

Table 6-6 Fuel and propulsion technologies in the ORIGAMI 2050 scenarios

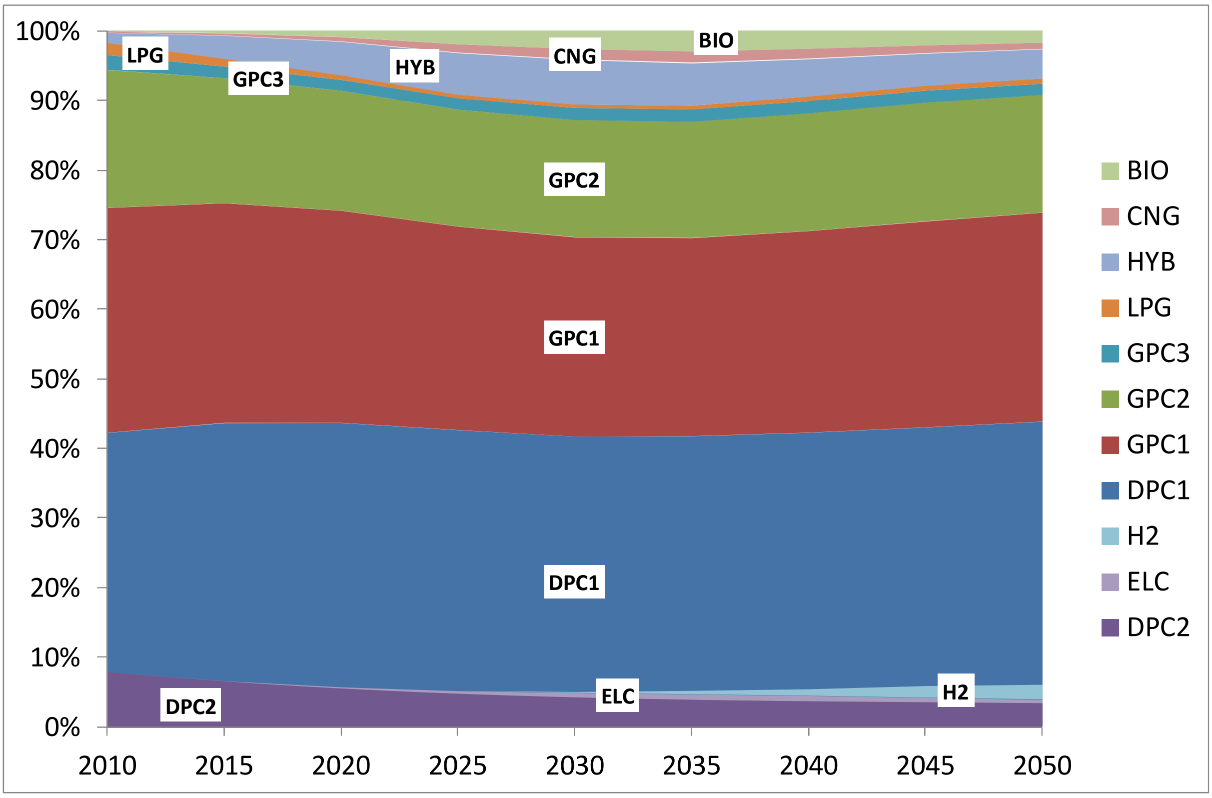
Code	Energy medium	Engine	Size	Non renewable
GPC	Gasoline	ICT	small, medium, large	Yes
DPC	Diesel	ICT	small, large	Yes
CNG	Compressed natural gas	ICT	small, medium, large	Yes
LPG	Liquefied petroleum gas	ICT	small, medium, large	Yes
BIO	Bio fuels (Ethanol, Biodiesel)	ICT	medium	No
HYB	Gasoline, Diesel	ICT/Electro	small, medium, large	Yes
H2	Hydrogen	Electro	medium	No
ELC	Battery	Electro	small, medium	No

Legend: ICT Internal combustion engine



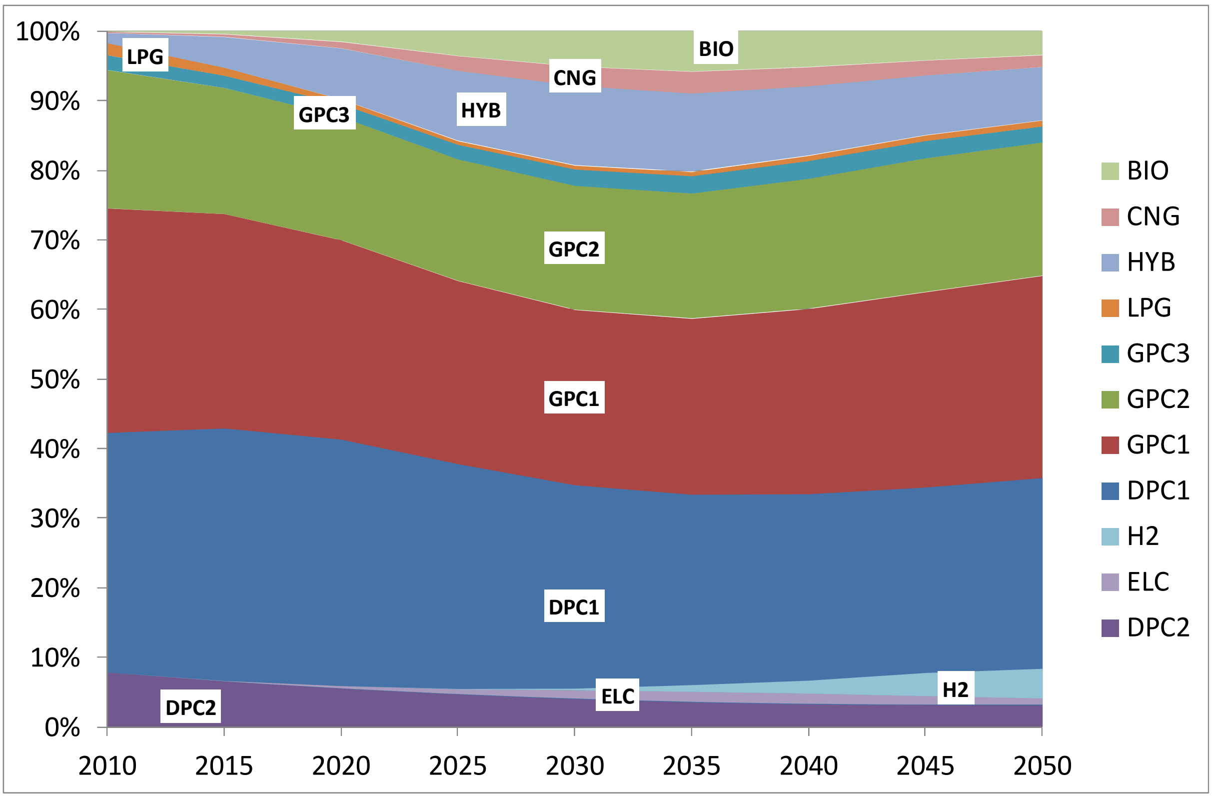
Source: GHG-TransPoRD

Figure 6-19 Car fleet vehicle size and propulsion technology – Baseline



Source: own assumptions based on GHG-TransPoRD

Figure 6-20 Car fleet vehicle size and propulsion technology – low emission



Source: GHG-TransPoRD

Figure 6-21 Car fleet vehicle size and propulsion technology – very low emission

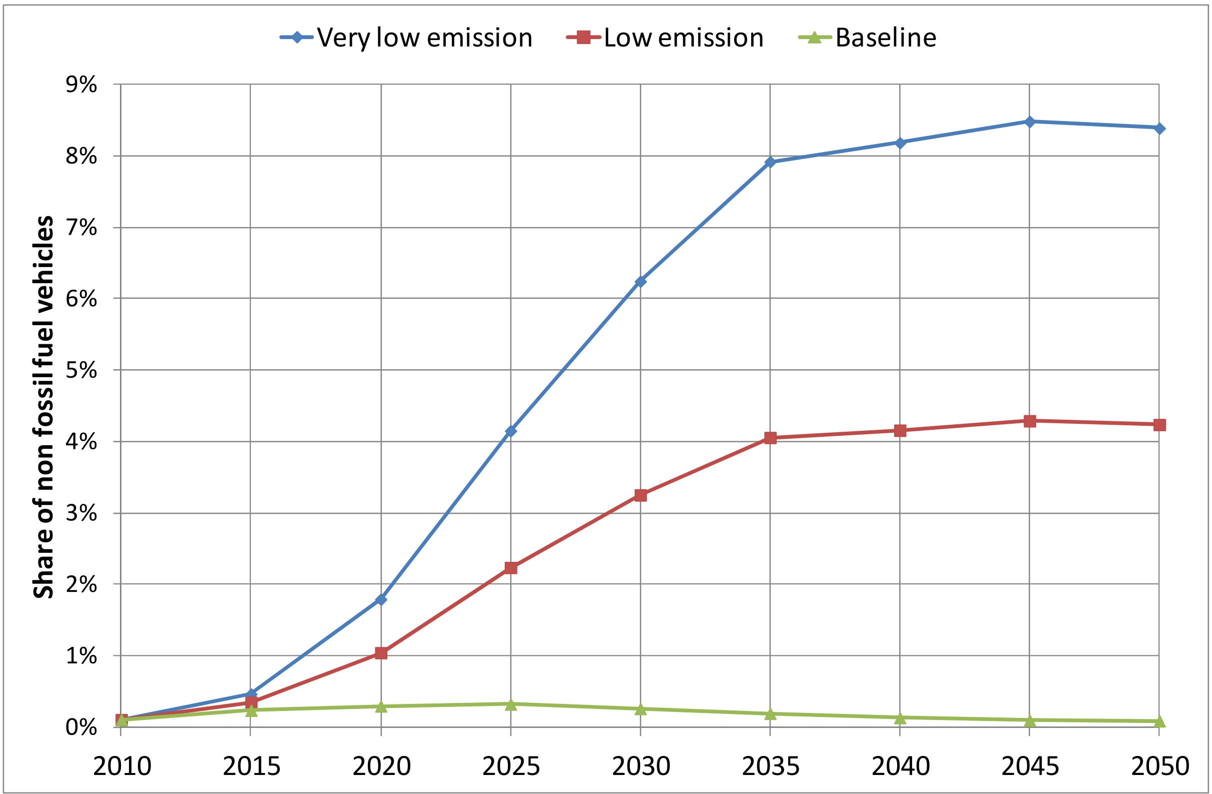


Figure 6-22 Share of renewable fuel cars by sub-scenario

The assumptions concerning the development of the well to wheel GHG-emissions per vehicle kilometre for each propulsion technology are based on (Haas 2008) and (Haas et al. 2009). Figure 6-23 and Figure 6-24 show the assumptions concerning the development of the GHG-emissions per vehicle kilometre by propulsion technology in the scenarios Baseline and very low emissions. Again the assumptions concerning the scenario low emission lie in the middle between these two scenarios. Figure 6-25 and Figure 6-26 show a comparison of the average specific GHG-emissions by vehicle kilometre in the EU27 plus Norway and Switzerland by scenario, and Figure 6-27 and Figure 6-28 by country for the Baseline and the very low emission scenario.

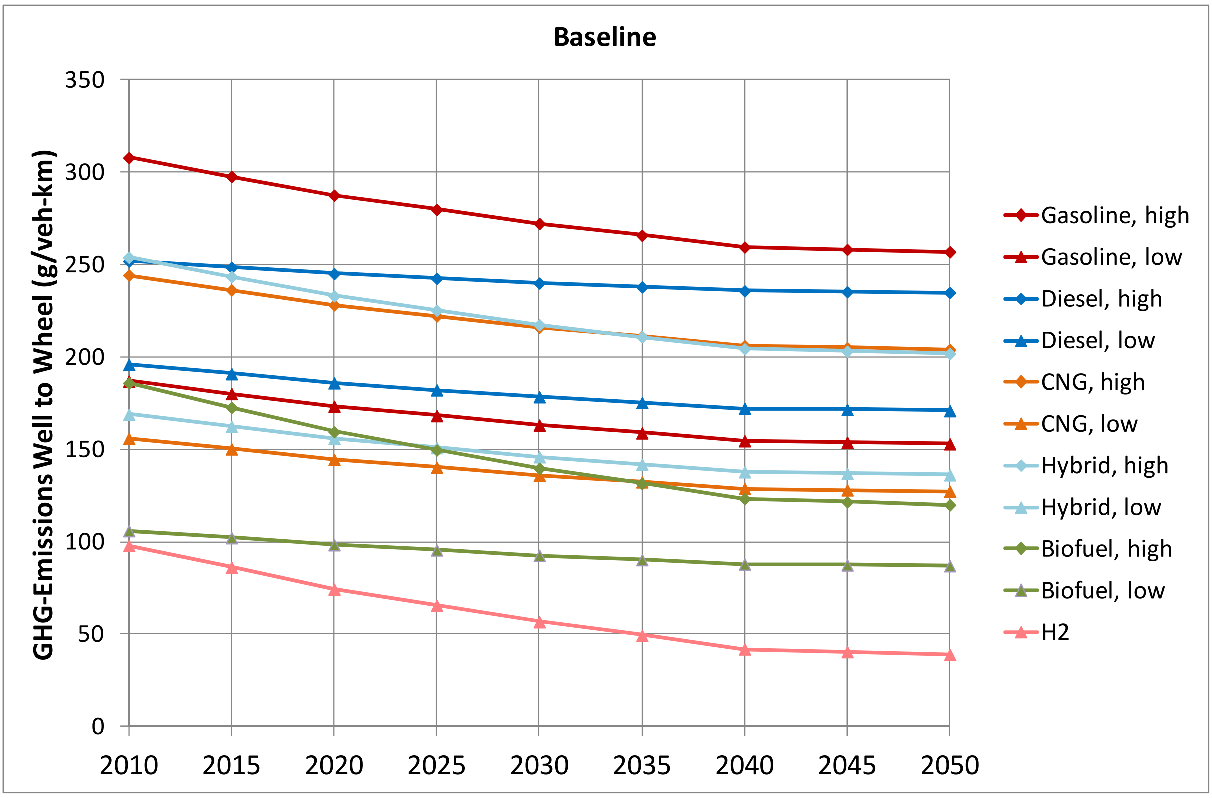


Figure 6-23 Specific GHG-emissions car Well to Wheel by propulsion technology – scenario Baseline

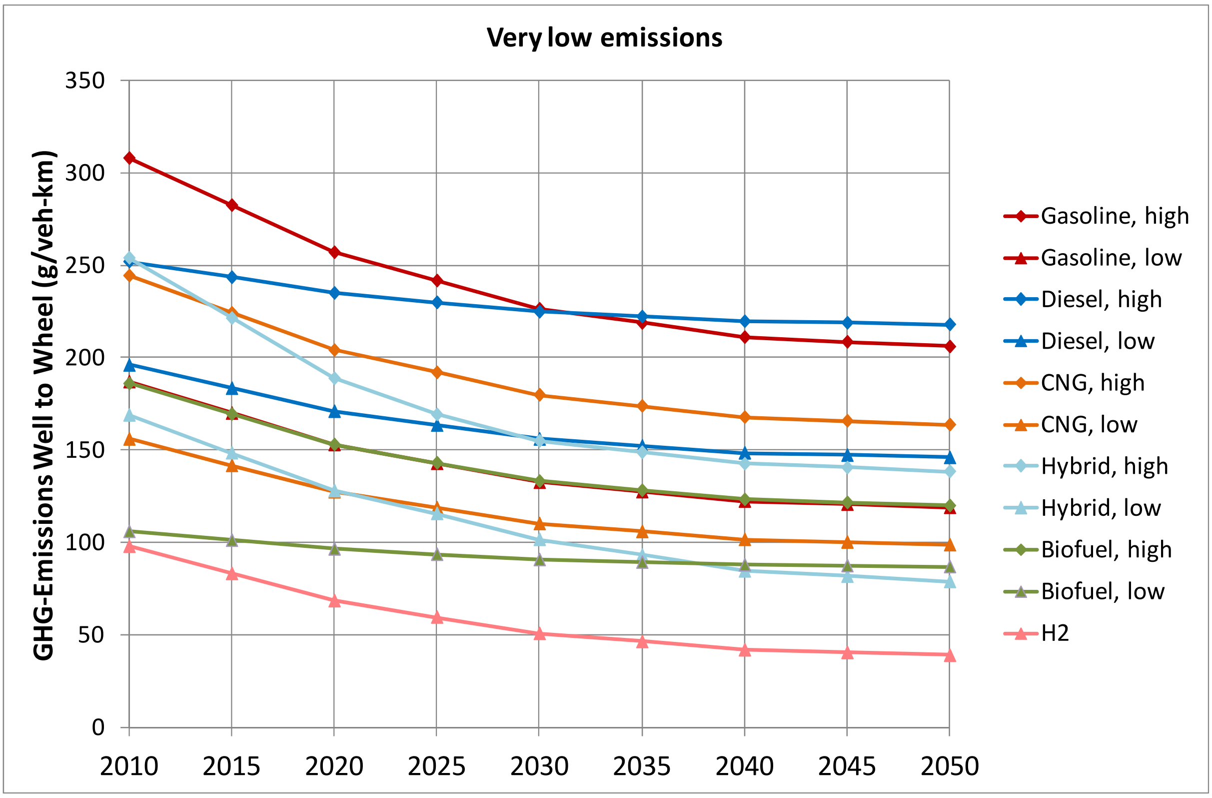


Figure 6-24 Specific GHG-emissions car Well to Wheel by propulsion technology – scenario very low emissions

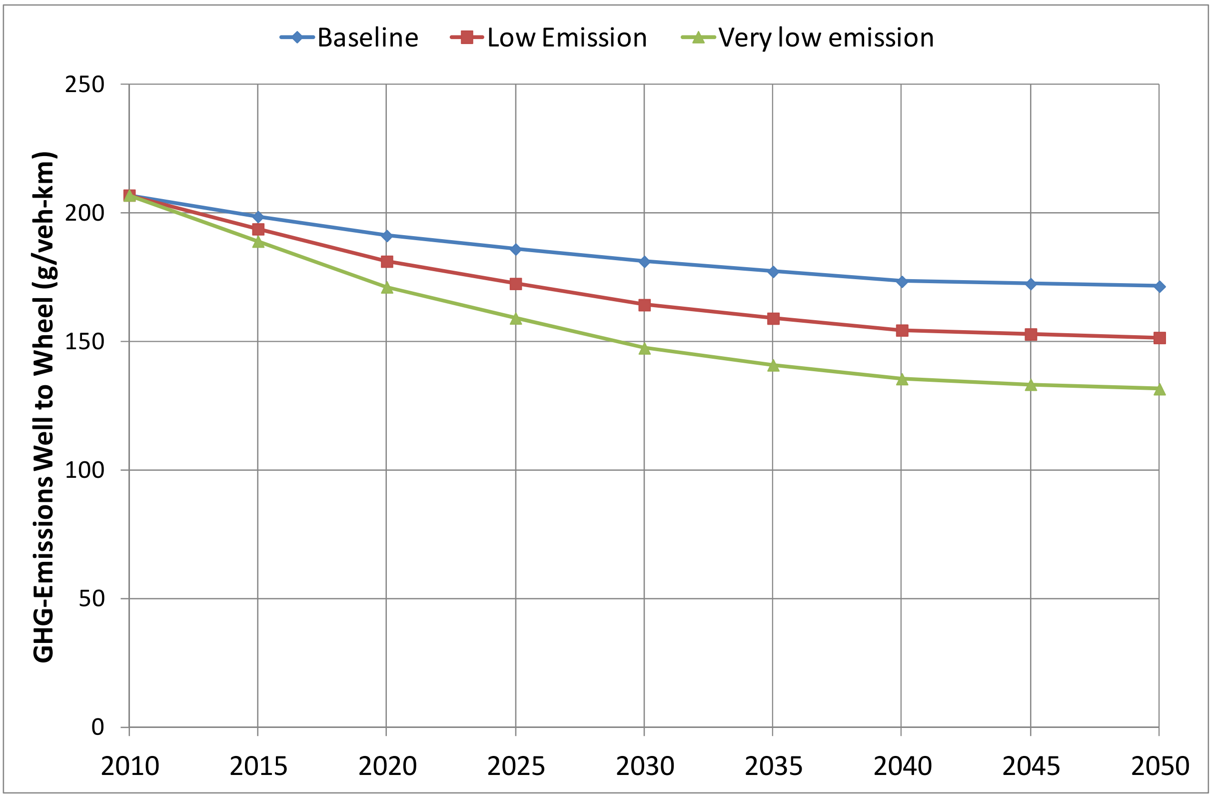


Figure 6-25 Average specific GHG-emissions car Well to Wheel by scenario

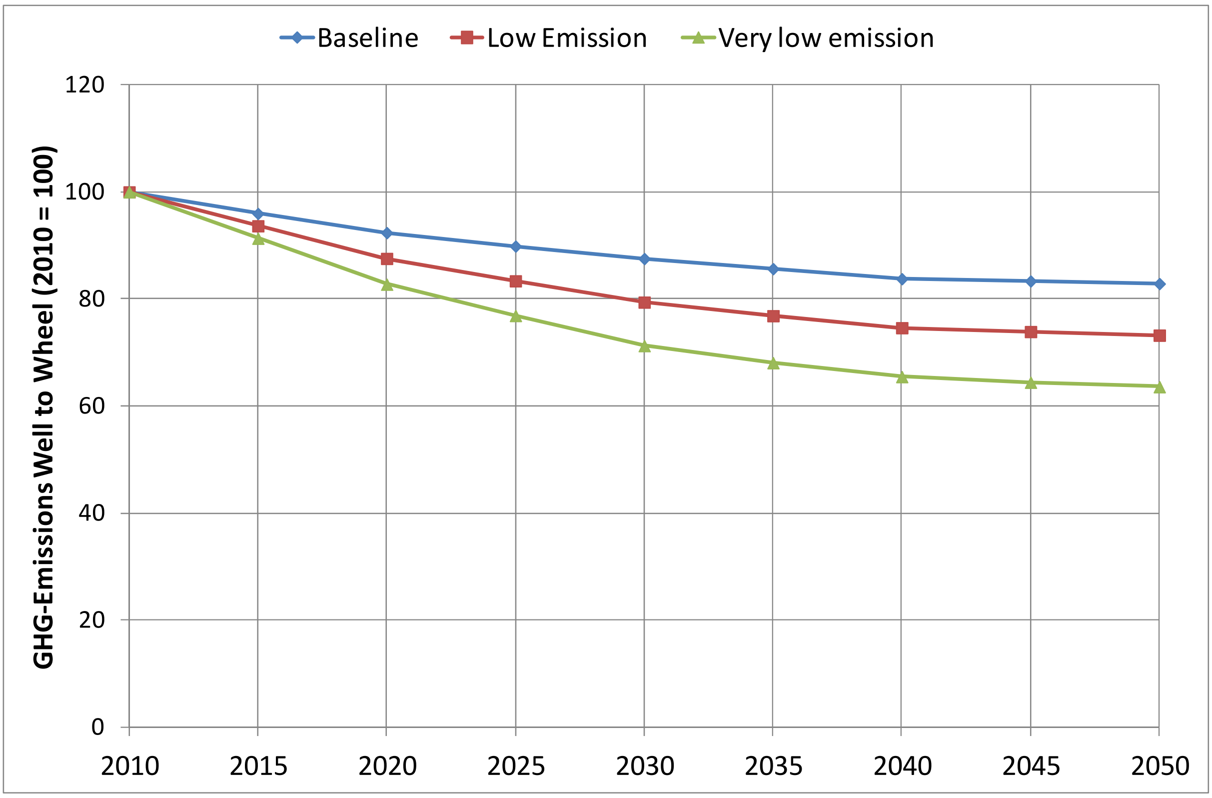


Figure 6-26 Average specific GHG-emissions car Well to Wheel by scenario (2010 = 100)

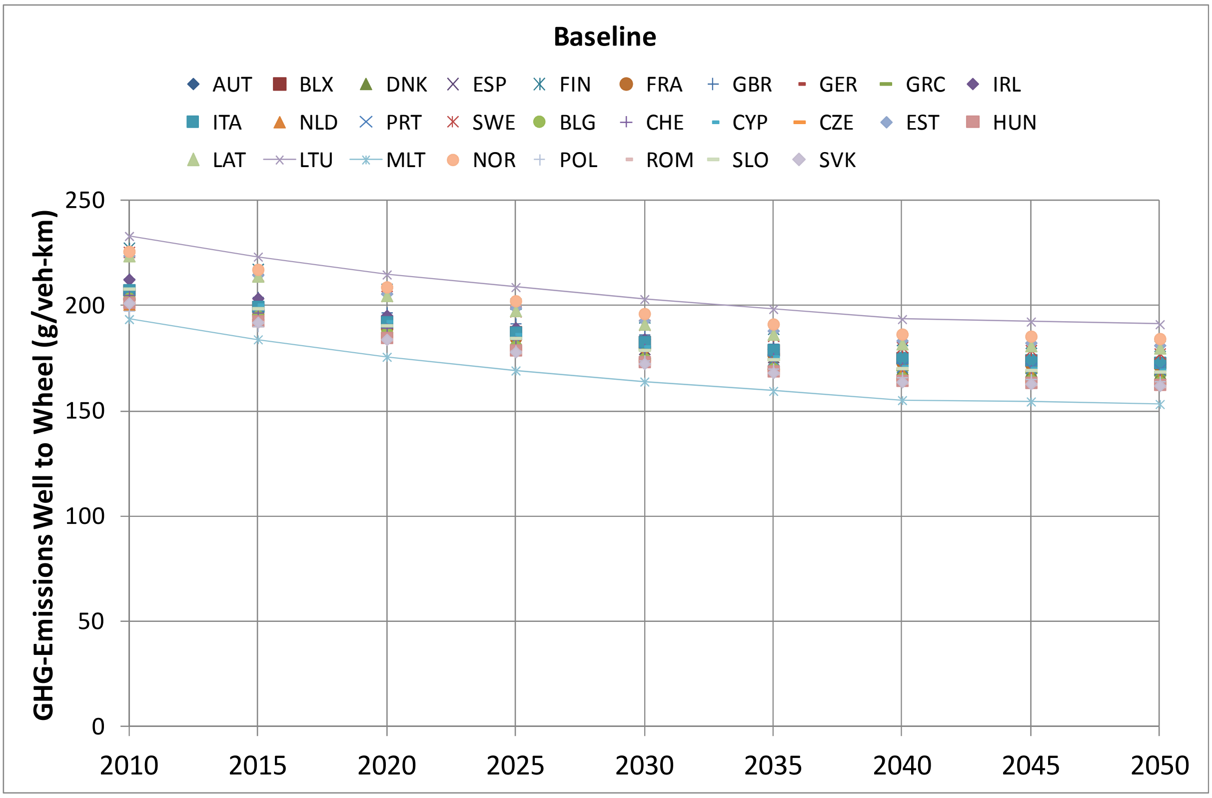


Figure 6-27 Specific GHG-emissions car Well to Wheel by country – scenario Baseline

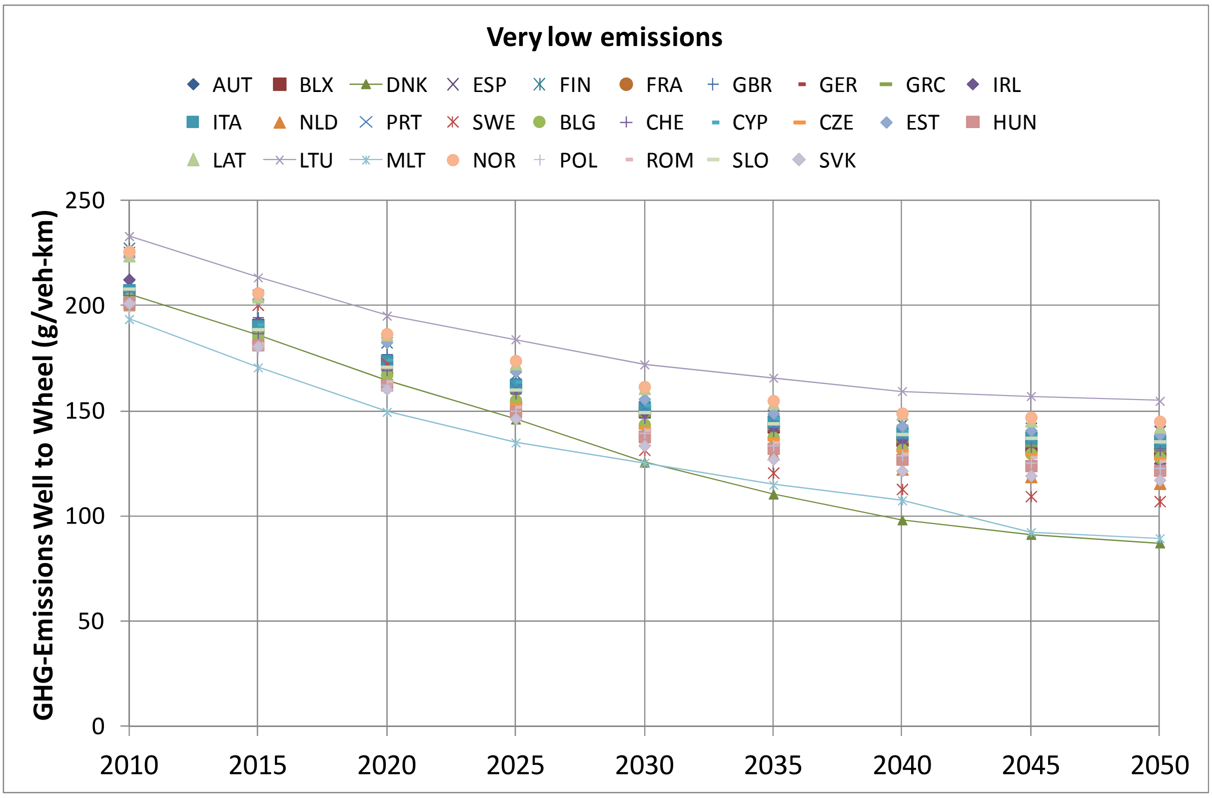


Figure 6-28 Specific GHG-emissions car Well to Wheel by country – scenario very low emissions

Bus/coach

No data about busses and coaches are available from GHG-TransPoRD (Fiorello et al. 2012). Scenario definitions concerning fuel consumption and emissions of buses/coaches hence rely on (EEA 2012) and own assumptions. Base year GHG emissions are uniformly estimated with 1,250 gram per vehicle kilometre. Figure 6-29 shows the scenario assumptions concerning the relative development of the specific GHG-emissions per bus/coach vehicle kilometre. In 2050 GHG-emissions are about 11 % (Baseline), 16 % (low emissions) and 21 % (very low emissions) lower than in 2010. The reason for the relatively low reduction rates is that diesel engine technology is already rather mature. Hence the potential for further efficiency gains is limited. Hybrid technology does not bring real advantages for long-distance travel.

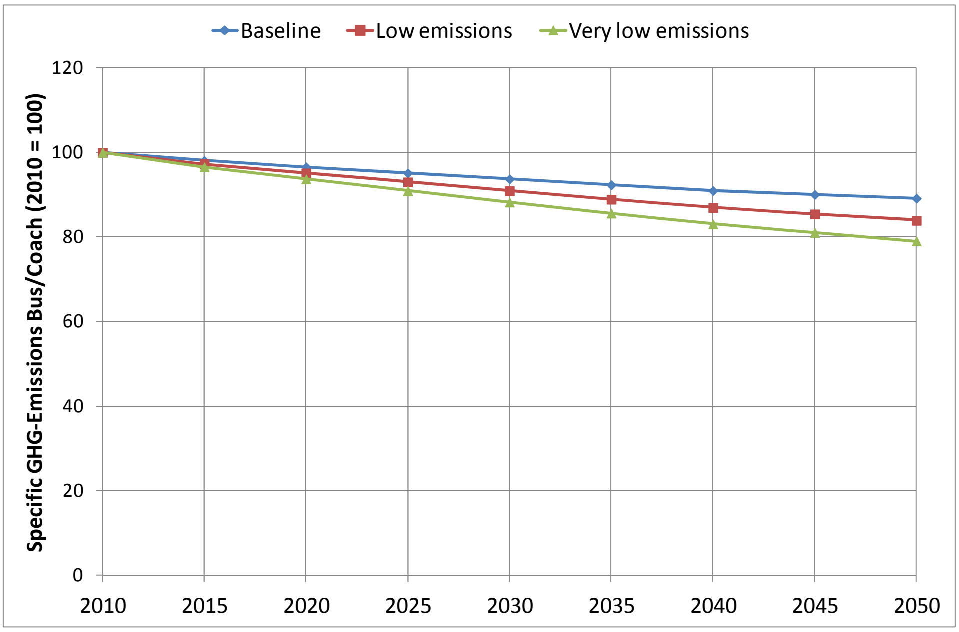


Figure 6-29 Relative GHG-emissions mode bus/coach by scenario

Rail

Scenario data concerning the share of diesel and electric traction of long distance rail journeys and CO_2-emissions of the respective power plant mix are available from GHG-TransPoRD (Fiorello et al. 2012). Base year GHG emissions are uniformly estimated with 8,625 gram per train kilometre. Figure 6-30 shows the scenario assumptions concerning the relative development of the specific GHG-emissions per train kilometre. In 2050 GHG-emissions are about 43 % (Baseline), 55 % (low emissions) and 64 % (very low emissions) lower than in 2010. The high reduction rates are mainly driven by the electrification of the rail network in combination with a shift to low GHG power plant mix.

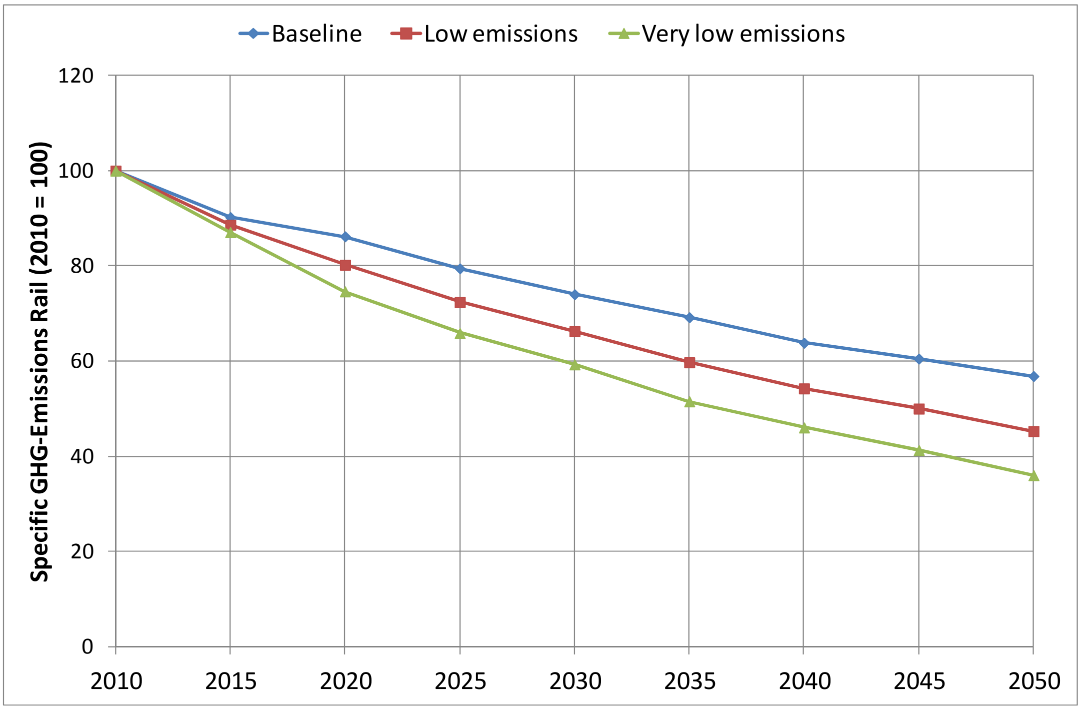


Figure 6-30 Relative GHG-emissions mode rail by scenario

Air

Data about the expected relative gains in fuel efficiency of air transport are available from GHG-TransPoRD (Fiorello et al. 2012). Base year GHG emissions are uniformly estimated with 25,000 gram per plane kilometre. Figure 6-31 shows the scenario assumptions concerning the relative development of the specific GHG-emissions per plane kilometre. In 2050 GHG-emissions are about 16 % (Baseline), 29 % (low emissions) and 49 % (very low emissions) lower than in 2010.

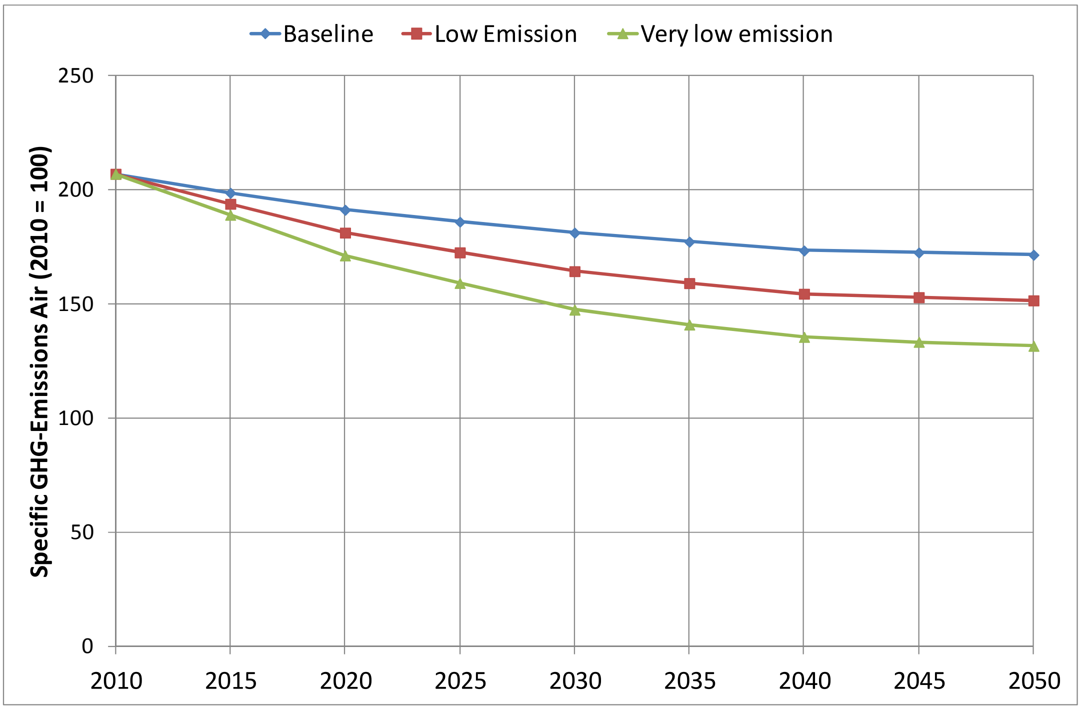


Figure 6-31 Relative GHG-emissions mode air by scenario

Maritime

Data about the expected relative gains in fuel efficiency of maritime transport are available from GHG-TransPoRD (Fiorello et al. 2012). GHG-TransPoRD assumes the same reduction rates in its Reference and Maximum Efficiency at Market Base scenario. Hence it is assumed that the reduction rates are equal in the Baseline, low emissions and very low emissions scenario. Base year GHG emissions are uniformly estimated with 5,156 gram per vehicle kilometre. Figure 6-32 shows the scenario assumptions concerning the relative development of the specific GHG-emissions per vehicle kilometre of the mode maritime. In 2050 GHG-emissions are about 12 % lower than in 2010.

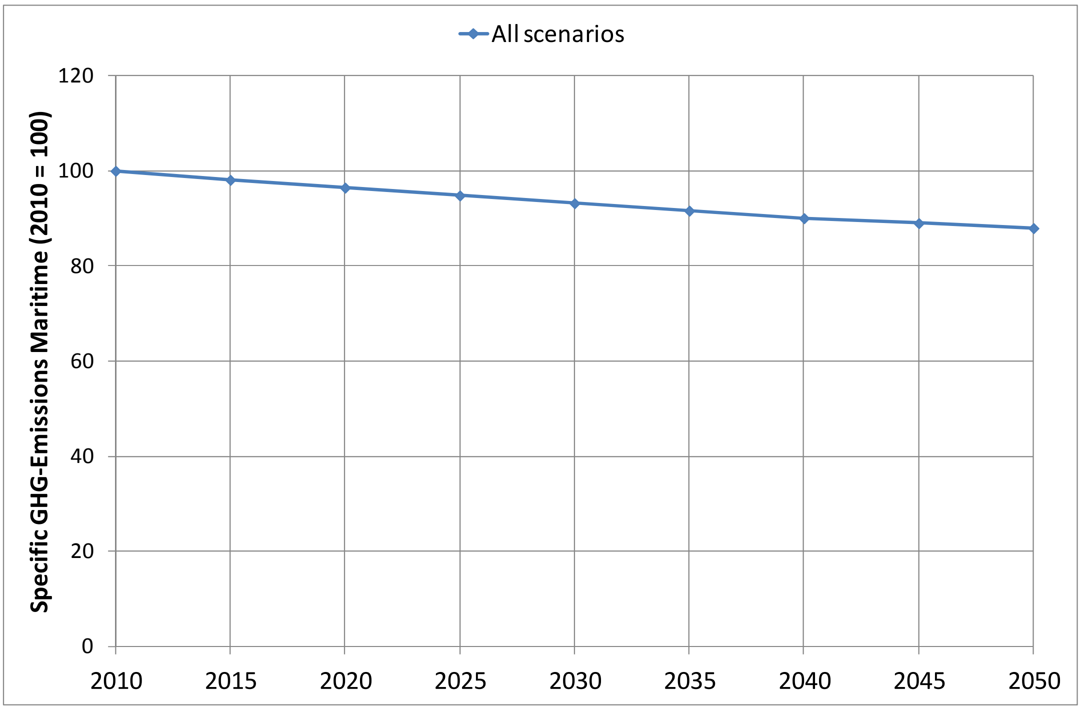


Figure 6-32 Relative GHG-emissions mode maritime

Summary

Table 6-7 gives an overview of the environmental technology scenario variables and indicators.

Table 6-7 Overview environmental technology scenario variables and indicators

	Baseline 2050	Low emission	Very low emission
Phase out conventionally fuelled cars	share of cars not using fossil fuels <1 %	~4 % cars not using fossil fuels in 2050	~8 % cars not using fossil fuels in 2050
Use cleaner and renewable energy	Increase in the use of renewable energies to power electric modes (mostly rail), and cleaner technologies for other modes (autogas, biofuels)	More renewable energies used in the transport sector, through increased use of biofuels and increased electrification of transport	More renewable energies used in the transport sector, through increased use of biofuels and increased electrification of transport
High percentage of low-carbon fuels in aviation and shipping	Low penetration of low-carbon fuels in aviation and maritime transport	Moderate penetration of low-carbon fuels in aviation and maritime transport	High penetration of low-carbon fuels in aviation and maritime transport
Average GHG emissions per paxkm by mode (WTW, well-to-wheel)	**car**: from 156 to 108 grams per paxkm **bus**: from 65 to 59 grams per paxkm **rail**: from 48 to 25 grams per paxkm **air**: from 212 to 158 grams per paxkm **maritime**: from 14 to 11 grams per paxkm	**car**: from 156 to 96 grams per paxkm **bus**: from 65 to 57 grams per paxkm **rail**: from 48 to 21 grams per paxkm **air**: from 212 to 132 grams per paxkm **maritime**: from 14 to 11 grams per paxkm	**car**: from 156 to 85 grams per paxkm **bus**: from 65 to 55 grams per paxkm **rail**: from 48 to 17 grams per paxkm **air**: from 212 to 111 grams per paxkm **maritime**: from 14 to 11 grams per paxkm
Noise pollution	Progressive decline in noise, mostly due to improves technologies on cars, airplanes, trains and ferries	Not substantially different from Baseline	Sharp decrease in transport noise. More silent vehicles in all modes: car / rail / air / ferry
Water pollution	Moderate decrease	Moderate decrease	Sharp decrease thanks to technology

6.2.4 Transport

The transport policy packages are either the Baseline or the one for the Normative reference scenario 2030. The differences are summarised in Table 6-8.

Table 6-8 Key assumptions transport policy relative to Baseline

		Normative reference
Private car	Free flow speed	0.8%
	Road costs	5.0%
	Car occupancy rate	10.0%
Bus/coach	Fares	5.0%
Rail	Speed	13.7%
	Fares	-2.5%
	Access costs	-10.0%
	Load factor	10.0%
Air	Commercial speed air network	0.0%
	Fares	2.5%
	Access costs	-3.0%
	Load factor	10.0%
	Check in/security time	-10.0%
	Transit time	-10.0%
Maritime	Commercial speed	0.0%
	Fares	2.5%

Summary

Table 6-9 gives an overview how user needs and efficiency scenario variables and indicators are treated in the ORIGAMI 2050 scenarios without and with the Normative Transport Policy in place.

Table 6-9 Overview user needs and efficiency scenario variables and indicators

	Baseline 2050	Normative reference
User pays for full costs of transport	Increased costs of transport due to increased fuel costs, and moderate internalisation of road transport externalities	Moderate internalisation of road transport externalities. Subsidies reduced
Safety	General increase of transport safety in line with observed trends over the last 2 decades	Smarted vehicles allow for substantial safety increase in the road transport. Almost zero accidents.
Security	Despite no significant increases in security procedures, no significant decreases in transport security	Increased security procedures, but technological advances allow to reduce time devoted to security procedures in transport terminals
Accessibility for people with impaired mobility	Most significant obstacles for impaired users addressed in transport terminals	Improved accessibility for impaired users in transport terminals but also in cars, as vehicles become increasingly customisable to different user needs, and more automated
Comfort and convenience	Moderate increase in transport comfort, mostly thanks to improved vehicle, and better user information	Moderate increase in transport comfort, mostly thanks to improved vehicle, better user information, and enhanced transport terminals
Attractive service frequencies	Progress in the provision of attractive service frequencies for services with high levels of demand. Some DRT systems in areas with low demands	Progress in the provision of attractive service frequencies for services with high levels of demand. Some DRT systems in areas with low demands
Reliable transport services	Increased reliability of services. Just in time traveller information allows passengers to adapt more easily to incidences in service provision	Substantially more reliable, especially for rail services and air services, mostly due to large technology deployment allowing for more efficient management.
High quality mobility services	Increased overall quality of mobility services	High quality mobility services, in rail and public transport, and in air
Intermodal integration of services	No significant integration beyond specific commercial agreements reached by operators	Public sector is in receptive integration, but no specific actions are envisaged to promote agreements between operators
Awareness of intermodal services	Users become more aware of transport alternatives, and on the carbon footprint they bring associated	Users become more aware of transport alternatives, and on the carbon footprint they bring associated
IT for simpler transfers	ITs are mostly deployed for increased user information (just-in-time service information)	ITs are mostly deployed for increased user information (just-in-time service information)
Deployment of air traffic management infrastructure	Advances in ATM allow for moderate improvements in management efficiency of air space and airport capacity	Advances in ATM allow for moderate improvements in management efficiency of air space and airport capacity
Road and Rail ITS deployment	Advances in ITS implementation in transport infrastructure allow for moderate improvements in management of available capacity	Advances in ITS implementation in transport infrastructure allow for moderate improvements in management of available capacity
Deployment of maritime transport management systems	Advances in maritime services operation	Advances in maritime services operation
Administrative burden	Not significantly reduced	Significantly reduced

6.3 ORIGAMI 2050 SCENARIOS

In the previous section 6.2 the different dimensions for the scenarios have been defined and described. These building blocks, i.e. sub-scenario definitions, are the basis for the definition of six different scenarios for 2050 (Table 6-10). The socio-demographic and economic background is defined by two variations around the base scenario which represent a Prospering Europe (PE) and a Europe which is Lagging behind (LE). The policies concerning transport and transport technology can be classified as business as usual and Normative reference.

The PE scenario is different from the Baseline scenario in that Europe is assumed to prosper with the higher projections of fertility and life expectancy due to increased affluence across the whole EU with the higher growth in GDP being realised. With the general levels of wealth increasing, there is less reason for internal migration and we see a central migration scenario developing. As the world is prospering and GDP is increasing, this brings with it higher investments in propulsion technology and so low emission technologies are introduced in all sectors as expected in the maximum efficiency and market conditions scenario from GHG-TransPoRD as described above.

For the LE scenario, things are generally worse than expected in the base case. Fertility and life expectancy are at the lower end of the projections, as is growth in GDP across the EU. The migration and propulsion technologies are assumed to be the same as the base.

The transport policy will be varied between the base (no change to Business As Usua (or BAU for short) and the Normative reference scenario under each context scenario as described earlier. In moving from the BAU to the Normative transport package, the emissions factors are also improved in both cases from low to very low in the PE scenario and from Baseline to low in the LE scenario.

Table 6-10 Definition of the ORIGAMI 2050 scenarios

Scenario	2050A	2050B	2050C	2050D	2050E	2050F
	Baseline	Baseline + Normative Transport Policy	Prospering Europe + BAU Transport Policy	Prospering Europe + Normative Transport Policy	Lagging Europe + BAU Transport Policy	Lagging Europe + Normative Transport Policy
Socio-demography & economy						
Total fertility	Baseline	Baseline	High growth	High growth	Low growth	Low growth
Life expectancy	Baseline	Baseline	High growth	High growth	Low growth	Low growth
Migration	Baseline	Baseline	Concentration	Concentration	Baseline	Baseline
Employment	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline
GDP	Baseline	Baseline	Uniform high growth	Uniform high growth	Uniform low growth	Uniform low growth
Transport Policy						
Propulsion technology	Baseline	Low emission	Low emission	Very low emission	Baseline	Low emission
Transport	Baseline	Normative reference	Baseline	Normative reference	Baseline	Normative reference

7 EVALUATION OF THE SCENARIOS FOR 2050

7.1 PREAMBLE

Although the focus of this chapter is the year 2050, many of the following figures show the full line of development of the various indicators from 2010 to 2050, including obviously the year 2030. However, a direct comparison between any numbers for 2030 here and those in section 4 with the scenarios for 2030 is not possible. First of all, the geographic coverage is different, with the scenarios here only covering the EU27 plus Switzerland and Norway, while the 2030 scenarios include Iceland, Turkey, the former Yugoslav countries and large parts of Eastern Europe. Second, MOSAIC also includes day trips, while LUNA only models journeys with at least one overnight stay. Third, MOSAIC only contains journeys within the European continent and Turkey, while LUNA also includes intercontinental journeys, which by nature will increase the share of flights. Finally, the assumptions underlying the two sets of scenarios are not necessarily the same. For instance the 2030 scenarios assume a share of 20 to 30 % of electric cars, which is on the optimistic side for long-distance transport, while the 2050 scenarios assume a much more conservative maximum of 8%. On the other hand, the assumptions about emission reductions are more optimistic in the 2050 scenarios than the 2030 ones, and these are only two examples of many differences.

Moreover, while it was the general idea that the Normative Policy used here should be as close as possible to the Normative scenario for 2030, one key issue for the 2030 scenarios was the very strong increase in the HSR network that led, as shown in chapter 4.1.1, to a very strong shift towards rail travel due to a doubling of travel speed in many key corridors. However, in contrast to the MOSAIC model used for the 2030 scenarios, the LUNA model used here does not include a network model and was not designed to model individual corridors. To simulate the effect of the increase in the network size as much as possible, the average speed for rail travel has been increased and the average cost for rail travel reduced. This also led to a significant shift towards rail travel but not to the same extent as in the 2030 scenarios. Hence the Normative Policies adopted by the 2030 and 2050 scenarios are very similar but not quite the same.

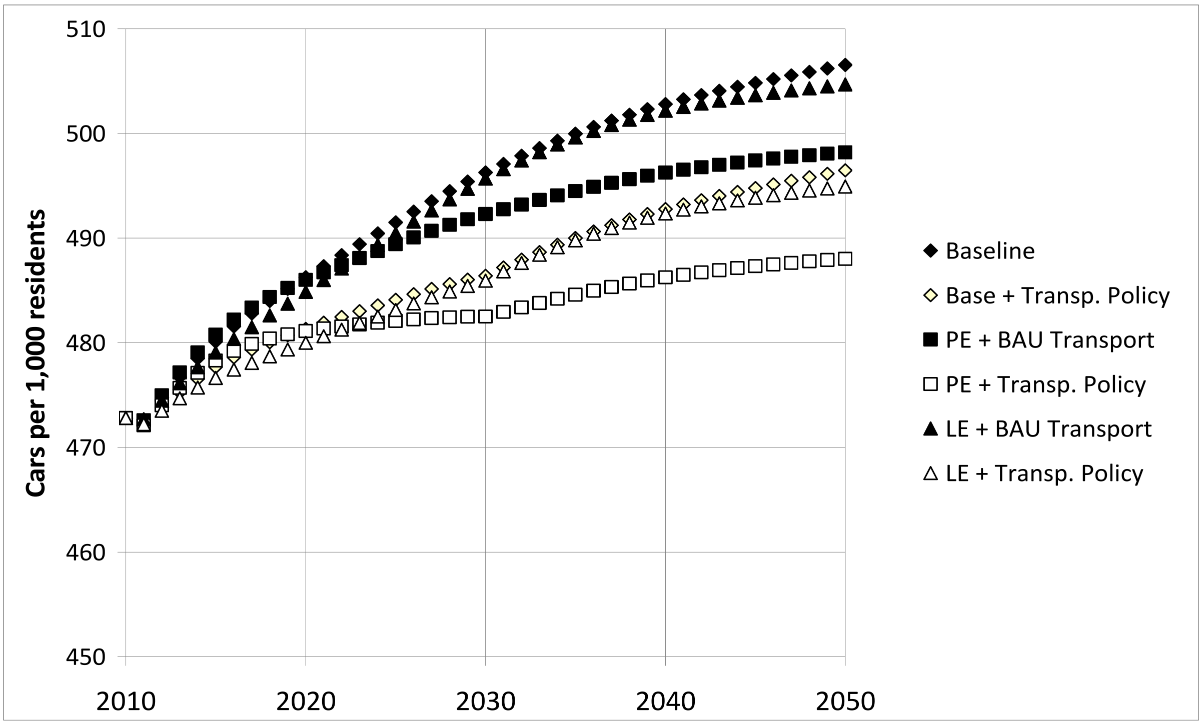
7.2 BASIC INDICATORS

7.2.1 Car Ownership and Mobility

Figure 7-1 shows the development of the first indicator, namely car ownership. Changes in car ownership are driven by socio-demographic and economic developments as well as the Normative Transport Policy with the latter reducing car ownership in 2050 by about 10 cars per 1,000 residents in all three sets of scenarios.

All scenarios show some increase in car ownership from just over 473 cars per 1000 residents to between about 488 to 507. The differences between the Baseline and Lagging Europe scenarios are very small, with the Baseline only being slightly higher than LE, both with and without the Policy. It seems counterintuitive that the ones for Prospering Europe are the lowest, since Prospering implies increased GDP and increased household income. From the sensitivity tests of high/low GDP it could be seen that GDP alone indeed changes car ownership, as expected, in the range of +/-4-5% for a GDP change of +/-20%. However, against that stand the higher population growth, larger average household sizes and an increase in very old population, which are all factors leading to a reduction in car ownership.

In fact, fertility sensitivity tests show that fertility set to ‘high’ reduces car ownership in all countries and low fertility increases car ownership in all countries, the net effect being about +/-5%. Increased fertility increases population, which decreases GDP per person, which in turn decreases available income per person for all household types. Finally this results in a lower car ownership rate when fertility is increased in all countries – the opposite is true for low fertility. When changes in GDP and migration are added, then effects per country become difficult to predict. The aggregate effect is lower car ownership in the PE case. There are many compensating interactions including changes in distribution between household sizes due to migration rates by age etc – but the fertility impact seems to be the dominating effect due to overall growth in population which affects the income.



Legend: PE = Prospering Europe, LE = Lagging Europe, BAU = Business as usual, Transp. Policy = Normative Transport Policy

Figure 7-1 Development of car ownership in the six scenarios

In any case, the development is not uniform across all of Europe and some countries have a lower car ownership rate and some a higher ownership rate under the PE scenarios as compared to Baseline.

It should also be noted that while the car ownership level is lower under PE scenarios, the total number of cars in the EU is still higher as there is a higher population in this scenario (Figure 7-2). On the other side, in the LE scenarios, both car ownership and the number of cars are lower than in the Baseline.

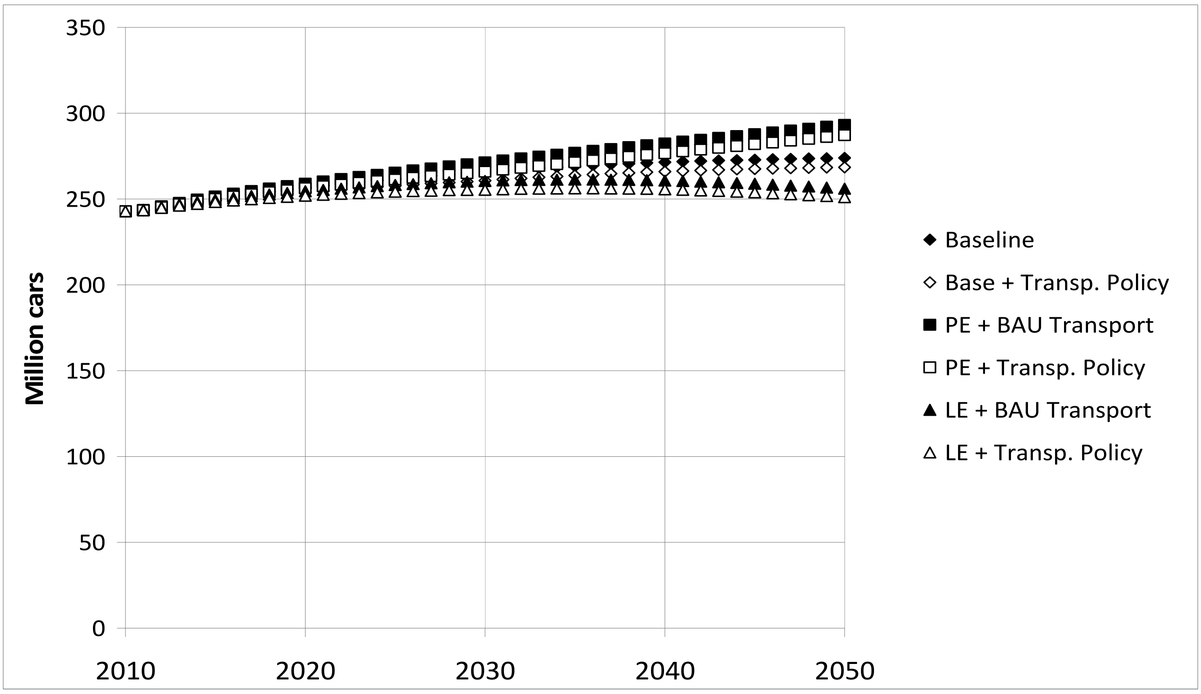


Figure 7-2 Development of the total number of cars in the six scenarios

A comparison between Figure 7-1 and Figure 7-2 suggests that the influence of the Transport Policy on car ownership is much larger than its influence on the total number of cars, and in relative terms this is certainly true, However, the different scales of the two graphs are misleading and the numbers in Table 7-1 show that the absolute influence of the Transport Policy is exactly the same concerning car ownership and number of cars in all three sets of scenarios – the differences between the two figures really lie in the same socio-demographic assumptions that make PE the scenarios with the lowest car ownership, but the highest number of cars.

	Car ownership		Number of cars	
Scenario	**2010-2050**	**2050 (with/without Transp. Policy)**	**2010-2050**	**2050 (with/without Transp. Policy)**
Baseline	7.1%		12.8%	
Base + Transp. Policy	5.0%	-1.99%	10.6%	-1.99%
PE + BAU Transport	5.4%		20.7%	
PE + Transp. Policy	3.2%	-2.04%	18.3%	-2.04%
LE + BAU Transport	6.7%		5.4%	
LE + Transp. Policy	4.7%	-1.93%	3.4%	-1.93%

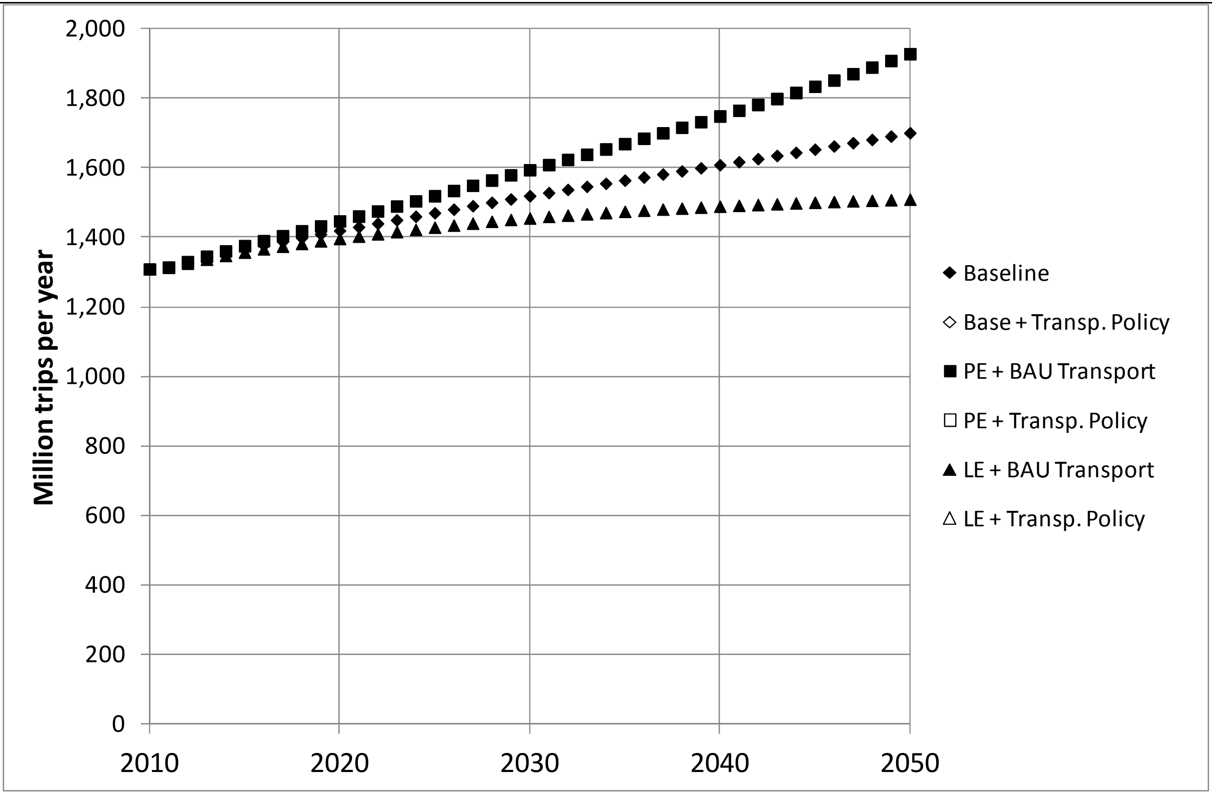
Table 7-1 Influence of the Transport Policy on car ownership and number of cars

Figure 7-3 shows mobility levels measured both in terms of trips per year and in terms of pax km per year. The first thing to note is that there are really only three lines visible for the number of trips, which means that assumptions made about Transport Policy do not play any role, i.e. trip rates are not influenced by the Transport Policy but only by the socio-demographic and economic assumptions. And even for passenger kilometres, the influence of the Policy is very small indeed and with it pax km only increase very marginally between 0.4% and 0.7% by 2050.

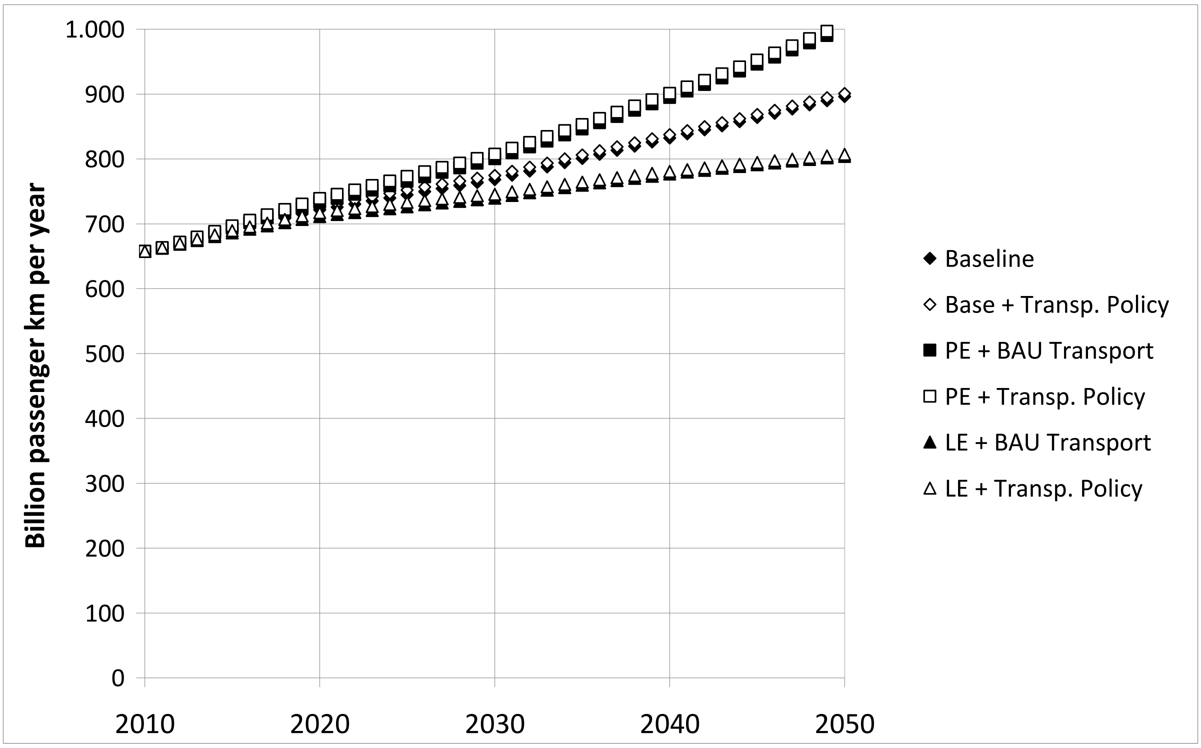
Mobility increases in all scenarios, and as could have been expected, least in the Lagging scenarios and most in the Prospering scenarios. Furthermore, the three scenarios diverge ever more over time. By 2050, PE has reached 47% growth in the number of trips, Baseline 30% and LE still 15%. The respective figures for pax km are with 53%, 37% and 23% still higher, but the main factor is the higher number of trips, while their lengthening is the smaller factor.

What the figure does not show is the difference that exists for different trip purposes. Changes in fertility affect trip rates for holidays via changes in income, but they do not affect the trip rate for business trips. Trip rates for holidays vary strongly by country, as will be shown later on, as income per capita might be up or down dependent on the relative growth of fertility, i.e. population, and GDP per capita, i.e. available income per person.

Trip rates for business trips are changing only when GDP per employee is changing and not due to different GDP per person. They increase/decrease by around 20% in the PE and LE scenarios respectively.



Million trips / a



Billion km travelled / a

Figure 7-3 Mobility levels in the six scenarios

Figure 7-4 shows the relationship between car ownership and trip rates per person and year.

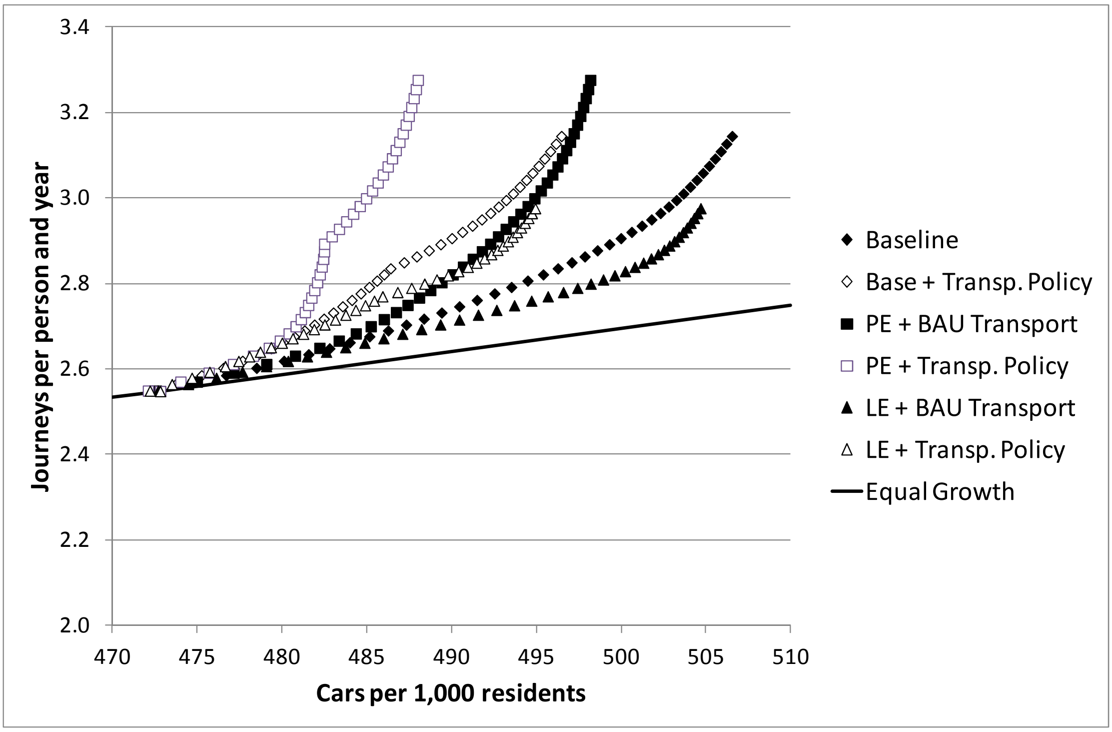


Figure 7-4 Relationship between car ownership and number of journeys per person and year EU27 + Norway and Switzerland

There is a clear basic correlation between trip rates per person and car ownership levels, but the relationship is different in different scenarios. The number of trips per person and year is growing faster than car ownership per person in the Baseline and PE scenarios while it is growing slower in the LE scenarios. The growth rates are listed in Table 7-2.

Table 7-2 Car ownership and trip rates

	2010	Baseline	Baseline + Policy	PE + BAU	PE + Policy	LE + BAU	LE + Policy
Car ownership	473	7.1%	5.0%	5.4%	3.2%	6.7%	4.7%
Trip rates	2.55	23.4%	23.4%	29.0%	29.0%	16.5%	16.5%

It is clear from both the figure and the table that the Transport Policy only curbs car ownership, but not the number of trips made overall – these are the same with and without Policy. Figure 7-4 illustrates very neatly how the scenarios with the Policy reach the same number of trips at a lower level of car ownership than the same scenarios without the Policy.

Figure 7-5 shows the relationship between car ownership and trip rates per person and year by country in 2010 and in 2050. Car ownership is growing for all countries, but with so many countries in the figure, it is somewhat difficult to filter out the development for individual countries in the middle field, but at the edges the picture is a bit clearer. The main highlights are:

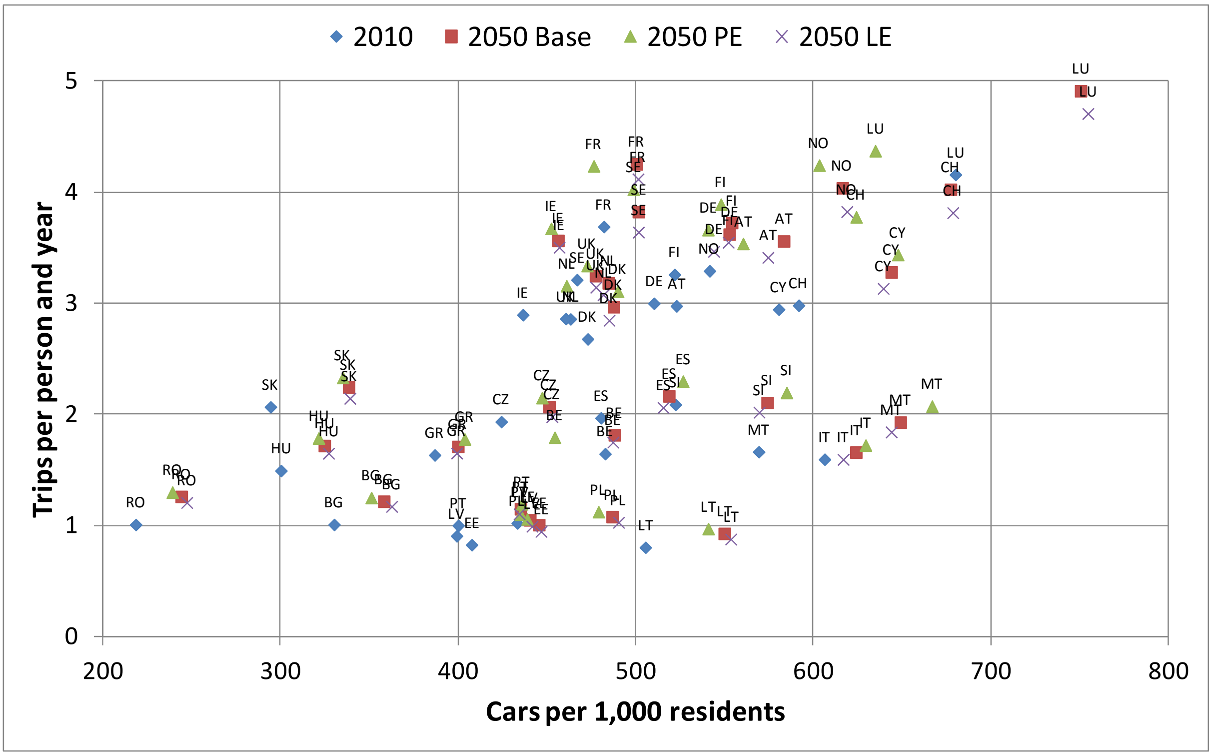


Figure 7-5 Relationship between car ownership and number of trips per person and year by country in 2010 and 2050 without Transport Policy

- Romania has the lowest car ownership per person in all scenarios: 218 (2010), 244 (2050 Baseline), 239 (2050 PE) and 247 (2050 LE).
- Luxembourg has the highest car ownership per person in 2010 (680 cars/1,000 residents), 2050 Baseline (750 cars/1,000 residents) and 2050 LE 754 cars/1,000 residents).
- Malta has the highest car ownership per person in 2050 PE (666 cars/1,000 residents).
- The growth in car ownership in the Baseline as well as in LE ranges from 1% (Belgium) to 15% (Slovakia), and in PE from -7%% (Luxembourg) to 17% (Malta).
- Trip rates are increasing in all countries and scenarios with one exception. In Slovenia the trip rate is decreasing by -3 % from 2010 to 2050 in the scenario LE.
- Lithuania has the lowest trip rate in all scenarios, while Luxembourg has the highest one. Trip rates range from 0.80 to 4.16 in 2010, 0.93 to 4.91 (2050 Baseline), 0.97 to 4.37 (2050 PE) and 0.88 to 4.71 (2050 LE).
- The growth in trip rates in the Baseline ranges from 1% (Slovenia) to 35% (Switzerland), in PE from 5% (Slovenia) to 29 % (Romania) and in LE from -3% (Slovenia) to 28% (Switzerland).

It should be noted that the numbers for the scenarios with Policy differ slightly from those shown in Figure 7-5, but the differences are marginal and would not be really discernable in a comparison between Figure 7-5 and one with the Transport Policy.

7.2.2 Network Usage

Figure 7-6 shows the network usage by passengers for the Baseline. Air has by far the largest share in passenger kilometres due to a combination of the length of trips involved in much of air travel and the high number of trips made by air[43]. Second highest is the car due to its dominance on shorter trips. Rail, coach and maritime all have very low passenger shares measured on a pax km basis.

[43] Billion is used in this report under the UK convention of meaning 10^9.

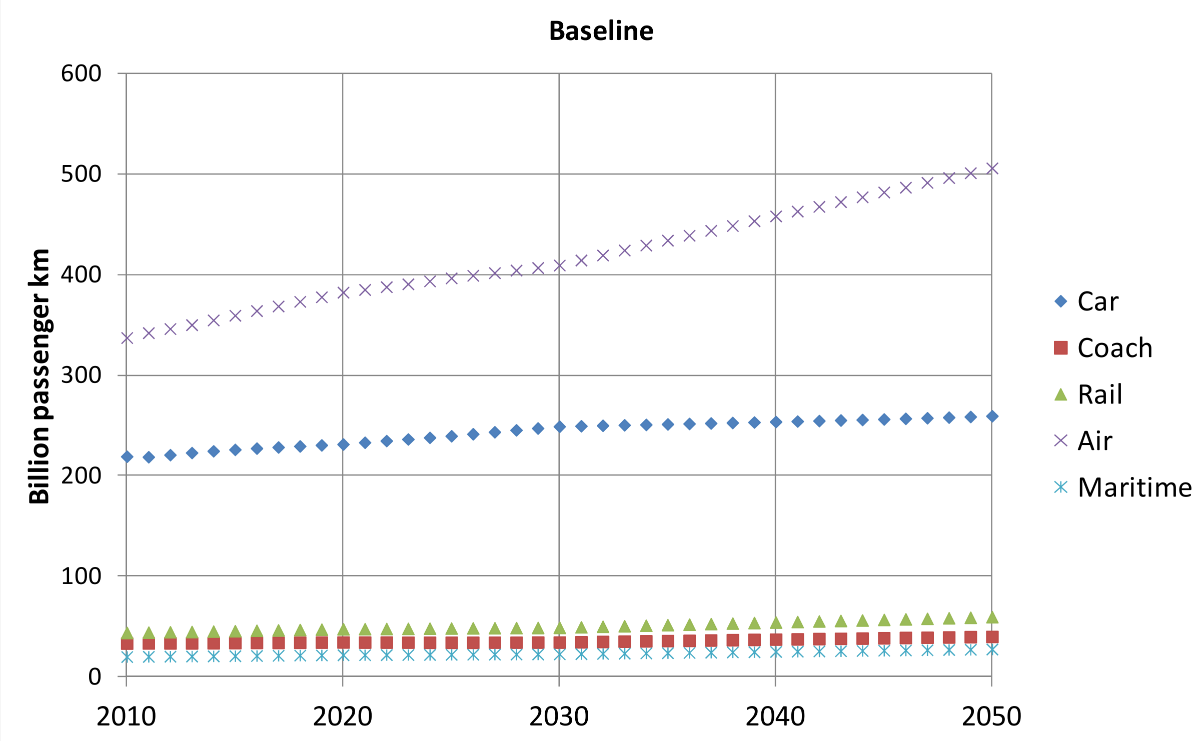


Figure 7-6 Network usage by passengers, Baseline scenario

Between 2010 and 2050 passenger kilometres increase by about 50% for air, but only 18 % for car. Even if starting and remaining still on a relatively low base, the increases are 36% for maritime, 35% for rail, and 20% for bus/coach.

Figure 7-7 compares the changes in the different scenarios. In this case the Policy does influence the overall picture, at least to some extent, so that there are now six distinct scenarios.

The top left picture shows the change within the Baseline with the year 2010 as 100. It shows a little clearer than Figure 7-6 that the growth for car is lower than any other mode, with air growth being largest and maritime and rail coming a close second and third. Travel by coach starts off with the smallest growth up to 2030, but catches up and just overtakes car by 2050.

On the top right, with the Transport Policy in place, on the lower end, the Policy reduces the share of coaches while not affecting the share of cars. The bigger change is on the upper end, where rail, with an increase of 9.6% is now nearly catching up with the air travel, which with an increase of just 0.3% is hardly affected at all. Along with coach travel maritime transport is the other mode that is disadvantaged by the Policy and loses 3.5% of its share.

In Prospering Europe pax km increase for all modes, and for all of them stronger than in the Baseline. The highest growth arrives with 65% for air travel, followed by 51% for rail, 41% for maritime transport, 38% for the car and, finally 30% for bus and coach. Similar to the Baseline, the Transport Policy slightly curbs the growth of coach and maritime travel and very marginally of car travel. Air travel grows again by a small amount, here by 0.7%, while the big winner is again rail travel which is boosted by an additional 9.9%, so that its increase over the 2010 Baseline for PE with Policy is now 66%, the same as air travel.

For Lagging Europe, car travel slightly increases up to around 2030, but then slowly declines again, so that by 2050 it is just 3% higher than in 2010. The other modes of travel rise steadily, in similar proportion to the Baseline scenario but to a lesser extent, with even air traffic only reaching a 36% increase – significantly less than to the 65% in PE or even 50% in the Baseline. The Policy, as in the other two scenarios, changes very little for all modes except rail, which even in the LE case still gets a 9.2% push from the Policy.

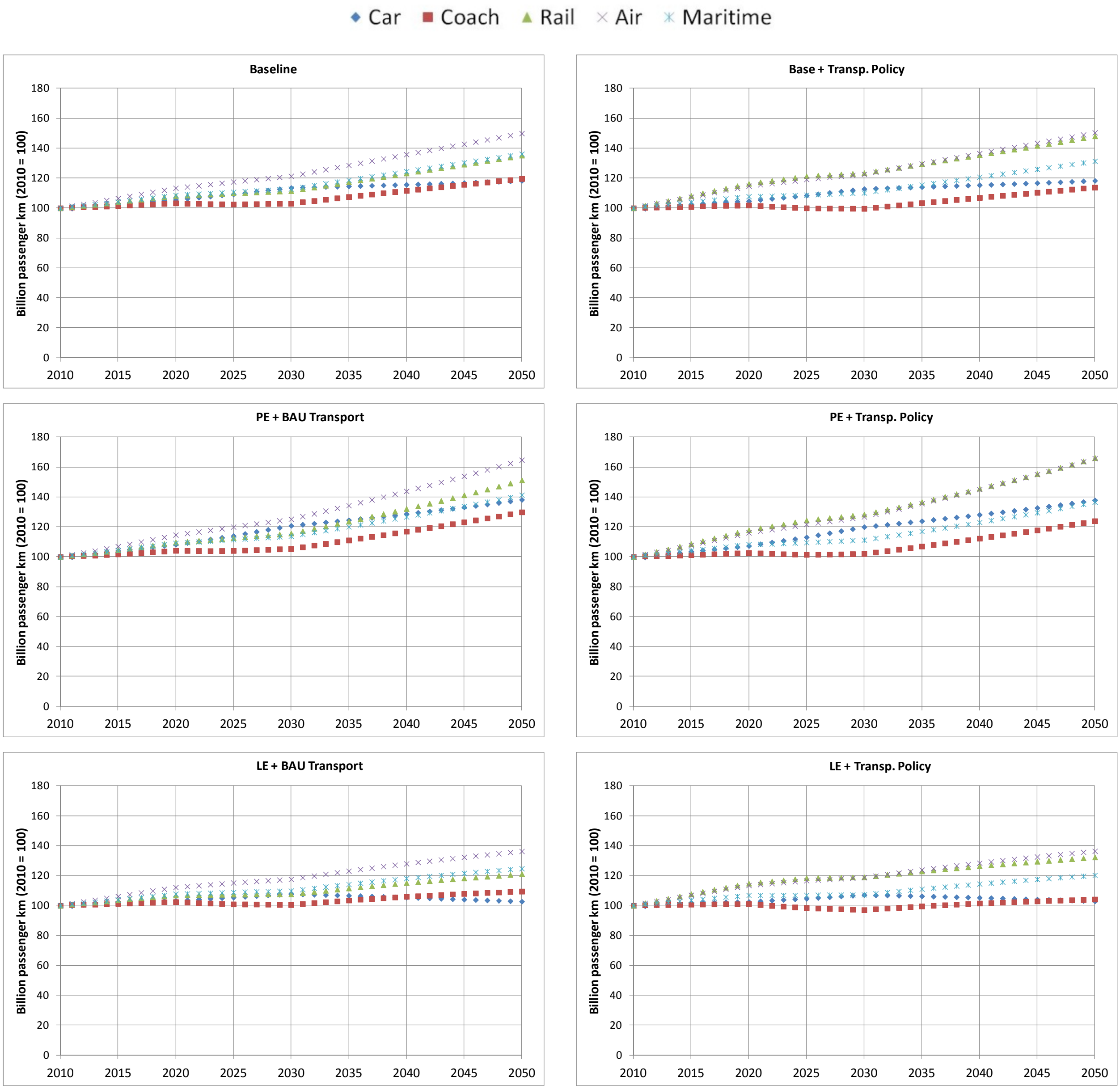


Figure 7-7 Change in network usage by passengers

Summarising it all on a mode by mode basis rather than scenario by scenario, the first thing to note is that air travel grows strongest in all scenarios, under all socio-demographic circumstances considered, more or less independent of the existence of the Transport Policy.

The development of car travel also depends very little on the Transport Policy, but in contrast to air, its growth depends very strongly on the socio-economic and demographic changes: in a Prospering Europe growth may be 38%, but in a Lagging Europe remain nearly stagnant at just + 3%. However, for car travel to decline, as is the European transport policy target, much stronger population changes would be needed and / or much stronger transport policies.

Rail travel is the one mode that has been most impacted on by the Transport Policy, although the Policy's parameters are relatively modest and certainly is no way unrealistic. The combination of a Prospering Europe with a Normative Transport Policy could lead to an increase in rail travel by 66%, bringing it to the same level as the growth in air travel.

Coach and maritime travel are both expected to grow continuously, slightly less with than without the Policy, but in terms of overall pax km, they will still remain less important than the other modes.

Figure 7-8 shows the network usage by vehicles for the Baseline scenario. The very first thing to note is that the figure applies one scale for cars and one for all other modes. The network usage for cars is therefore not 2.4 billion veh km, as could be assumed on first glance, but around 133 billion veh km, so at a totally different order of magnitude to that of the four other modes. Indeed, in 2010 car vehicle kilometres are 27 times the vehicle kilometres of all collective modes together, and in 2050 the relationship is still the same.

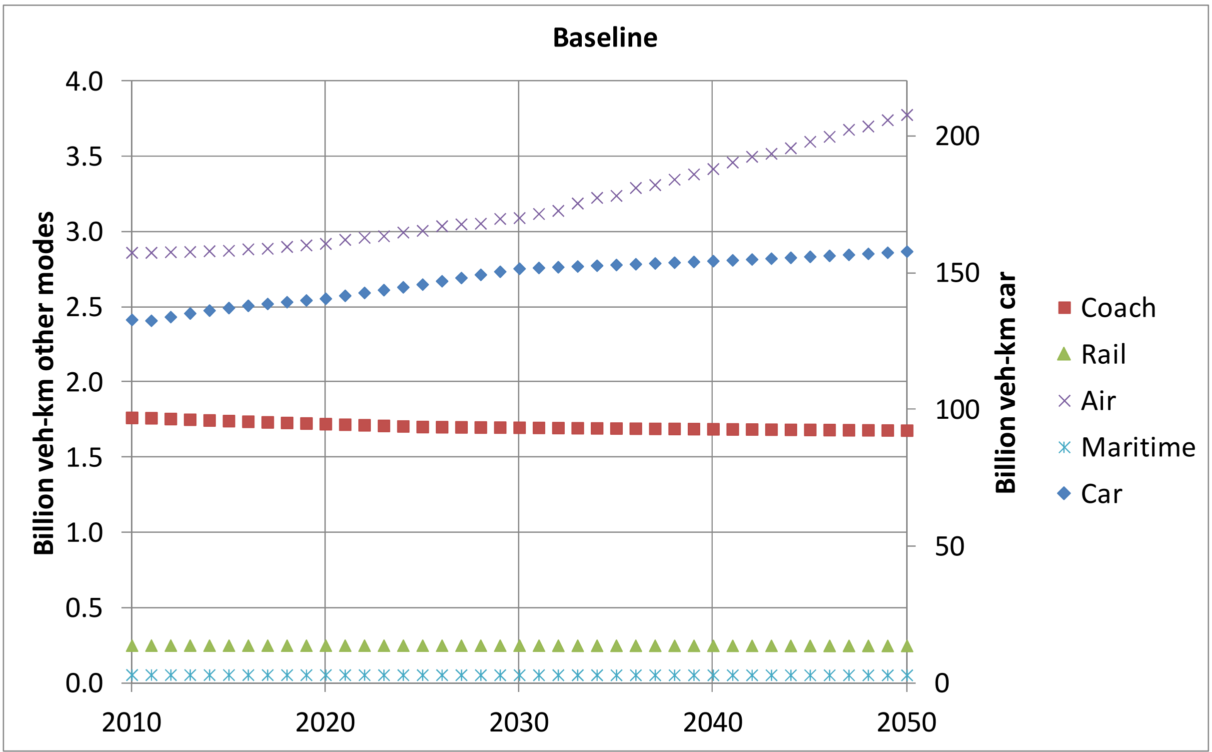


Figure 7-8 Network usage by vehicles in the Baseline scenario

In spite of the different scales it becomes clear from Figure 7-8 that car miles are growing faster than air miles until 2030 with a growth of 14% and 8% respectively, while after that the two lines diverge. Growth of airplane miles from 2030 to 2050 is 22%, while for cars it slows down to 4%, ending up with a total growth over the 40 years of 19% for car miles and 32% for air plane miles. The reason for this change in the development of the two modes in 2030 is that it was assumed that air fares stay constant from 2030 on while operating costs for car are assumed to continue to grow. The assumption that air fares stay constant was made because of two different competing trends which are levelling out each other: on the one hand costs decrease due to competition and better utilisation and on the other hand increase due to increasing fuel costs.

For the three other modes there is a more or less steady decline over the forty years. Since trains and maritime vessels in average carry high passenger numbers and therefore, as for pax km, stay at the bottom of the scale, coach and bus mileage has here jumped up to the middle of the figure since their average load increases from 19 pax / coach in 2010 to 26 pax / coach due to supply decreasing slightly more than demand, but is still of course much lower than that for the other public modes.

Figure 7-9 shows the development of the veh km by mode for each of the six scenarios in relation to the Baseline 2010.

The top left figure just confirms the impression from Figure 7-8: rail, maritime vessel and coach mileage decline marginally over the next forty years, while car mileage initially grows most, but is then overtaken by airplane mileage.

The introduction of the Transport Policy, top right in the figure, does not change the ranking between modes, all it does is bring air and car closer to the base year value and switch rail from a -1% decline to a small +4% increase.

The PE scenario does not affect coach or maritime mileage, both have the same small decline as in the Base 2050. Rail travel remains constant rather than declining by 1% as in the base, while air travel and car travel both soar further above the Baseline: airplane miles by another 8% compared to the Base 2050 and car miles even by another 17%. The Transport Policy has the same effect as in the Baseline by curbing the growth of air and car travel in favour of growth of rail travel.

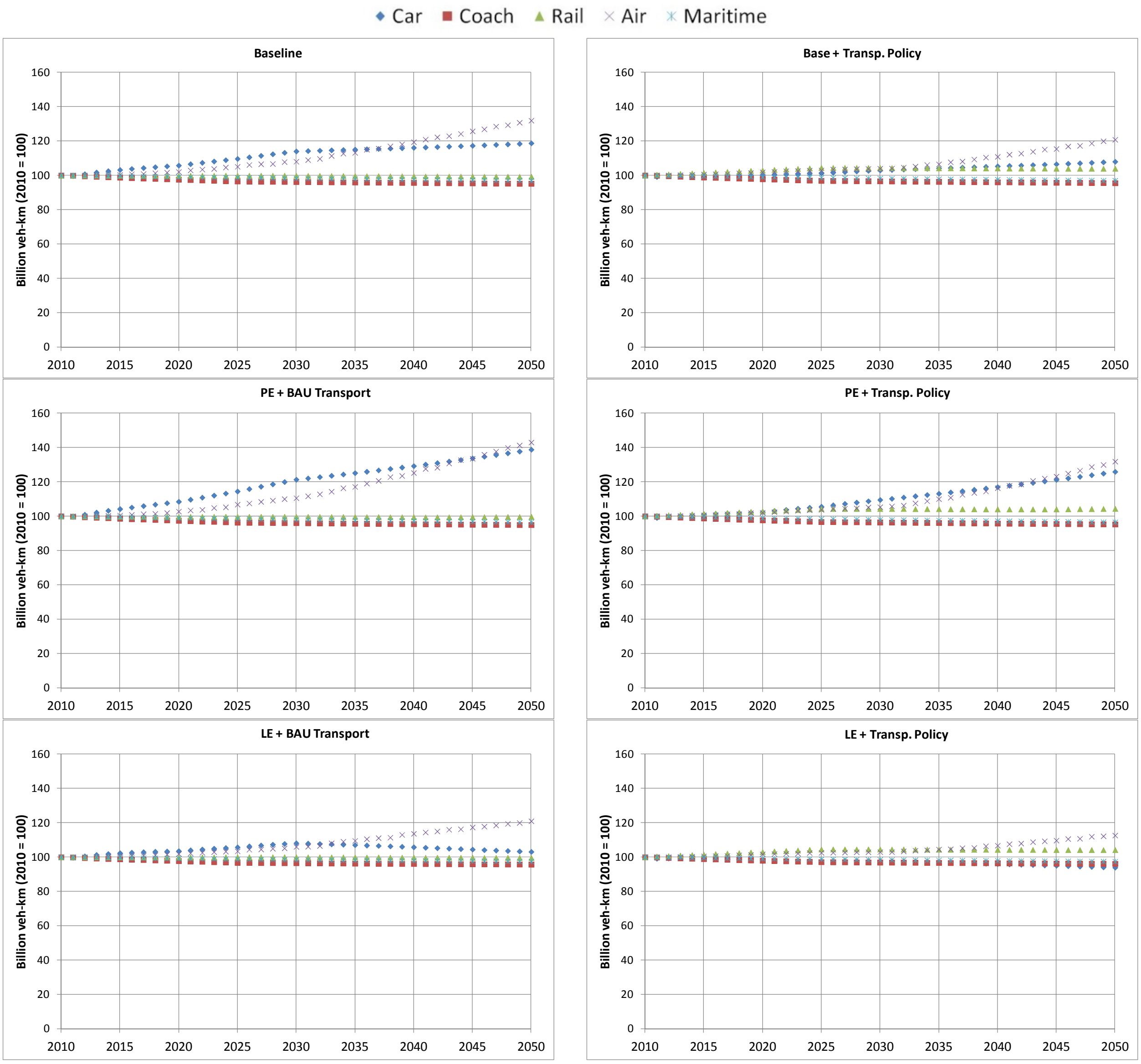


Figure 7-9 Change in network usage by vehicles

The LE scenario is very similar to the Baseline for rail, maritime and coach mileage. It reduces the growth in air travel from 32% to 21%, but the relatively biggest change against the Baseline occurs for car travel which in LE only increases by 3% instead of 19%. The Transport Policy does the same here as in the Baseline and PE, by curbing car and airplane mileage and increasing rail mileage.

Overall, it appears that neither socio-economic nor demographic changes, nor the Transport Policy, have more than the most marginal effect on miles travelled by coaches and marine vessels.

Also kilometres travelled by trains are hardly affected by socio-economic and demographic changes; they are only increased through a Transport Policy that increases rail speed and reduces rail cost.

Airplane mileage rises in all scenarios from 21% in LE to 41% in PE, and while the Policy reduces that by approximately 4.7 %, it prevents the strong rise in none of the scenarios at all, and any Policy that tried to achieve that would have to have much more groundbreaking parameters. The effect of the Policy is to a large extent caused by the underlying assumptions concerning load factors.

Car travel is the mode most susceptible to changes in both aspects. The socio-demographic and economic assumptions underlying the scenarios result in different household income levels. On the one hand household income affects the relative weight of costs in mode choice. On the other hand household income also influences car ownership rates. This combined effect allows a range from just +3% in LE to +39% in PE, and the Policy reduces car mileage by around 9% in all three sets of scenarios. The car mileage reducing effect of the Policy is, as already just mentioned, to a large extent caused by the underlying assumptions concerning occupancy rates.

Figure 7-10 shows the network usage of passengers in terms of average distances travelled by passengers per mode. In all scenarios, the longest trips are made by air followed, perhaps somewhat surprisingly, by maritime trips.

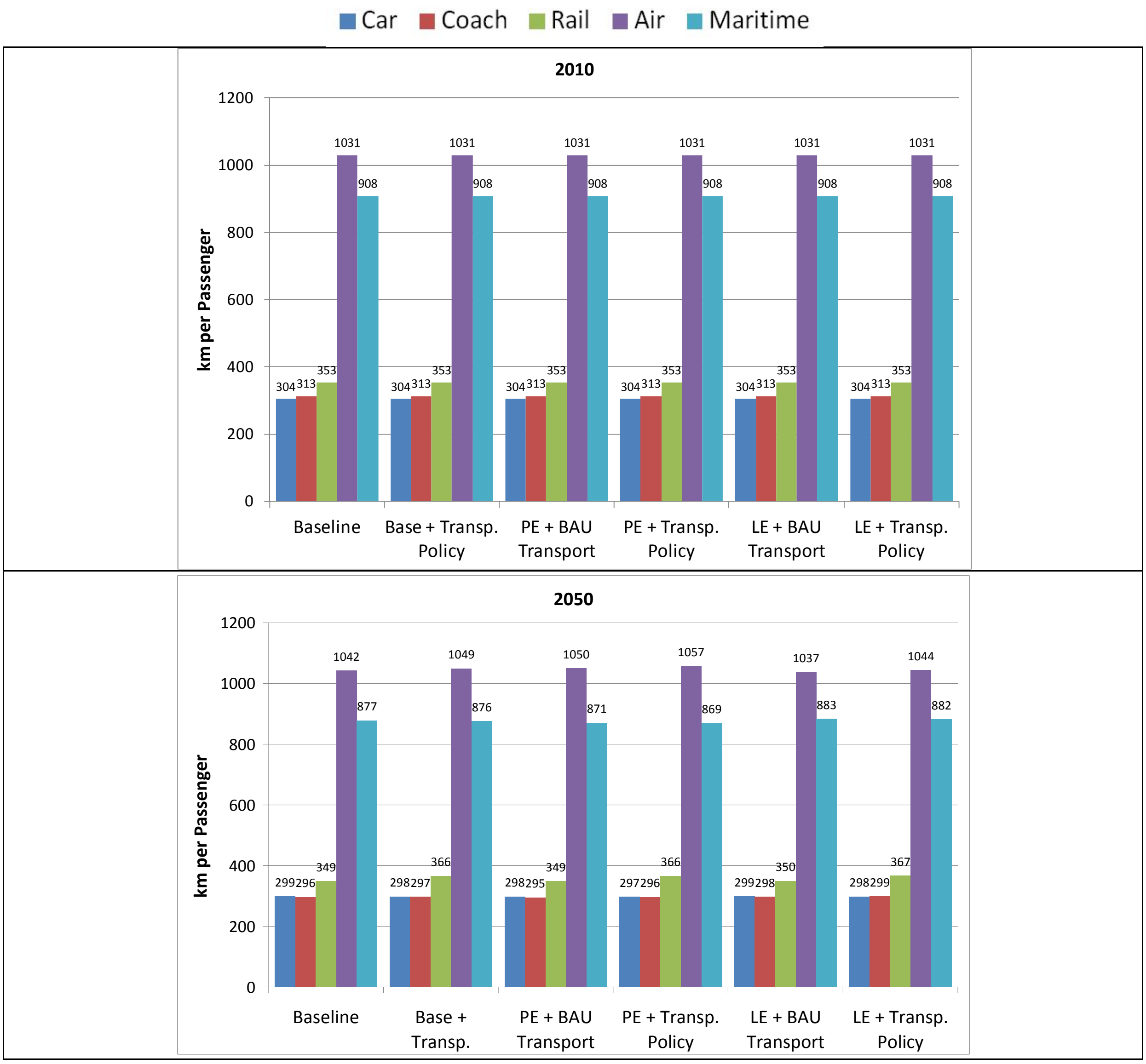


Figure 7-10 Network usage by passengers across the six scenarios 2010 and 2050

The average trip length for a sea crossing in Greece is only 370 km, but since maritime as the main mode was only allowed for longer distance bands in some other countries, there is a dominance of holiday cruises, not only within the Mediterranean and the Baltic Sea, but even across the Atlantic, which clearly increases the average length very significantly. It should be noted however, that the maritime mode is the weakest link in the LUNA modelling, due to the lack of basic data, and should be revisited once more when better shipping data is becoming available.

The lengths of trips by car, rail and coach are all in a similar range and around 1/3 of that of flights and sea journeys.

In the Baseline, distances travelled by ship decrease slightly from 908 km/passenger to 877 km/passenger, by rail from 353 to 349 km/passenger, by coach/bus from 313 to 296 km/passenger, and by car from 304 km/passenger to 299 km/ passenger, while air trips increased slightly in length from 1,031 to 1,042 km/passenger. All of these changes are clearly very marginal. Moreover, differences between scenarios are also very small, with the largest difference between them coming from the Transport Policy, which increases the length of rail trips by 4.9% from 349 to 366 km/passenger in the Baseline, and similarly for PE and LE.

Figure 7-11 shows how many kilometres a car drives per year in the different scenarios. Up to 2030, without the Policy, they increase for all three types of scenarios, ranging from just +3 km for LE over +22 km for the Baseline to +49 km, or + 9%, in the PE scenario. After 2030 they diverge and by 2050 they range from -12 km against 2010 for LE, over + 29 for the Baseline to +82 km, or + 15% for PE. The differences between the scenarios are driven by car ownership rates, car occupancy rates and transport demand in pax km. The Transport Policy suppresses car usage and reduces the annual km for all three scenarios by 2050 by 42 to 45 km. The dominant drivers of this effect are the assumptions concerning car occupancy rates.

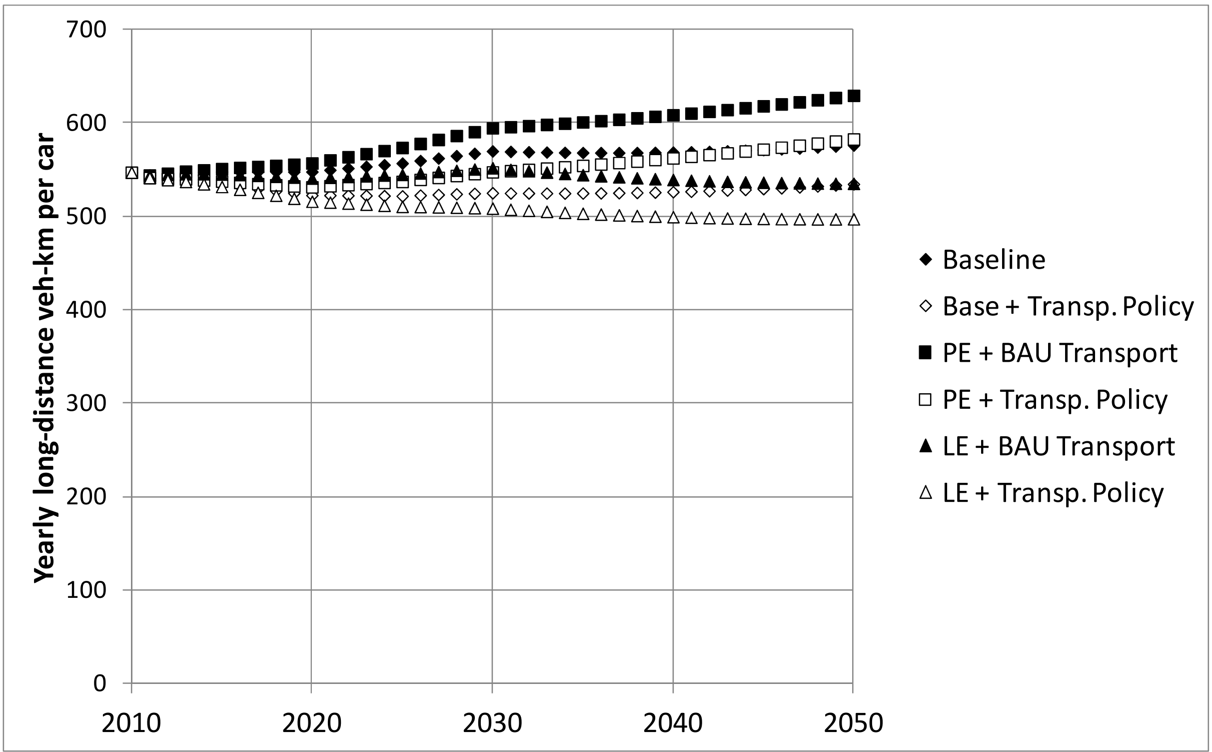


Figure 7-11 Network usage by cars across the six scenarios

Table 7-3 lists the relationship between passenger kilometres and vehicle kilometres, which is an expression of the efficiency of the vehicle utilisation. This is in part driven by the underlying scenarios assumptions, in particular the load factors that are part of expressing the Transport Policy, and in part by the transport demand and supply calculated by the model.

For car utilisation, the occupancy factor is the only element that does have any influence, hence the only difference between the six scenarios is that those with the Policy have a 9% higher utilisation than those without.

For coaches, differences are negligible up to 2030, and then diverge just a little more with figures ranging from 22 to 24 pax km / veh km without the Policy. The Policy has here only a marginal influence by reducing the utilisation by 1 pax km / veh km in each of the three sets of scenarios.

Table 7-3 Vehicle utilisation by passengers

		Vehicle utilisation (pax km / veh km)					
		Baseline	**Base + Transp. Policy**	**PE + BAU Transport**	**PE + Transp. Policy**	**LE + BAU Transport**	**LE + Transp. Policy**
Cars	2010	1.66	1.66	1.66	1.66	1.66	1.66
	2030	1.65	1.81	1.65	1.81	1.65	1.81
	2050	1.65	1.81	1.65	1.81	1.65	1.81
Coaches	2010	19	19	19	19	19	19
	2030	21	20	21	20	20	19
	2050	24	23	26	25	22	21
Rail	2010	178	178	178	178	178	178
	2030	199	210	206	219	191	202
	2050	242	253	270	283	216	226
Air	2010	118	118	118	118	118	118
	2030	133	139	134	142	131	136
	2050	134	147	136	148	133	143
Maritime	2010	375	375	375	375	375	375
	2030	430	420	435	425	418	408
	2050	526	508	549	530	480	463
Total	**2010**	4.77	4.77	4.77	4.77	4.77	4.77
	2030	4.90	5.46	4.80	5.36	4.97	5.52
	2050	5.48	6.04	5.25	5.82	5.64	6.20

For rail the bigger differences come from larger differences in demand with pax km / veh km increasing from 2010 to 2050 by 21% in LE, 36% in the Baseline and 52% in PE, thus ranging from 216 in LE to 270 in PE. The Policy increases utilisation further by 10 to 13 pax km / veh km. The reason is the assumption that under the Policy option the rail operators set measures to increase the load factor.

In contrast to rail, airplane utilisation shows hardly any difference between the three sets of scenarios. It increases from 2010 to 2050 in all BAU scenarios by around 15% and it is then only the Transport Policy that makes a difference in 2050 by increasing the utilisation from between 133 to 136 in BAU to between 143 to 148, or approximately by 8 to 10%. Again the reason is the assumption that under the Policy option the air operators take measures to increase the load factor.

Finally, maritime utilisation increase significantly in all three sets of scenarios from 2010 to 2050, ranging from +105 or +28% in LE over +151 or +40% in the Baseline to +174 or +46% in PE, i.e. in a similar range to the increase in rail utilisation. This is due to changes in demand and a relative large vessel size, i.e. oversupply, in the base year. The Policy reduces the increase by between 17 and 19 pax km / veh km, because of a relative reduction in demand for maritime transport.

7.2.3 Door-to-Door Travel Time

Figure 7-12 shows the development of travel time over time in the Baseline. It looks very similar to the network usage by passengers in pax km in Figure 7-6, except for the fact that maritime travel has moved from last into third place. Given that flying is clearly faster than driving by car, and given from Figure 7-6 that in the 2050 Baseline there are roughly 500 billion pax km by air and 250 pax km by car, one could have expected that hours travelled by car would have been higher than hours spent on planes. However, the time spent on a journey by air is not only just time spent sitting in the plane, but includes egress and access, which in particular in more rural regions can be more than the actual flight time; on top of that come time spent in security and in transfers between flights. In fact, LUNA calculated access/egress times and flight speed from the TRANSTOOLS OD matrices, and although the project team felt that the resulting travel times for flights were excessively high, no better data was available, on which new calculations could have been based.

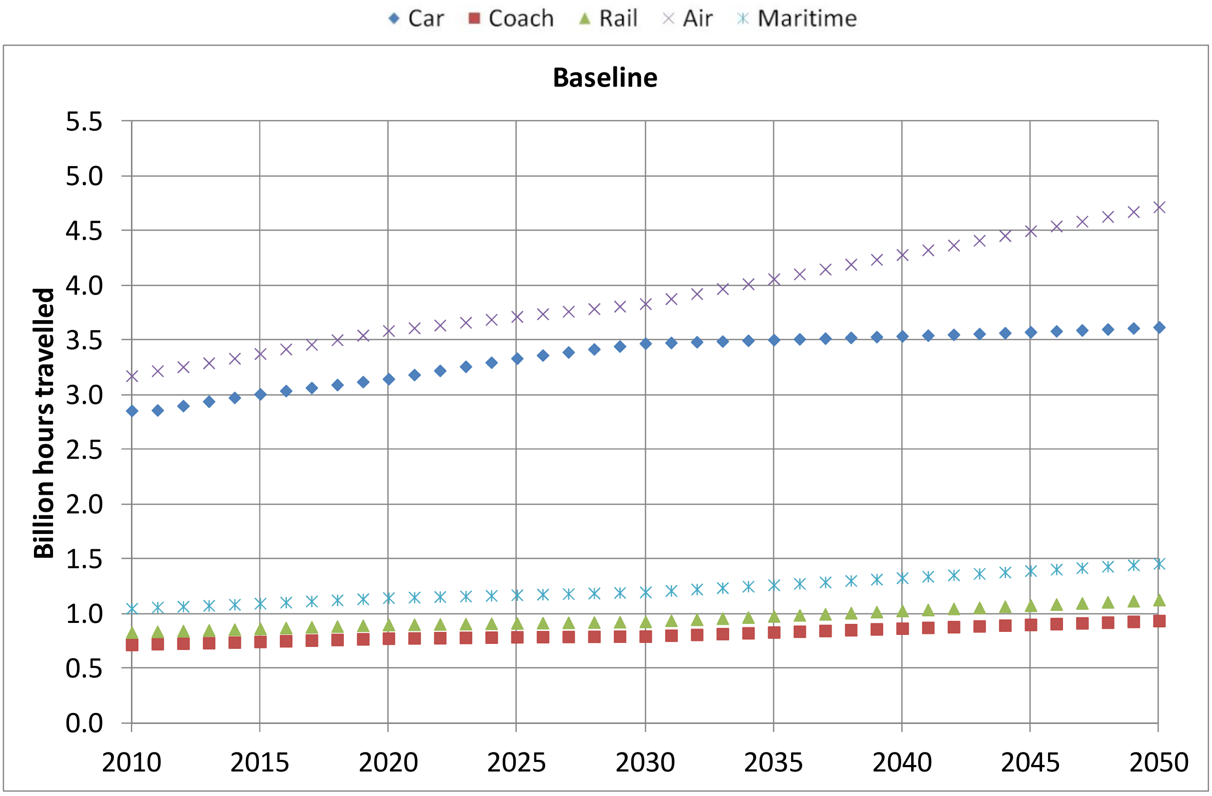


Figure 7-12 Absolute development of travel time on the Baseline scenario

Figure 7-13 shows the development of the travel time for all six scenarios relative to the base of 2010. The results are due to a combination of changes in number of trips due to socio-demographic and economic changes and improvements in the specific travel speeds.

The top line in all six scenarios by 2050 is the one for air travel, reaching an increase of up to 63% on 2010 for PE, but they mirror very closely the increases in pax km throughout all six scenarios.

The second highest in Baseline and LE is maritime travel. Due to the very slow travel speed in combination with the increased passenger mileage, time spent on maritime trips increases by 39% in the Baseline and still by 27% in LE. In PE it is even a 45% increase, but here it is overtaken by rail travel. The transport policy reduces that in all three cases by about 5 percentage points.

Rail indeed takes second place in the BAU PE scenarios with 51% respectively and third place in the Baseline and LE with increases from 36% and 22%, in all cases reduced by 3% through the Policy.

Coach travel times increase in LE BAU by 19%, in the Baseline by 30% and in PE by 41%; the Policy brings them all down by 7%.

The mode with the biggest differences between scenarios is car. Growth in car travel time is even highest of all modes until 2030 in PE and Baseline, but with flight operating costs staying constant at this stage, while car operating cost increase further, flight operators are drawing in former car drivers as customer especially for longer distance trips, and the increase in trip length for Baseline and for PE slow down towards 2050, and in LE even decline, ending up just 10% over the 2010 values both with and without the Policy.

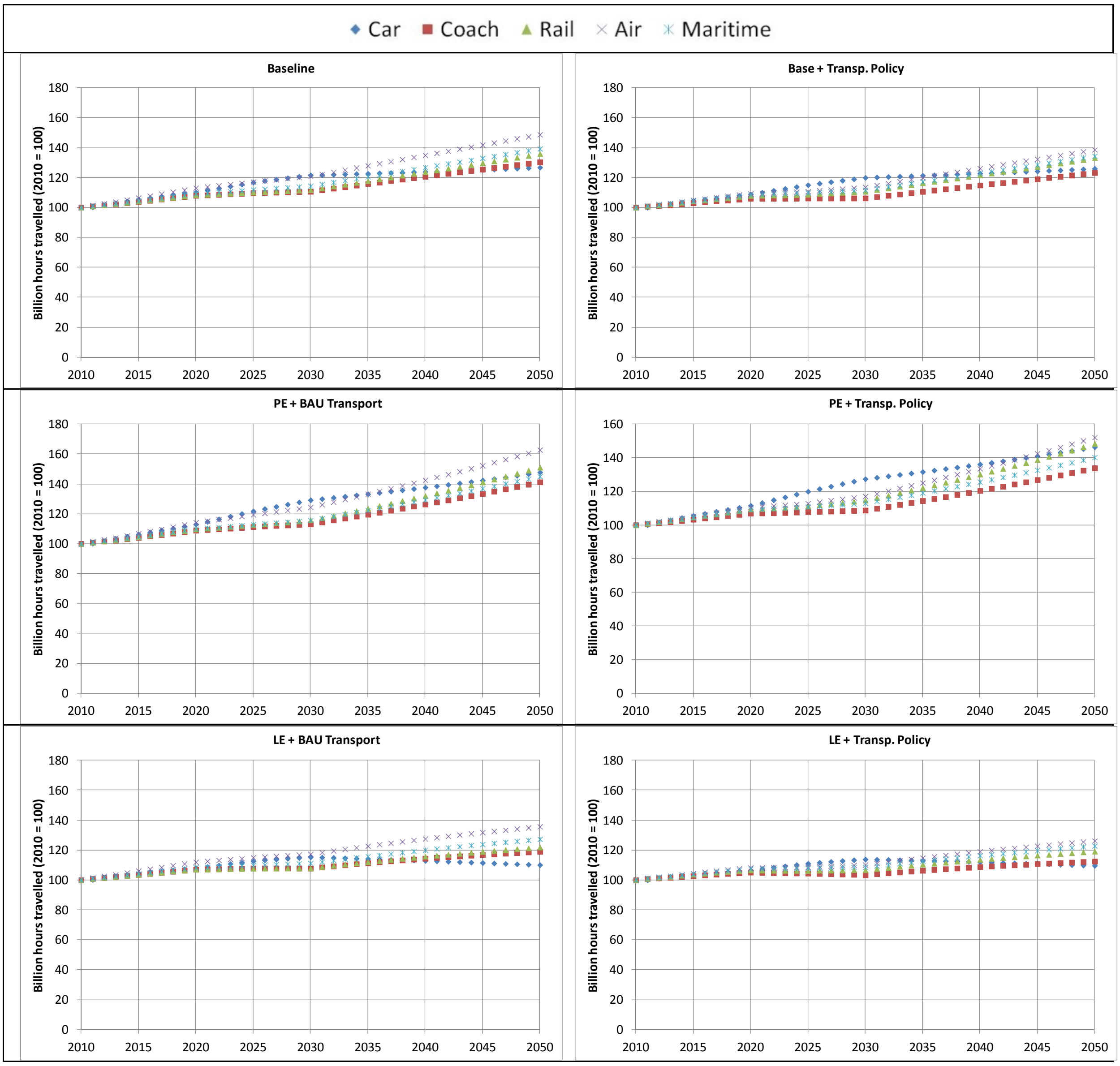


Figure 7-13 Relative development of travel time

Table 7-4 lists the times spent on long-distance transport per mode again, but this time not from a global transport systems view but rather in terms of time spent by each person, making it easier to imagine what the numbers mean to individuals. These figures need to be seen in the context of each person making approximately 2.55 long-distance trips in 2010, and 2.98 long-distance trips per year in LE, 3.14 in the Baseline and 3.28 in PE in 2050.

In 2010, with 2.55 trips per person, the average door to door trip length is 6.6 hours overall, including access and egress. This seems rather long, but needs to be considered in the light of the facts that these are trips with at least one overnight stay and include intercontinental trips. By 2050, the overall travel time per year and person in the LE case increased from 16.8 to 21.0 hours, while the average door to door trip duration increased to 7.1 hours. The Transport Policy decreased the overall travel time per person and year in 2050 to 20.0 hours and the average door to door trip duration to 6.7 hours. For the Baseline, everything increased with total travel time from 16.8 to 21.9 hours, number of trips from 2.55 to 3.14 and the door to door time per trip from 6.6 to 7.0 hours. The Transport Policy decreased the overall travel time per person and year in 2050 to 20.9 hours and the average door to door trip duration to 6.7 hours. For PE, the total door to door travel time per person and year increases to 22.4 hours in 2050, while the average door to door trip duration increased only slightly to 6.8 hours. The Transport Policy decreased the overall travel time per person and year in 2050 to 21.4

hours and the average door to door trip duration to 6.5 hours. The Transport Policy decreases the total door to door travel time per person in all three cases by one hour due to the increase in travel speeds.

Table 7-4 Times spent per person on long-distance transport per mode (h/a)

		Baseline	Baseline + Transp. Policy	PE + BAU Transport	PE + Transp. Policy	LE + BAU Transport	LE + Transp. Policy
Cars	2010	5.6	5.6	5.6	5.6	5.6	5.6
	2050	6.7	6.6	7.2	7.1	6.2	6.2
Coaches	2010	1.4	1.4	1.4	1.4	1.4	1.4
	2050	1.7	1.6	1.7	1.6	1.7	1.6
Rail	2010	1.6	1.6	1.6	1.6	1.6	1.6
	2050	2.1	2.0	2.1	2.1	2.0	1.9
Air	2010	6.2	6.2	6.2	6.2	6.2	6.2
	2050	8.7	8.0	8.8	8.0	8.5	7.8
Maritime	2010	2.0	2.0	2.0	2.0	2.0	2.0
	2050	2.7	2.6	2.6	2.5	2.6	2.5
Total	**2010**	16.8	16.8	16.8	16.8	16.8	16.8
	2050	21.9	20.9	22.4	21.4	21.0	20.0

The share of air travel in the overall door-to-door travel time is about 6.2 hours in 2010. Given that the average trip length in 2010 is 6.6 hours, this means that the average person currently undertakes about one air trip of average length in one year.

The low travel times per person on the other modes, in particular for coach, air and maritime do not reflect short trips, but instead the fact that fewer people take trips on these modes, thereby lowering the average time spent, even if any single trip undertaken, takes a much longer time. This is particularly pertinent for maritime trips where the average is derived from a very low number of people making very long trips at low cruising speeds.

Table 7-5 Relative share of travel time spent for each type of trip (%)

		Baseline	Baseline + Transp. Policy	PE + BAU Transport	PE + Transp. Policy	LE + BAU Transport	LE + Transp. Policy
Cars	2010	33.1	33.1	33.1	33.1	33.1	33.1
	2050	30.5	31.8	32.1	33.2	29.5	30.8
Coaches	2010	8.3	8.3	8.3	8.3	8.3	8.3
	2050	7.9	7.8	7.7	7.6	8.0	7.9
Rail	2010	9.6	9.6	9.6	9.6	9.6	9.6
	2050	9.5	9.8	9.5	9.8	9.5	9.7
Air	2010	36.8	36.8	36.8	36.8	36.8	36.8
	2050	39.8	38.2	39.2	37.7	40.4	38.8
Maritime	2010	12.1	12.1	12.1	12.1	12.1	12.1
	2050	12.3	12.4	11.5	11.7	12.5	12.7

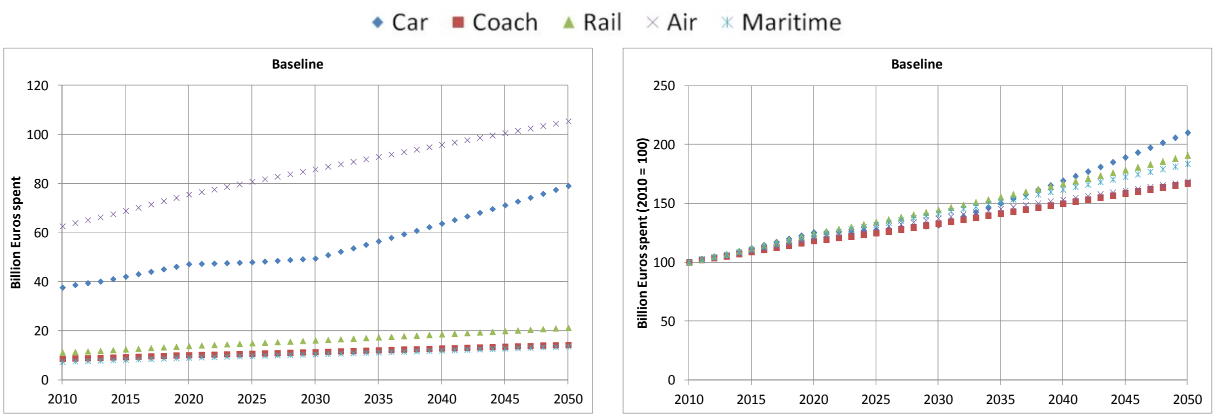
Table 7-5 lists the share of the travel time spent on each mode. It becomes even clearer than previous conclusion drawn from Figure 7-13 that the share of travel time spent on air travel goes significantly up in all scenarios, while the share of car travel goes slightly down. Coach travel goes significantly down, while rail travel is hardly affected at all and maritime travel only in PE, where its share in travel time goes down.

In conclusion, none of the socio-demographic or economic assumptions prevent the strong increase of time passengers spend on air travel, and only the Transport Policy manages to dampen that. On the other side, the increase in passenger km for rail travel is not reflected in the time spent on rail travel, but is absorbed by the increased train speeds. Car travel becomes faster too, so much so that it reduces time spent on car travel in spite of the increase in pax km.

7.3 TRANSPORT COSTS

Figure 7-14 shows the user expenditure for long-distance travel for the Baseline scenario. Total user expenditure is on the one hand driven by the development of specific travel costs (fuel, tickets, etc.) and on the other hand by the development of total demand.

The graph on the left with the absolute expenditure is again not very dissimilar to the ones for travel time or pax km (Figure 7-12 and Figure 7-6). Cost of air travel are by far the highest, followed by costs for road travel and cost for rail, coach and maritime travel are much lower than those two.



Absolute user expenditure | **User expenditure relative to base year**

Figure 7-14 Development of user expenditure per mode in scenario Baseline

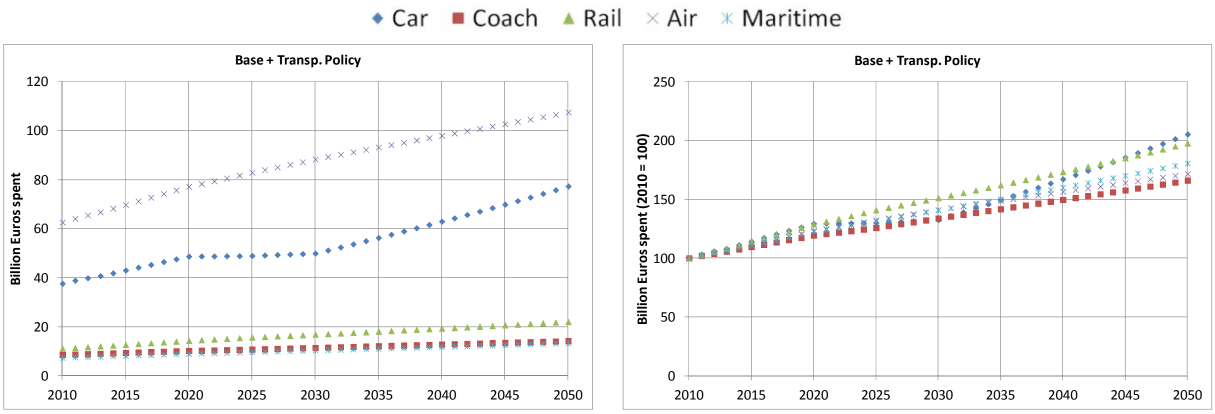
The two main differences to the travel time graphs are that the costs for car travel accelerate rather than decelerate from 2030 and that rail costs are higher than coach and maritime, with the latter two being very close together throughout, and the cost of coach travel overtaking that of maritime travel only very marginally.

It is only the graph on the right that makes it clear that the expenditure for air and coach travel are actually the ones that increase least over the 40 years, while it is the expenditure for car travel that increases most. So, in summary, the user expenditure per mode is largely driven by the demand for the mode, with the exception of the car, where the cost of driving becomes the dominant influence due to assumed increases in fuel costs from 2030.

Figure 7-15 shows the Baseline with the Transport Policy and the comparison with Figure 7-14 shows relatively small differences. On the one hand the Policy reduces total costs for car by -2.2%, for coach by -0.6% and maritime by -1.5%. On the other hand the Policy increases total costs for rail by about 3.7% and for air by about 2.0%. The same is true for all other scenarios (Figure 7-16), where the Policy reduces and increases the costs in each mode in the same order of magnitude (see also Table 7-6).

In contrast, differences between the three types of scenarios are much more pronounced: Total expenditure on all modes with BAU is in LE about 10% lower than in the Baseline and in PE about 9%

higher. Particularly strong are also the differences for rail with LE (BAU) 10.8% lower than Baseline and PE 12.0% higher than Baseline, although the assumptions on the cost of rail per km are the same in all BAU scenarios – so again the increase of expenditure is an expression of increased use of rail travel due to the higher population.



Absolute user expenditure **User expenditure relative to base year**

Figure 7-15 Development of user expenditure per mode in scenario Base + Transp. Policy

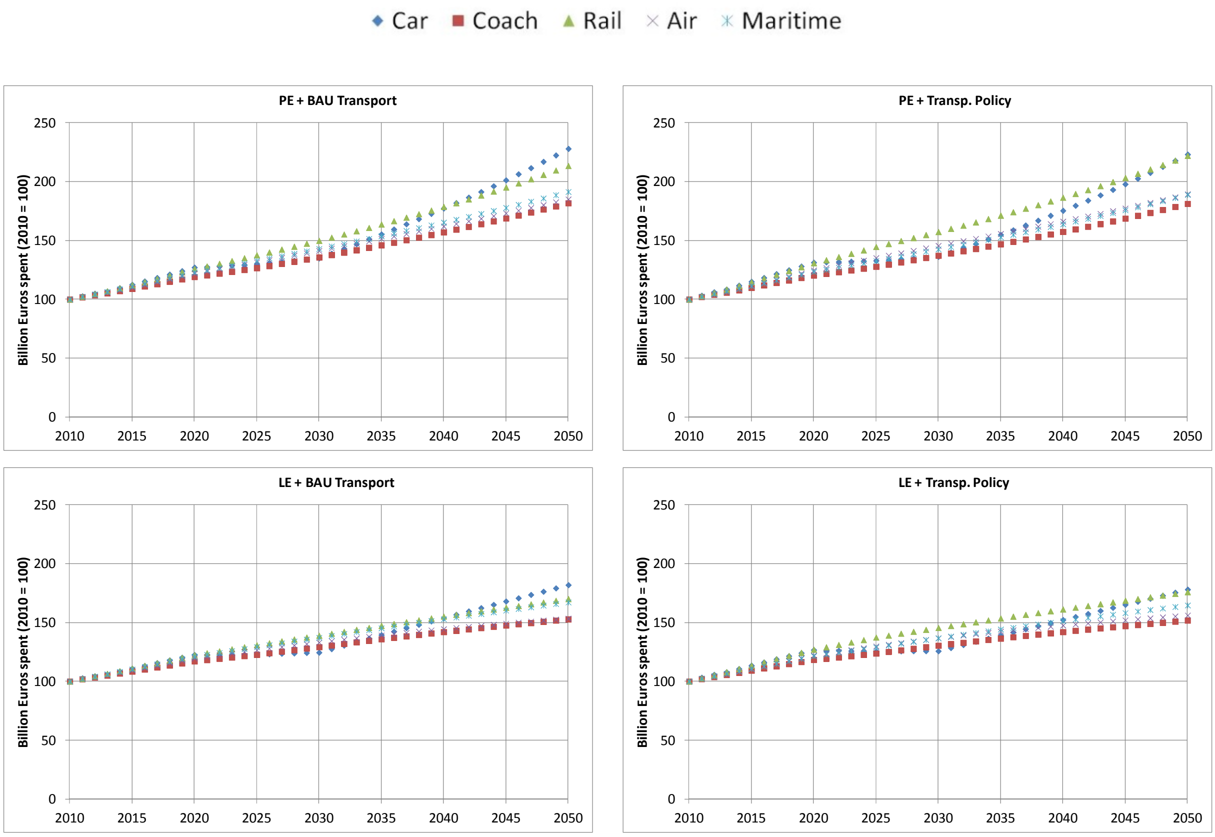


Figure 7-16 Development of user expenditure relative to base year in scenarios PE + LE

Table 7-6 User expenditure of long-distance transport

		User expenditure of transport (billion € / a)					
		Baseline	Base + Transp. Policy	PE + BAU Transport	PE + Transp. Policy	LE + BAU Transport	LE + Transp. Policy
Cars	2010	37.67	37.67	37.67	37.67	37.67	37.67
	2030	49.50	49.94	50.84	51.33	46.93	47.38
	2050	79.08	77.34	85.89	84.06	68.53	67.08
Coaches	2010	8.58	8.58	8.58	8.58	8.58	8.58
	2030	11.38	11.49	11.65	11.78	11.09	11.20
	2050	14.34	14.25	15.60	15.56	13.12	13.04
Rail	2010	11.17	11.17	11.17	11.17	11.17	11.17
	2030	16.12	16.90	16.74	17.58	15.52	16.25
	2050	21.29	22.08	23.84	24.80	19.00	19.65
Air	2010	62.63	62.63	62.63	62.63	62.63	62.63
	2030	85.85	88.33	88.52	91.21	83.35	85.65
	2050	105.41	107.53	115.94	118.64	96.10	97.79
Maritime	2010	7.40	7.40	7.40	7.40	7.40	7.40
	2030	10.45	10.42	10.57	10.55	10.15	10.12
	2050	13.56	13.36	14.16	13.98	12.37	12.18
Total	**2010**	**127.44**	**127.44**	**127.44**	**127.44**	**127.44**	**127.44**
	2030	**173.29**	**177.08**	**178.33**	**182.45**	**167.04**	**170.60**
	2050	**233.68**	**234.56**	**255.43**	**257.03**	**209.11**	**209.74**

Figure 7-17 to Figure 7-21 show the development of use expenditure individually for each mode.

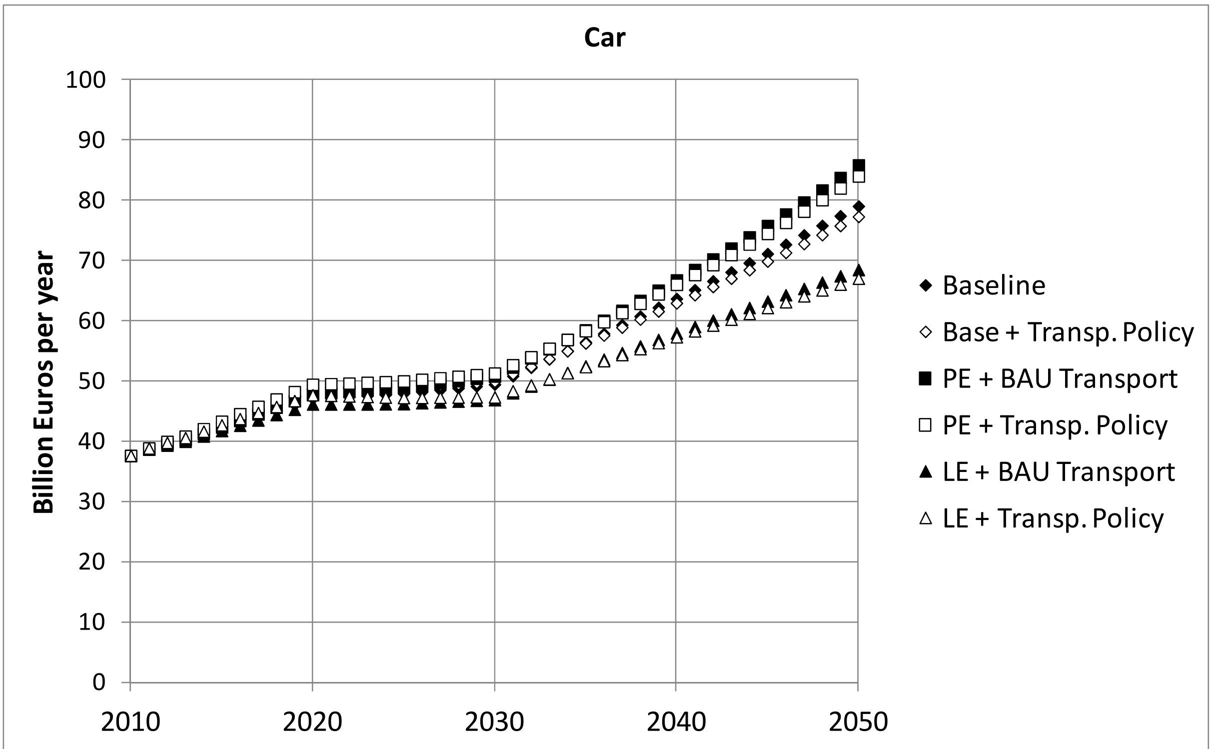


Figure 7-17 Development of user expenditure of car transport

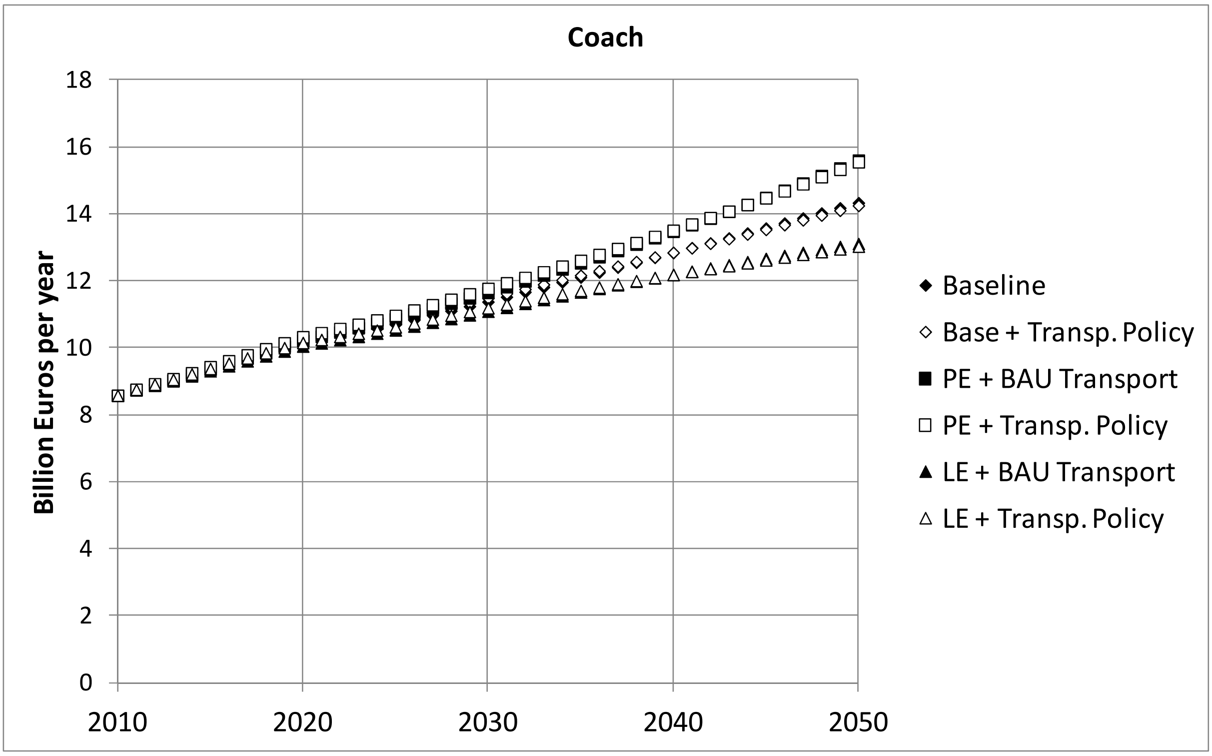


Figure 7-18 Development of user expenditure of coach transport

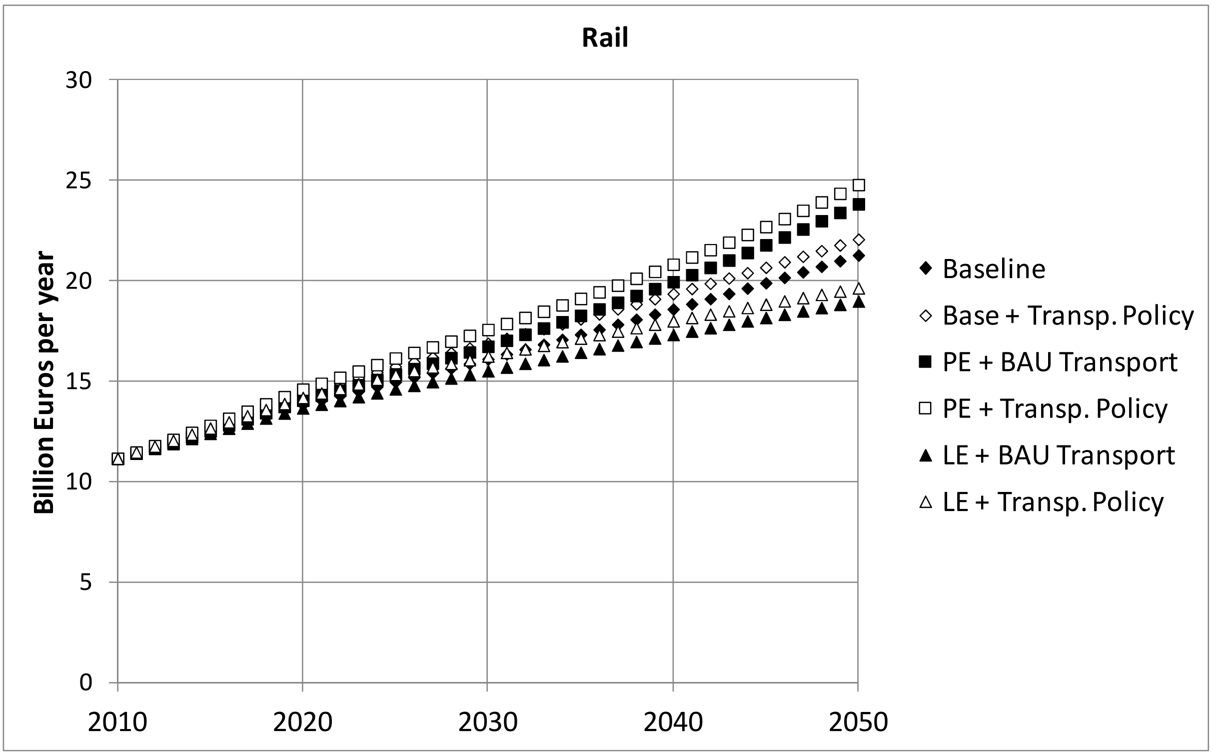


Figure 7-19 Development of user expenditure of rail transport

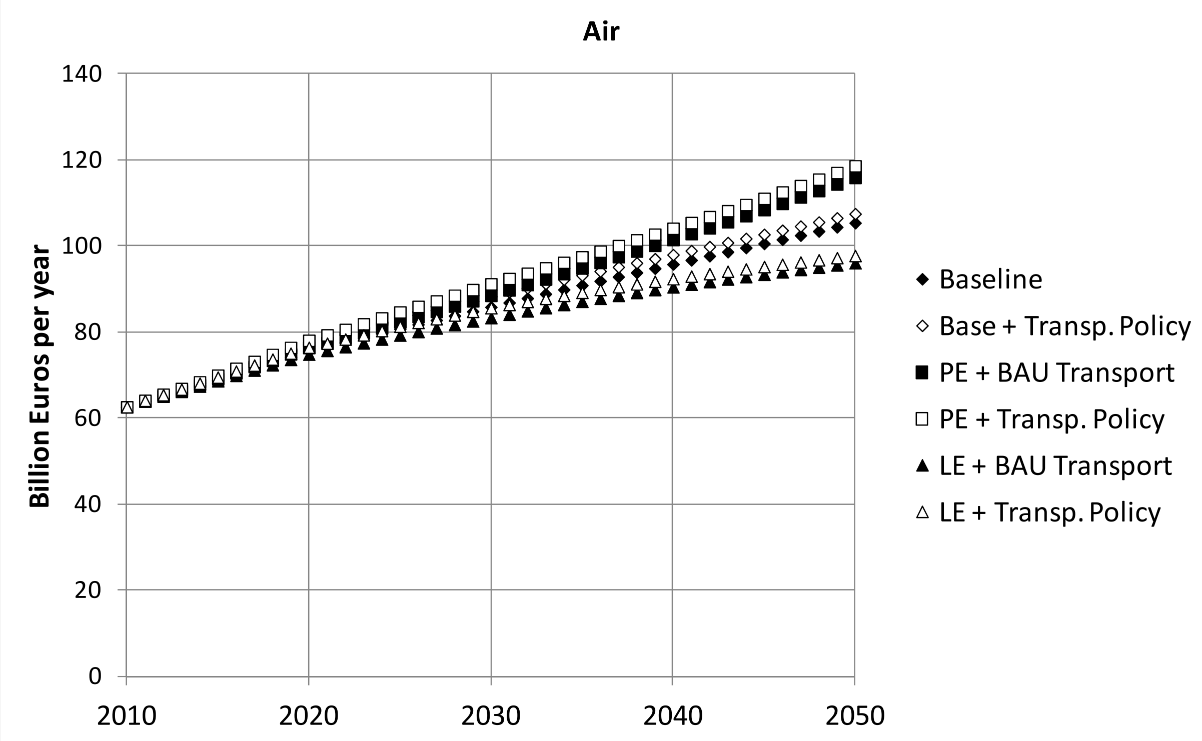


Figure 7-20 Development of user expenditure of air transport

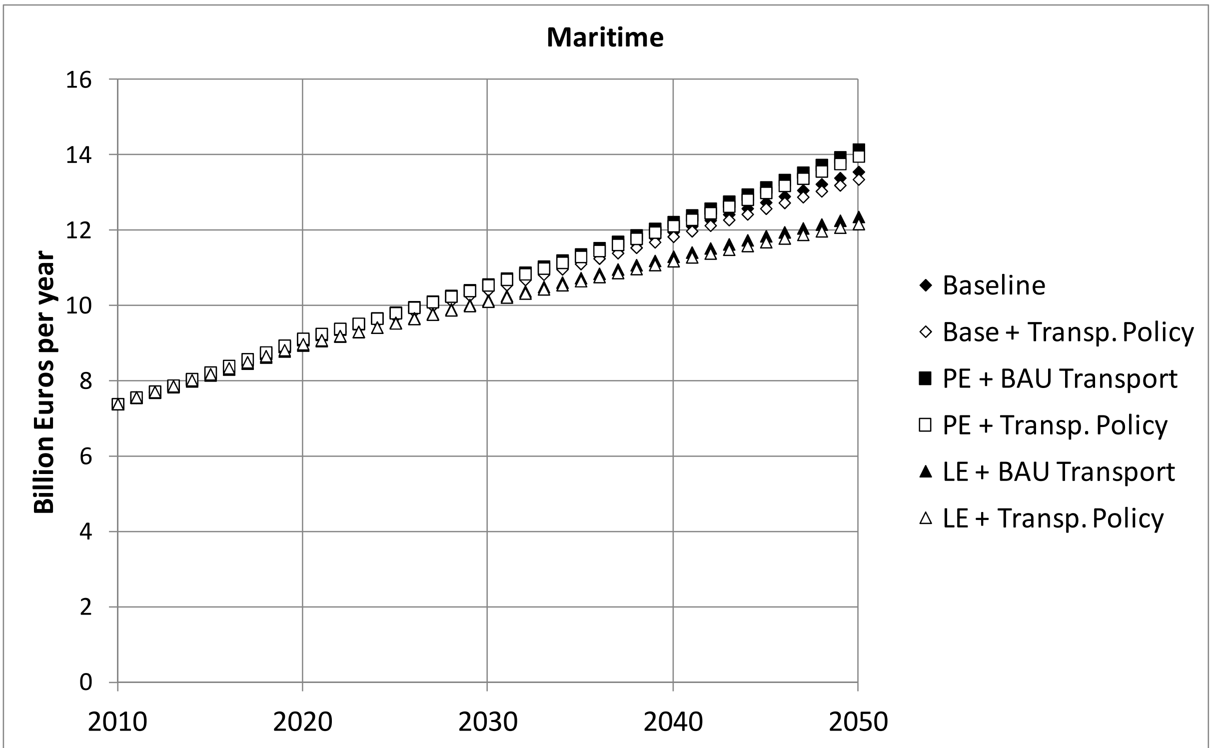


Figure 7-21 Development of user expenditure of maritime transport

Looking at the figures, it is clear again that for all modes PE produces the highest expenditure and LE the lowest. Furthermore, it is obvious that the Transport Policy has no impact on the expenditure for rail and air and hardly any on that for car usage, while it reduces expenditure for coach and even more so for maritime usage. For car usage, population effects are the dominant factor, outweighing the reduction in car ownership per person. More generally, the total expenditure is driven by population changes, while expenditure for business trips is driven by GDP.

Table 7-7 summarises the various values again per person, and the picture is again very similar to the one for time spent on transport with air in the clear lead, followed by car and then rail, coach and maritime. In the wider context of personal expenditure, a budget of anywhere between 412 and 437 € per annum for long-distance trips in 2050 is not insignificant, but taken as the average of between € 138 per trip and person for LE and € 133 for PE is for most households not too much of an obstacle to travel. Moreover, a difference of 25 €/a between the lowest and the highest value for the total annual budget is certainly not anything that would change any passenger's decision whether to make a trip or not. However, it is worth remembering that the calculation of per person expenditure includes the population which is not doing any long-distance travel at all as well as population in less well off countries with very low holiday trip rates, so an average of over € 400 includes many people who pay very high prices for a single trip as well as others who make many more than just three ling-distance trips per year.

Table 7-7 Long-distance transport expenditure for holiday and business per person and mode

		Transport user expenditure per person and mode (€/a)					
		Baseline	Base + Transp. Policy	PE + BAU Transport	PE + Transp. Policy	LE + BAU Transport	LE + Transp. Policy
Cars	2010	73	73	73	73	73	73
	2050	146	143	146	143	135	132
Coaches	2010	17	17	17	17	17	17
	2050	27	26	27	26	26	26
Rail	2010	22	22	22	22	22	22
	2050	39	41	40	42	37	39
Air	2010	122	122	122	122	122	122
	2050	195	199	197	202	189	193
Maritime	2010	14	14	14	14	14	14
	2050	25	25	24	24	24	24
Total	**2010**	**248**	**248**	**248**	**248**	**248**	**248**
	2050	**432**	**434**	**434**	**437**	**412**	**413**

Figure 7-22 shows the differences between the transport expenditure in different countries, this time not per person, but per household. In 2010 Luxembourg is well ahead, followed by Cyprus, Norway, Ireland and Switzerland. At the very bottom are, all with expenditure of under € 300 per household, Lithuania, Bulgaria, Portugal, Estonia and Latvia, and this general picture changes very little over time and in the different scenarios. The ranking of countries is very much fixed and not much affected by the underlying socio-demographic nor economic changes nor the Transport Policy. The reason for this is that on the one hand the GDP and income ranking among the 29 countries is pretty stable and on the other hand that it assumed that all countries are affected more or less uniformly by the Transport Policy. One notable exception at the top end is Cyprus, which overtakes Luxembourg and takes first place in the PE scenarios, both with and without Transport Policy with 2,205 and 2,259 €/a respectively. Partly this is reflecting the fact that flights from its peripheral location are becoming cheaper, while its population grows and becomes more affluent, which in turn increases demand. Nevertheless the main driver is changing household size. On a per person basis Cyprus continues to stay behind Luxembourg and Norway and is overtaken by Switzerland in the later years. At the bottom end, in the LE scenarios with Transport Policy, Poland slips down the scale from € 311 and 6th lowest place in 2010 to the bottom with € 383; the reason for this are changes in the demographics of the Polish population. Poland has a declining population in the Baseline with an increase in the older age cohort which results in a decrease in the average trip rates.

Overall, from 2010 to 2050, there is a diverging trend, with the spread between the lowest and the highest value increasing from about € 1,200 to about € 1,900. The Transport Policy has the tendency to slightly decrease travel expenditure in the countries which are wealthier while it slightly increases it in the less wealthy countries.

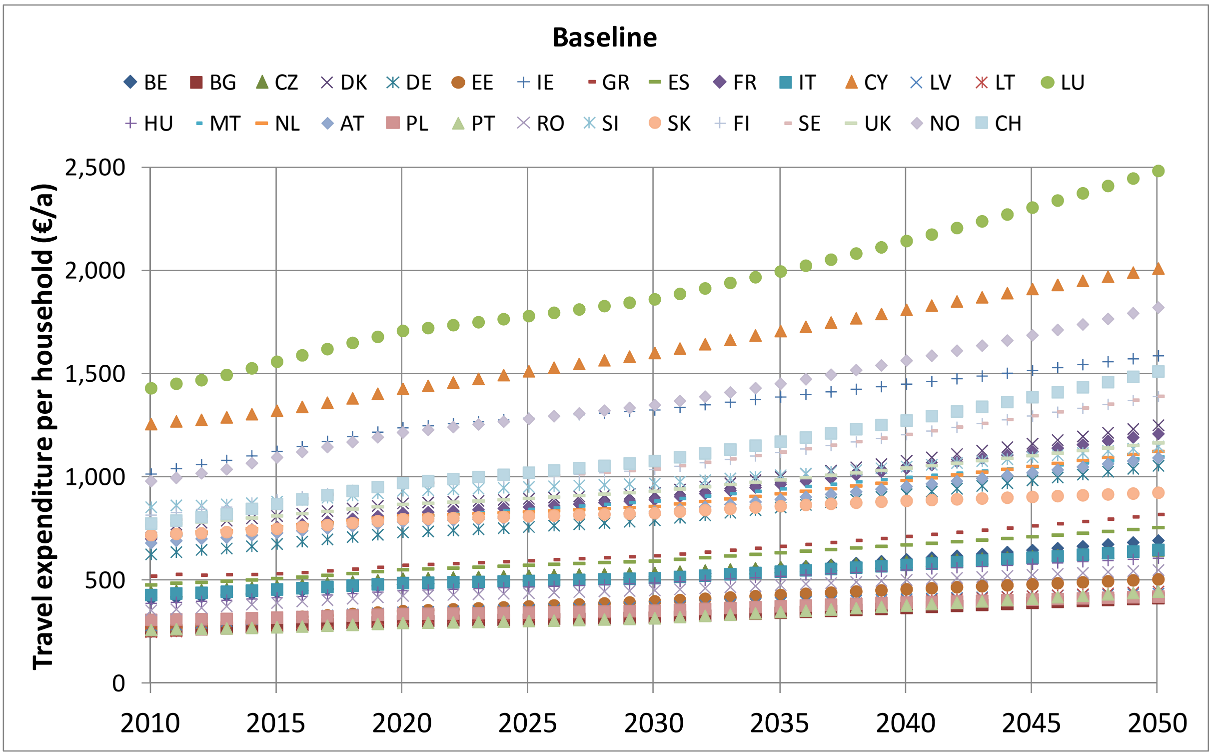


Figure 7-22 Development of transport user expenditure per household in scenario Baseline

7.4 ENVIRONMENTAL INDICATORS

7.4.1 Fuel consumption

Figure 7-26 shows the total fuel consumption in the six scenarios.

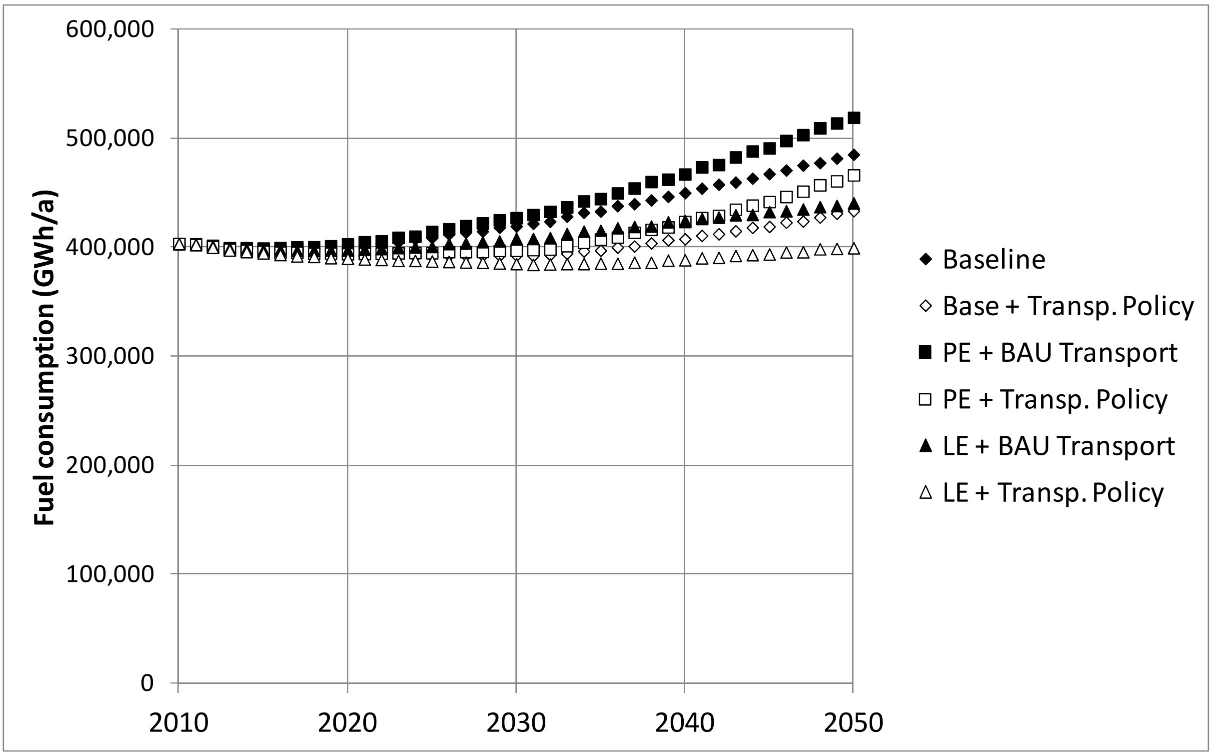


Figure 7-23 Development of total fuel consumption in the six scenarios

In all scenarios there is an initial decline in fuel consumption, but at some stage between 2015 and 2035 it is rising again, and the time when the rise starts also indicates how far it will have risen by 2050. Without the Transport Policy, the rise is 9% for LE, 20% for the Baseline and 29% for PE compared to 2010. This is driven by the development of the population and the related development of passenger kilometres as well as assumptions concerning fuel efficiency.

The Transport Policy reduces this to 7% in the Baseline and 16% in PE, and only the combination of a Lagging Europe with the Transport Policy reduces the consumption in 2050 by just 1% against 2010. This relatively large effect of the Policy stems mainly from the assumptions concerning developments in fuel efficiency and propulsion technologies rather than changes in demand and mode choice.

Hence fuel efficiency is a key factor for both differences between the three types of scenarios and between BAU and the Transport Policy as shown in Figure 7-24 for the six scenarios in terms of fuel consumption over distance travelled.

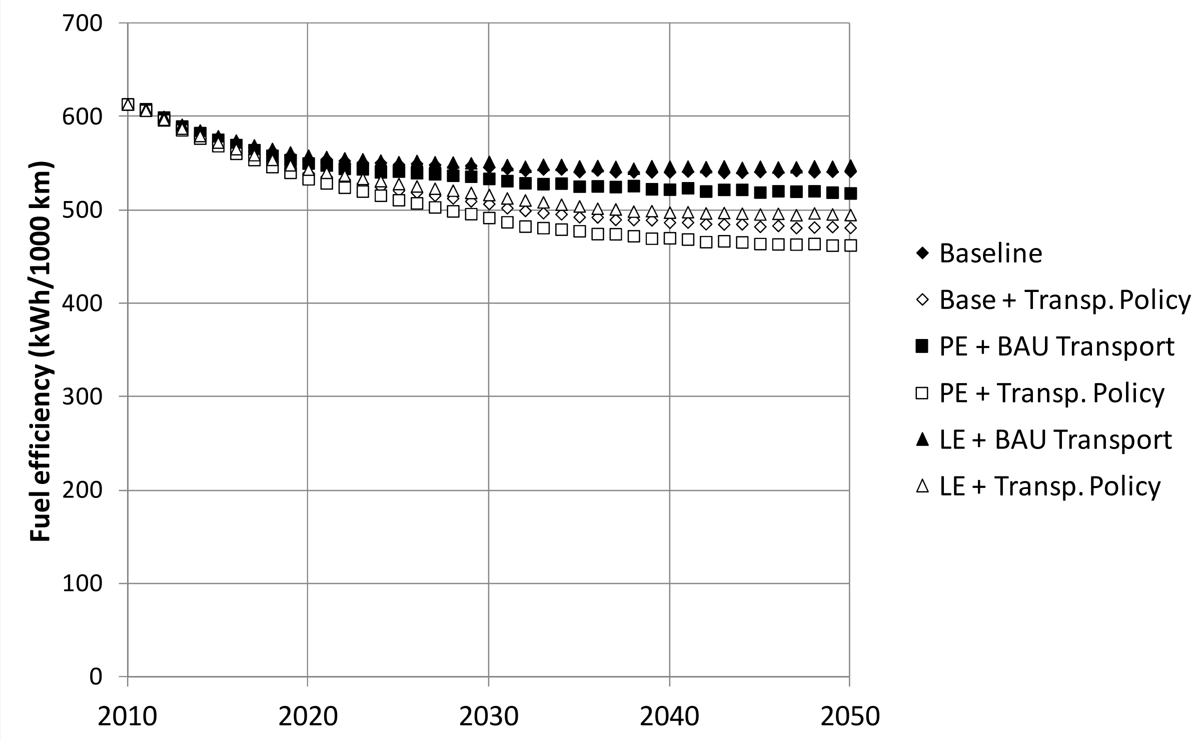


Figure 7-24 Fuel efficiency per kilometre in the six scenarios

Fuel efficiency increases most in Prospering and least in Lagging Europe, mainly due to the effect of emission factor assumptions, but to a certain extent also to the effect of mode and distance shifts, and increases further by another 10% to 11% with the introduction of the Transport Policy which involves even higher fuel efficiency.

In general, it is assumed that the majority of the technological improvements concerning efficiency will take place before 2030. Hence the progress concerning energy efficiency is slowing down or even stagnating (LE without Policy) in the later years.

Figure 7-25 shows the fuel efficiency by trip rather than by kilometre. The general picture is similar, but the lengthening of trips by 2050 reduces the improvement per trip and in LE and the Baseline without the Policy even reverses the development after around 2035, so that for these scenarios fuel efficiency per trip even declines again for reasons related to the air mode as shown later on.

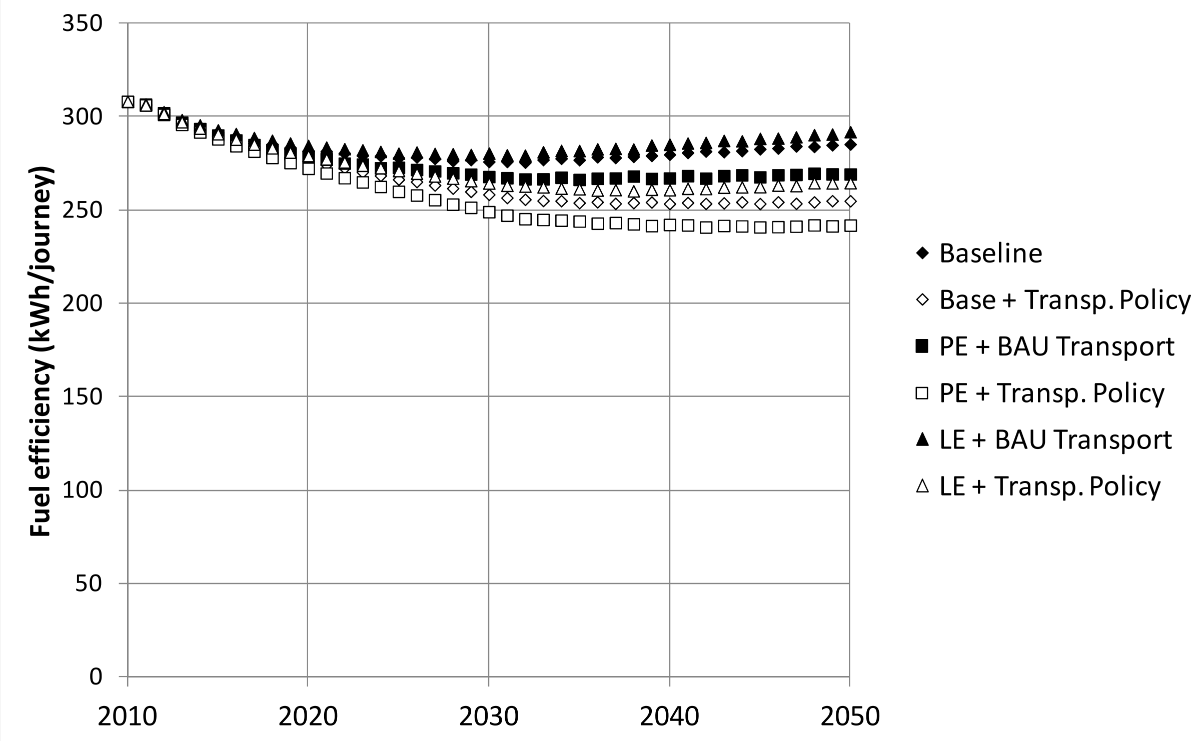


Figure 7-25 Fuel efficiency per trip in the six scenarios

Figure 7-26 uses two different scales to show the total fuel consumption by mode, because the consumption of two of the modes is on a totally different level than that of the remaining three. The axis on the left side is relevant for the modes coach, rail and maritime while the axis on the right side is relevant for the modes car and air.

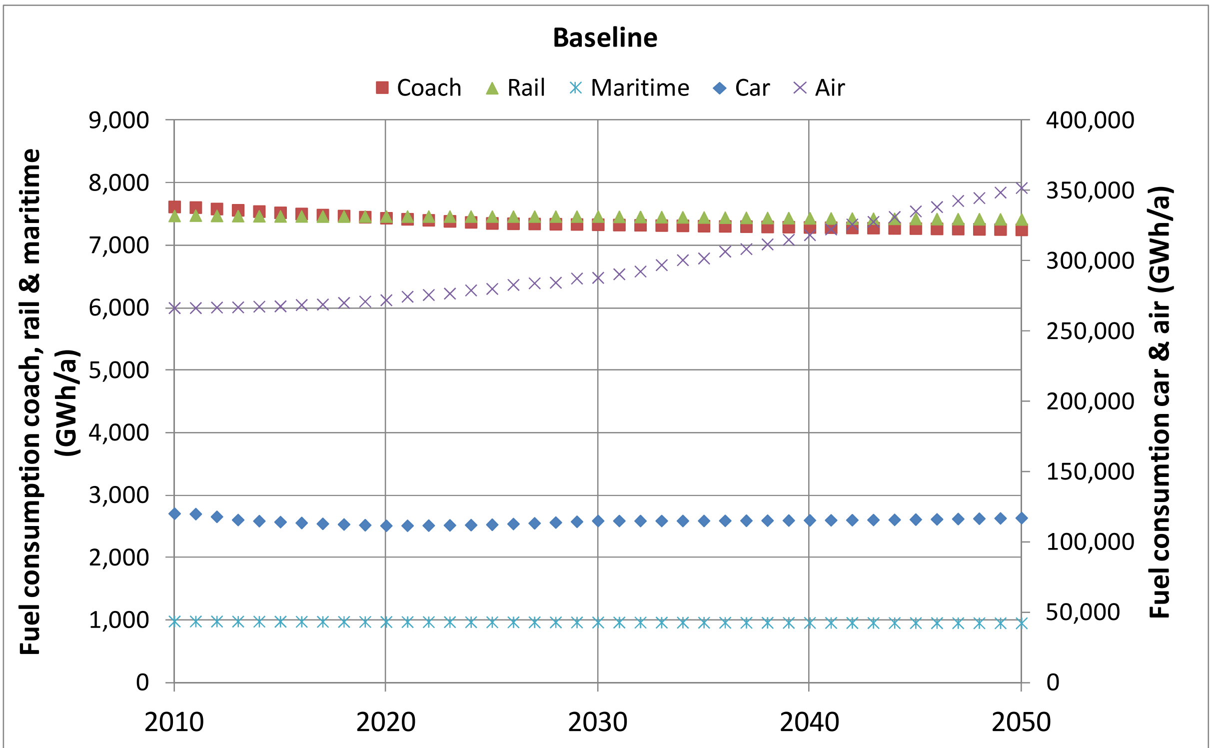


Figure 7-26 Fuel consumption in GWh/a by mode Baseline scenario

What becomes apparent is that the one mode that drives the total fuel consumption up is air travel, which by 2050 is 32% higher than in 2010. The consumption of all other modes declines by between 1% and 5%, but this is by far not enough to compensate for the air travel consumption.

Figure 7-27 compares the consumption per mode for each of the six scenarios, and shows that the increase in fuel consumption for air travel not only dominates the Baseline but all BAU scenarios. Only the reduction of car consumption through the Transport Policy manages to counteract that at least to some extent in the Baseline and PE, and only in PE is sufficient to reduce the total consumption as already shown before. It should be noted in this context that air fuel consumption is reduced by transport policies, although the different scales for the two PE graphs make it hard to see that actually air with transport policy is around 125 versus 140 without in 2050.

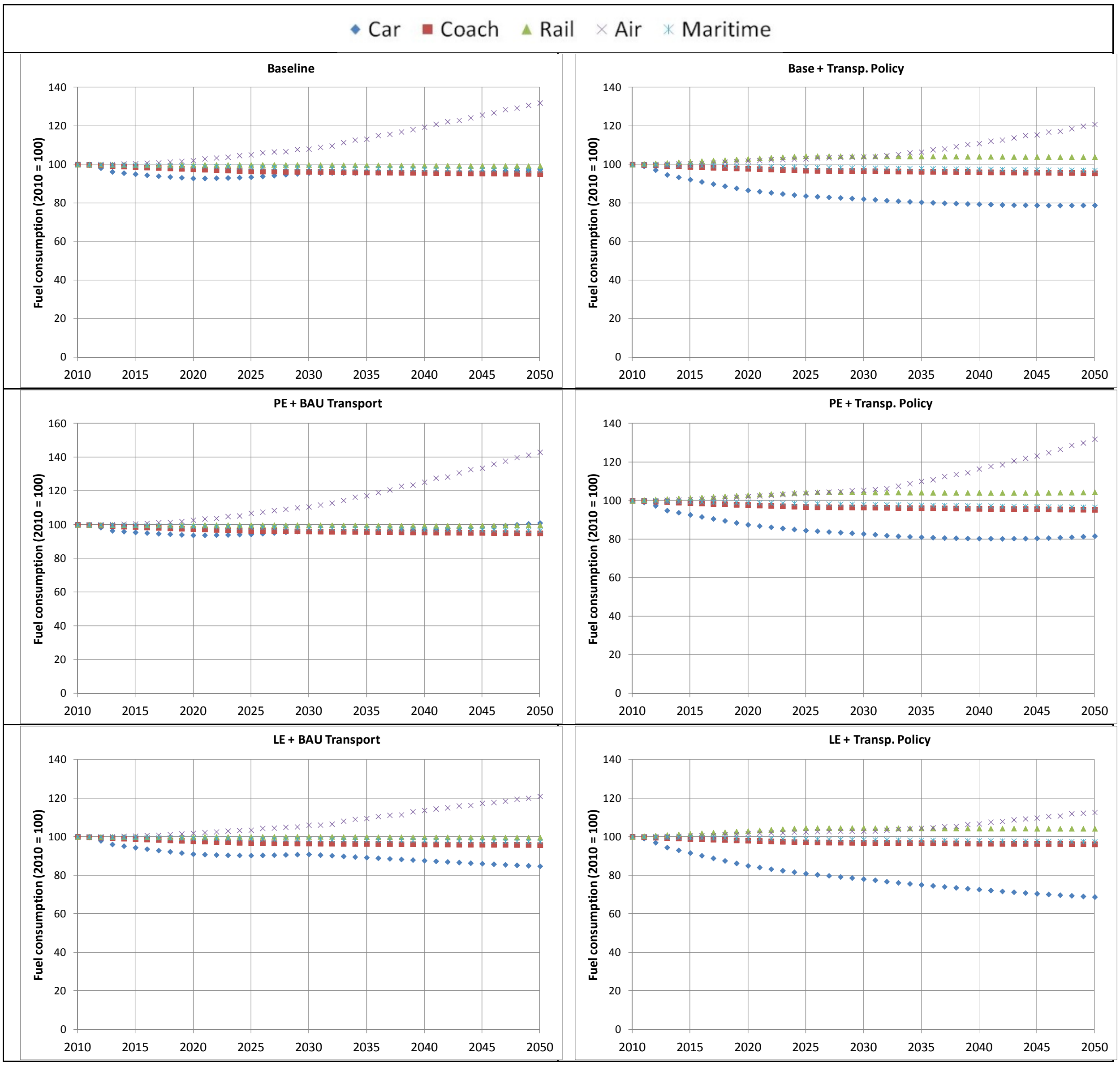


Figure 7-27 Total fuel consumption by mode relative to 2010

A look on the orders of magnitude in Table 7-8 makes it even clearer than Figure 7-26 that whatever changes take place for coaches, rail or maritime travel will only have the most marginal impact on the overall consumption which is totally dominated by the changes in air and car travel and only policies related to them can make a real difference. It also shows how fuel efficient maritime travel is, with its total consumption being only around 1/8th of that of rail and coach in spite of the fact that they have serve similar passenger kilometres.

Table 7-8 Fuel consumption per mode in each scenario

		Fuel consumption (GWh / a)					
		Baseline	**Base + Transp. Policy**	**PE + BAU Transport**	**PE + Transp. Policy**	**LE + BAU Transport**	**LE + Transp. Policy**
Cars	2010	120,472	120,472	120,472	120,472	120,472	120,472
	2050	117,366	95,007	121,786	98,353	102,084	82,838
Coaches	2010	7,621	7,621	7,621	7,621	7,621	7,621
	2050	7,255	7,284	7,238	7,267	7,299	7,328
Rail	2010	7,477	7,477	7,477	7,477	7,477	7,477
	2050	7,421	7,773	7,457	7,807	7,446	7,792
Air	2010	266,800	266,800	266,800	266,800	266,800	266,800
	2050	352,211	322,508	381,733	352,051	322,903	300,567
Maritime	2010	985	985	985	985	985	985
	2050	956	956	952	951	961	960
Total	**2010**	**403,356**	**403,356**	**403,356**	**403,356**	**403,356**	**403,356**
	2050	**485,210**	**433,528**	**519,165**	**466,429**	**440,693**	**399,486**

7.4.2 Greenhouse Gas Emissions

Figure 7-28 shows the total Greenhouse Gas emissions for all six scenarios. In all scenarios emissions decline until 2030, but without the Transport Policy they increase again after that, and in the case of the Baseline they are nearly back to 2010 levels. The fact that the Baseline levels are 5% higher than those for a Prospering Europe in spite of the fact that PE has 12% more passenger kilometres than the Baseline is due to the higher emission standards in the PE scenario.

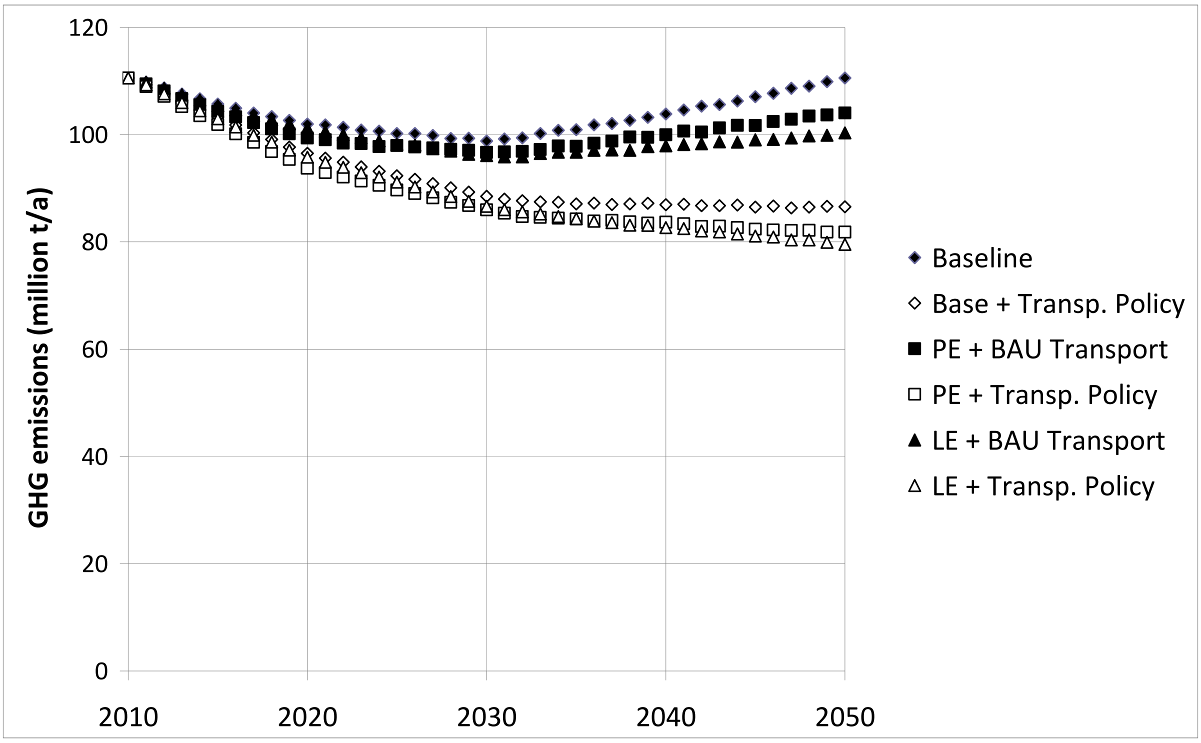


Figure 7-28 Development of Greenhouse Gas emissions in the six scenarios

Only with the Transport Policy option there are significant reductions achieved, with a 22% decrease for the Baseline, 26% for PE and 28% for LE. This is largely due to the changes in emission factors assumed as part of the transport policy. All three results surpass the EU targets for 2030, but are far below the EU's long-term GHG emission target of reducing transport emissions by 67% by 2050. The differences between the three base scenarios are relatively small, so even much bigger changes in the socio-demographics or the economy than those assumed in these scenarios would not change the picture significantly, and only much more stringent policy changes could bring the GHG emissions closer to the EU targets. However, as the 2030 scenarios in chapter 4 have already shown, even that will not be sufficient to meet these targets and what is really needed to achieve anything like the EU targets will have to be a step change in propulsion technology.

A more detailed analysis of the GHG emissions by mode for each of the scenarios (Figure 7-29) explains some of the background to these figures, but does nothing to change the findings from the global figures. A Prospering Europe reduces emissions from all modes except the car, because the growth in population and increased GDP cancels out the impact of the improved emission factors. The Transport Policy has the biggest impact on GHG emissions from air travel and to a lesser extent to those from car and rail travel, but none of these changes are anywhere near the step change needed to achieve EU targets.

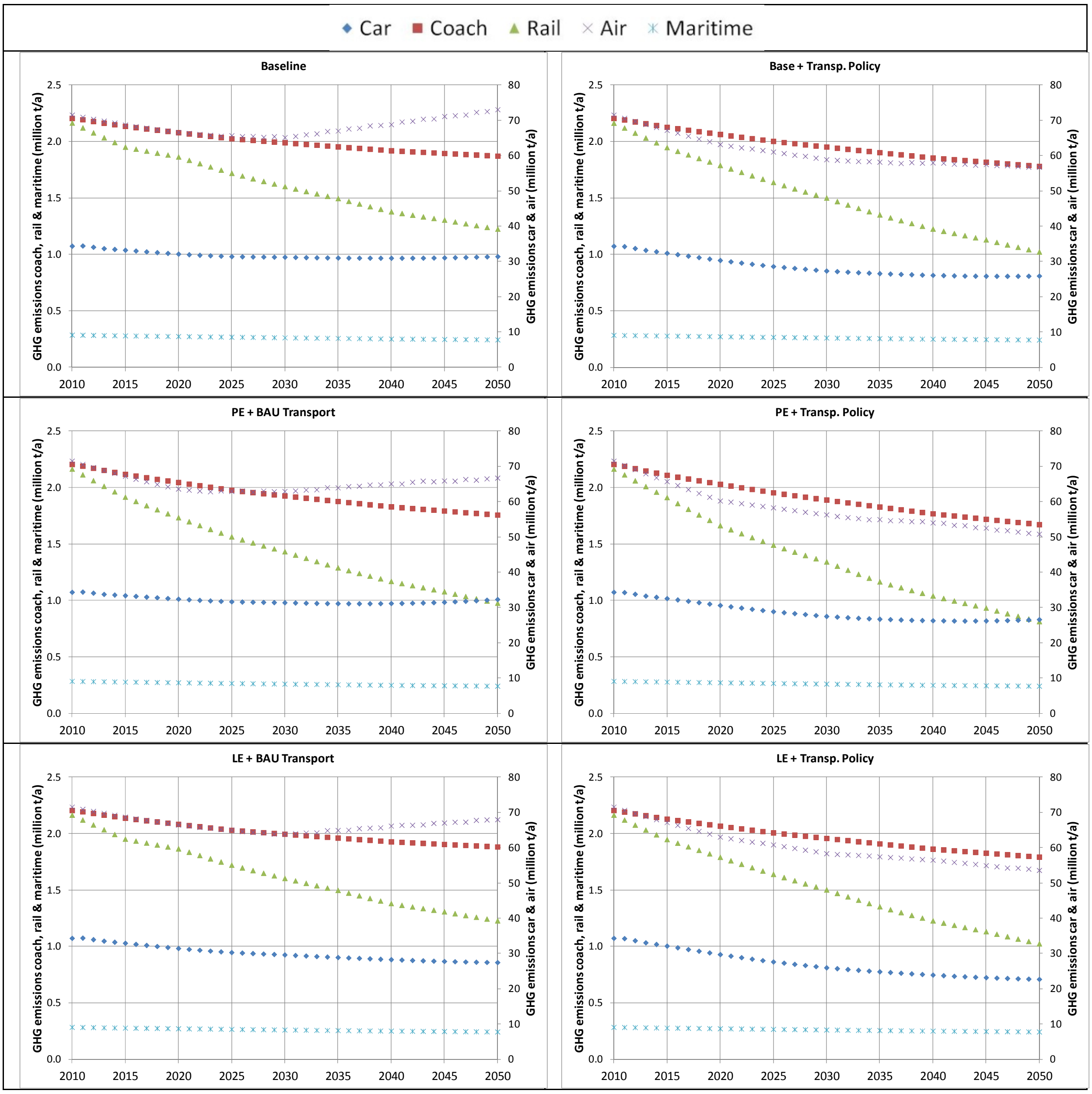


Figure 7-29 Greenhouse gas emissions by mode

Finally, Table 7-9 lists the figures for each mode and scenario in detail for completeness since the GHG emissions are at the core of the ORIGAMI project, but the table does not elicit any further insights over and above those discussed already.

Table 7-9 Greenhouse gas emissions per mode in each scenario

		Greenhouse gas emissions (million tons / a)					
		Baseline	**Base + Transp. Policy**	**PE + BAU Transport**	**PE + Transp. Policy**	**LE + BAU Transport**	**LE + Transp. Policy**
Cars	2010	34.4	34.4	34.4	34.4	34.4	34.4
	2030	31.2	27.4	31.4	27.5	29.7	26.0
	2050	31.4	25.9	32.3	26.6	27.5	22.7
Coaches	2010	2.2	2.2	2.2	2.2	2.2	2.2
	2030	2.0	2.0	1.9	1.9	2.0	2.0
	2050	1.9	1.8	1.8	1.7	1.9	1.8
Rail	2010	2.2	2.2	2.2	2.2	2.2	2.2
	2030	1.6	1.5	1.4	1.3	1.6	1.5
	2050	1.2	1.0	1.0	0.8	1.2	1.0
Air	2010	71.6	71.6	71.6	71.6	71.6	71.6
	2030	65.2	58.9	62.9	56.3	63.9	58.4
	2050	73.1	56.8	66.7	50.9	68.0	53.6
Maritime	2010	0.3	0.3	0.3	0.3	0.3	0.3
	2030	0.3	0.3	0.3	0.3	0.3	0.3
	2050	0.2	0.2	0.2	0.2	0.2	0.2
Total	**2010**	**110.6**	**110.6**	**110.6**	**110.6**	**110.6**	**110.6**
	2030	**100.2**	**90.0**	**98.0**	**87.3**	**97.4**	**88.1**
	2050	**107.8**	**85.7**	**102.0**	**80.2**	**98.8**	**79.4**

7.4.3 Particulate Emissions

Figure 7-30 shows the development of the particulate emission in the six scenarios. Particulate matter emissions decrease in all scenarios. In the Baseline the reduction compared to 2010 is stabilising for a time between 2020 and 2030 but starts to decrease again from 2030 onwards. Until about 2030 the trend in the PE and LE scenarios without Policy is very similar. From about 2030 on the effects of changes in demand start to override technological improvements. In PE particulate matter emissions start to increase slightly and are in 2050 about the same level as in the Baseline while in LE decreases are getting stronger, diverging from the other two scenarios. With the Transport Policy in place particulate matter emissions decrease more or less continuously in all scenarios. Again there is a diverging trend in between 2040 and 2050 between Baseline and PE on the one hand and LE on the other hand.

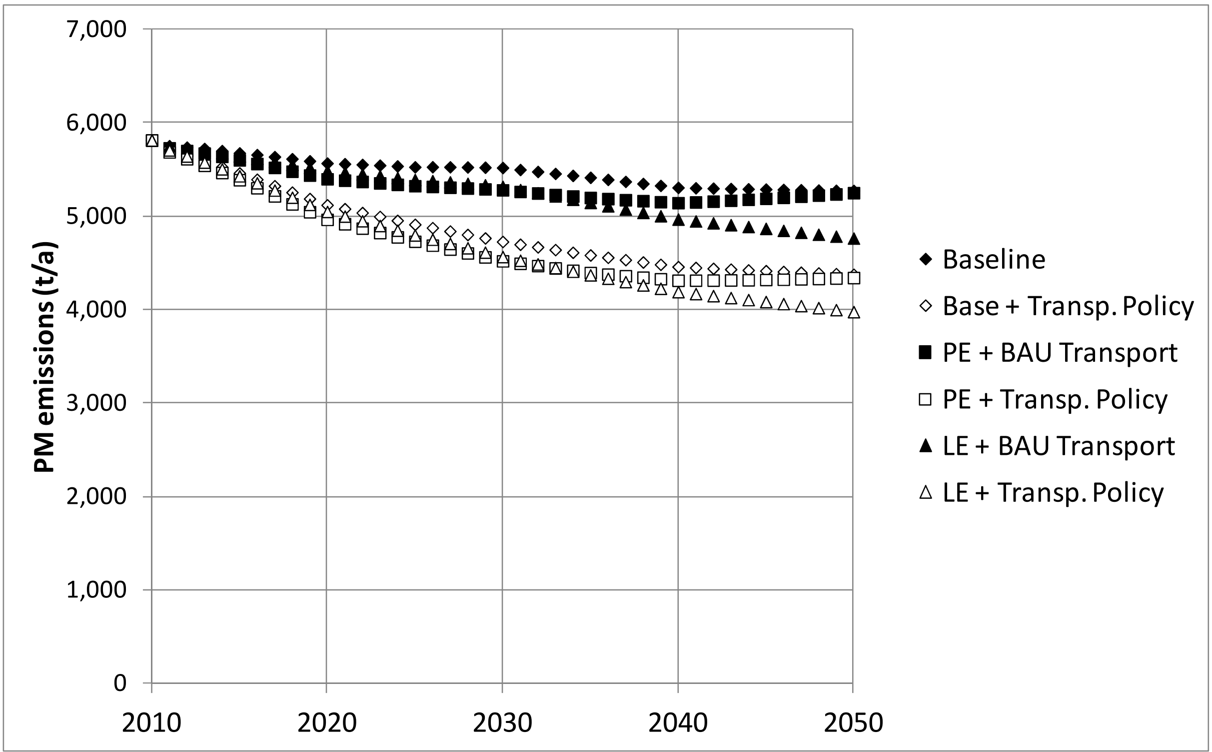


Figure 7-30 Development of particulate emissions in the six scenarios

Table 7-10 and Figure 7-31 show the particulate emissions by mode and scenario. Again for Figure 7-31 it is crucial to note the different scales for coach, rail and maritime on the left, and for car on the right.

The big difference to the GHG emissions is that those were coming to two thirds from air traffic, while there are no particulates coming from this mode, and it is the car which responsible for 69% of all particulates in 2010 and for 74% in the Baseline by 2050. Car emissions are also the strongest factor in shaping the overall particulate emissions, which follow quite closely those of the car, which also increase slightly in PE and by about 15% in LE (again because of the demand effects). The Policy reduces the car emissions by about -20% in Baseline and PE and by about -17% in LE. These very strong reductions are due to the assumptions made about the underlying car fleet. The share of diesel cars is decreasing significantly in all countries except Spain and Slovenia in favour of less polluting alternatives like hybrids, CNG, LPG, electric or hydrogen cars. One of the most extreme cases is Denmark where the share of diesel cars is decreasing from 65% in 2010 to 18% in 2050, while the share of alternative propulsion technologies is increasing from 2% to 71%.

Bus/coach accounts for about 10% of the particulate matter emissions in 2010. The share of the bus/coach particulate matter emissions is nearly the same in 2050, ranging from 9% to 11%. Without Policy absolute particulate matter emissions decrease by about -15% in Baseline and LE and by about -20% in PE. The effect of the Policy is a further reduction of about -5%.

Rail accounts for about 12% of the particulate matter emissions in 2010. By 2050 the share of the rail particulate matter emissions is decreasing to 8% in Baseline and LE and to 6% in PE. Without Policy the decrease in particulate emissions is, both in absolute and in relative terms, by far the strongest for rail with around -40% in Baseline and LE and about -55% in PE. The effect of the Policy is a further reduction of about -8% to -9%. The main reason for the large reduction in rail particulate matter emissions are the scenario assumptions about the electrification of the European rail network. The fleet assumptions stem from the GHG-Transpord project (Fiorello at all. 2012).

Maritime accounts for about 10% of the particulate matter emissions in 2010. The share of the maritime particulate matter emissions stays nearly constant up to in 2050, ranging from 9% to 12%. Absolute maritime particulate matter emissions decrease uniformly by about -15% in all scenarios.

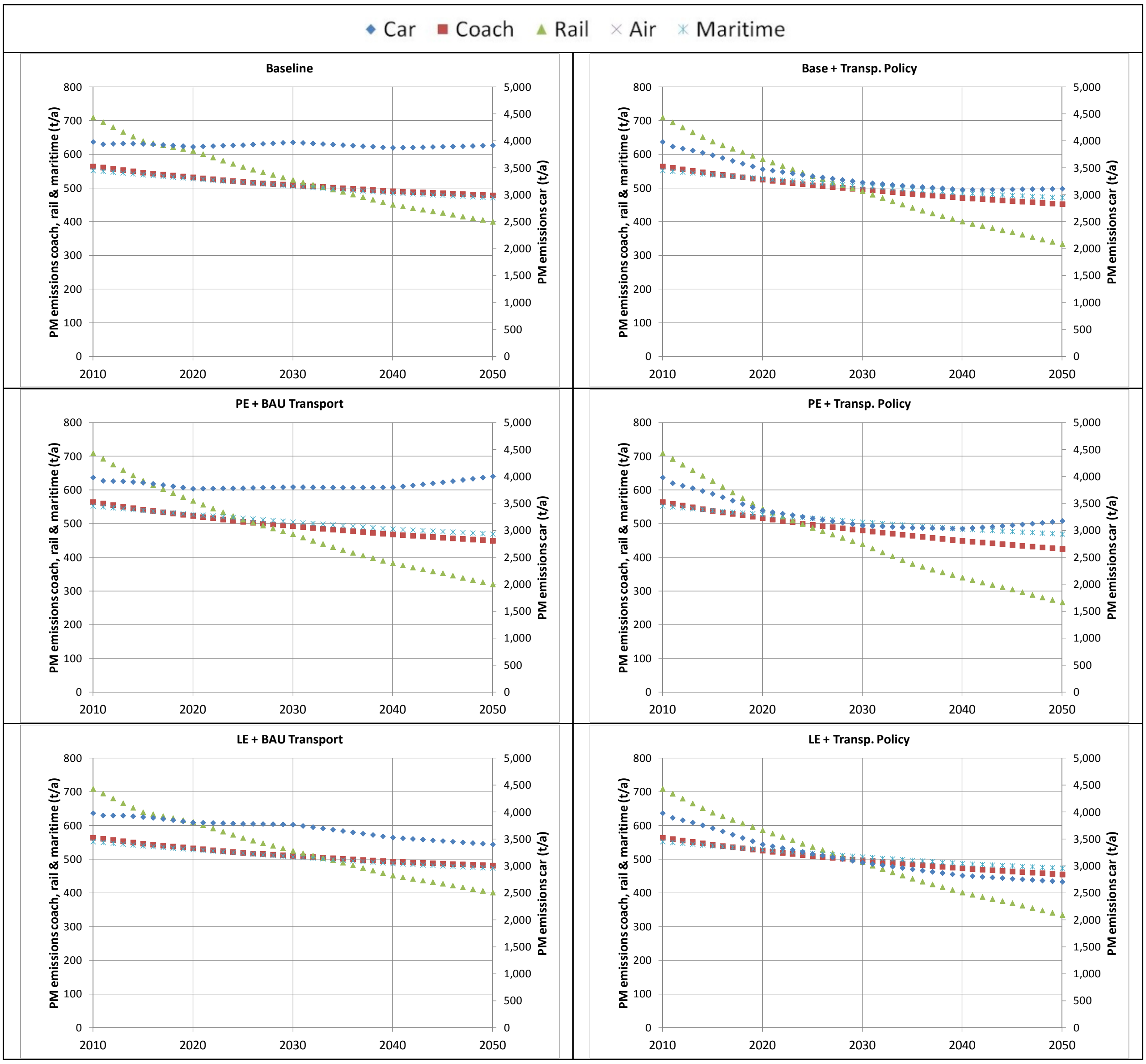


Figure 7-31 Particulate emissions by mode

Table 7-10 Particulate emissions per mode in each scenario

		Particulate emissions (tons / a)					
		Baseline	Base + Transp. Policy	PE + BAU Transport	PE + Transp. Policy	LE + BAU Transport	LE + Transp. Policy
Cars	2010	3,987	3,987	3,987	3,987	3,987	3,987
	2050	3,923	3,118	4,010	3,181	3,406	2,713
Coaches	2010	565	565	565	565	565	565
	2050	479	453	450	425	482	456
Rail	2010	710	710	710	710	710	710
	2050	401	334	321	267	402	335
Air	2010	0	0	0	0	0	0
	2050	0	0	0	0	0	0
Maritime	2010	553	553	553	553	553	553
	2050	472	472	470	470	474	474
Total	**2010**	**5,815**	**5,815**	**5,815**	**5,815**	**5,815**	**5,815**
	2050	**5,275**	**4,378**	**5,251**	**4,343**	**4,765**	**3,978**

So, in summary, the biggest absolute and relative decrease in particulate emissions in the three BAU scenarios from 2010 to 2050 comes from rail, based on the assumptions made about the electrification of rail. However, the biggest absolute decrease overall comes from the Transport Policy, and therein for the cars: the reduction for cars in 2050 from BAU to With Policy in the Baseline is -805 tons /a, i.e. significantly more than the 710 tons/a that the whole rail sector contributed in 2010, and the total reduction from 2010 to LE with Policy is even -1,274 tons/a due the change in the car fleet detailed before.

7.5 SOCIAL WELFARE

The only indicator for social welfare available from the LUNA modelling are the leisure trips for the different age groups as an expression of affluence and well-being.

Figure 7-32 shows the development for the three types of scenarios for the three age bands 0-19, 20-64 and 65+ years. The number of leisure trips is not affected by the Transport Policy, hence there are only the three lines per age group.

The first thing to note is that the number of leisure trips increases steadily over time in all scenarios. Second, in the base year the age group 20-64 years has the highest holiday trip rate followed by the age group 0-19 years, and the age group 65+ years has the lowest trip rate. This does not essentially change over the next 40 years. What increases steadily over time is the gap between what would be happening in a Prospering Europe with the highest growth rate, The Baseline in the middle and a Lagging Europe at the bottom. The differences in growth rates can be explained by GDP and associated disposable incomes.

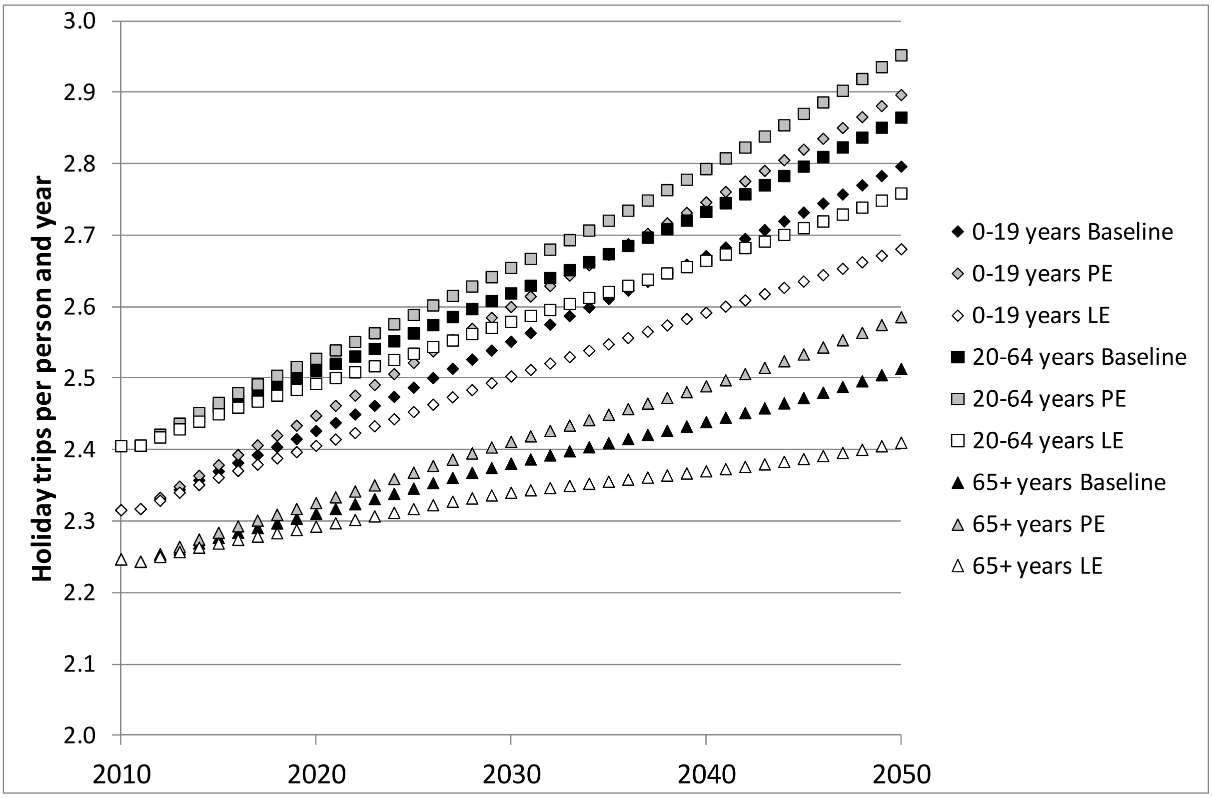


Figure 7-32 Annual leisure trips per age group across Europe

Table 7-11 lists the trips and the differences between age groups and scenarios. It shows obviously the same patterns of PE creating more trips than Baseline and that more than the LE, but what becomes here clearer than from the figure is the disparity between age groups. It is young peoples' travel that grows fastest in relative, but also in absolute terms. They start off with 0.09 less of an annual trip than the 20-64 years old in 2010 and by 2050 reduce the gap slightly to 0.05 of a trip in Baseline and PE. In percentage terms their growth is between 1% ahead in LE and 2% in the

Baseline and PE. This is due to changes in the household types of the middle aged group, where the share of people with lower income per head is increasing.

More concerning is the development for the over 65 year olds. In any of the scenarios with more people getting older in a good state of health, especially in Prospering Europe, one should have expected an over proportionate growth in leisure travel by older people. Instead they are lagging more and more behind, gaining just 0.27 of a trip per year in the Baseline, 0.34 of a trip in PE and even only 0.16 of a trip in LE, equating to growth rates of just between 7% and 15%, just around half of that of young people. This inequitable outcome goes back to differences in the development of car availability which influences trip rates and which does not grow at the same pace as their longevity.

Table 7-11 Changes in leisure trips for the different age groups and scenarios

		Trips/a		Trip difference	
Age group	**Policy**	**2010**	**2050**	**absolute**	**relative**
0-19 years	Baseline	2.32	2.80	0.48	21%
	PE	2.32	2.90	0.58	25%
	LE	2.32	2.68	0.37	16%
20-64 years	Baseline	2.41	2.87	0.46	19%
	PE	2.41	2.95	0.55	23%
	LE	2.41	2.76	0.35	15%
65+ years	Baseline	2.25	2.51	0.27	12%
	PE	2.25	2.59	0.34	15%
	LE	2.25	2.41	0.16	7%

For the investigation of the differences in the number of trips undertaken the countries have been grouped into three, vaguely attributed to Western, Central and Eastern Europe (Table 7-12), with Luxembourg omitted from the list, because for unknown reasons it created some irregularities that were not credible. The reason for using three groups instead of showing all countries in one figure was to avoid overcrowding of the figures and increase their readability, but the allocation of countries was somewhat arbitrary, although the following analysis shows that marked differences between the averages for east and west.

Table 7-12 Country groups for the investigation of trip rates

Western Europe	Central Europe	Eastern Europe
Ireland	Norway	Finland
UK	Sweden	Estonia
Belgium	Denmark	Lithuania
The Netherlands	Germany	Latvia
France	Switzerland	Poland
Spain	Austria	Hungary
Portugal	Czech Republic	Bulgaria
	Slovakia	Romania
	Slovenia	Greece
	Italy	Cyprus
	Malta	

Figure 7-33 to Figure 7-35 show the holiday trip rates for the three country groups for each of the three age bands. They show that for every age group the average holiday trip rate for people from Central Europe is about double of that of those from Eastern Europe, and for those from Western Europe is roughly another 10% higher. Differences between the three sets of scenarios are quite small in each of the three figures, most of all for Eastern Europe.

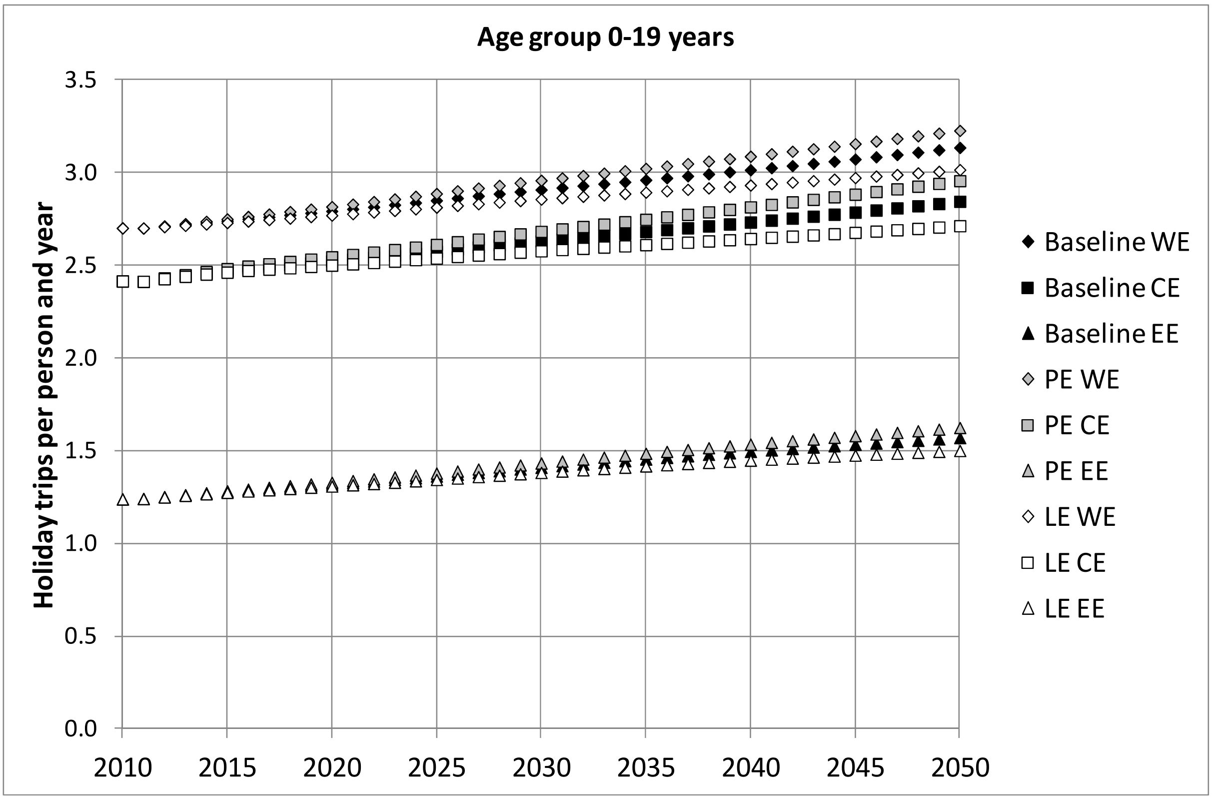


Figure 7-33 Annual holiday trips per person and year age group 0-19 years by region

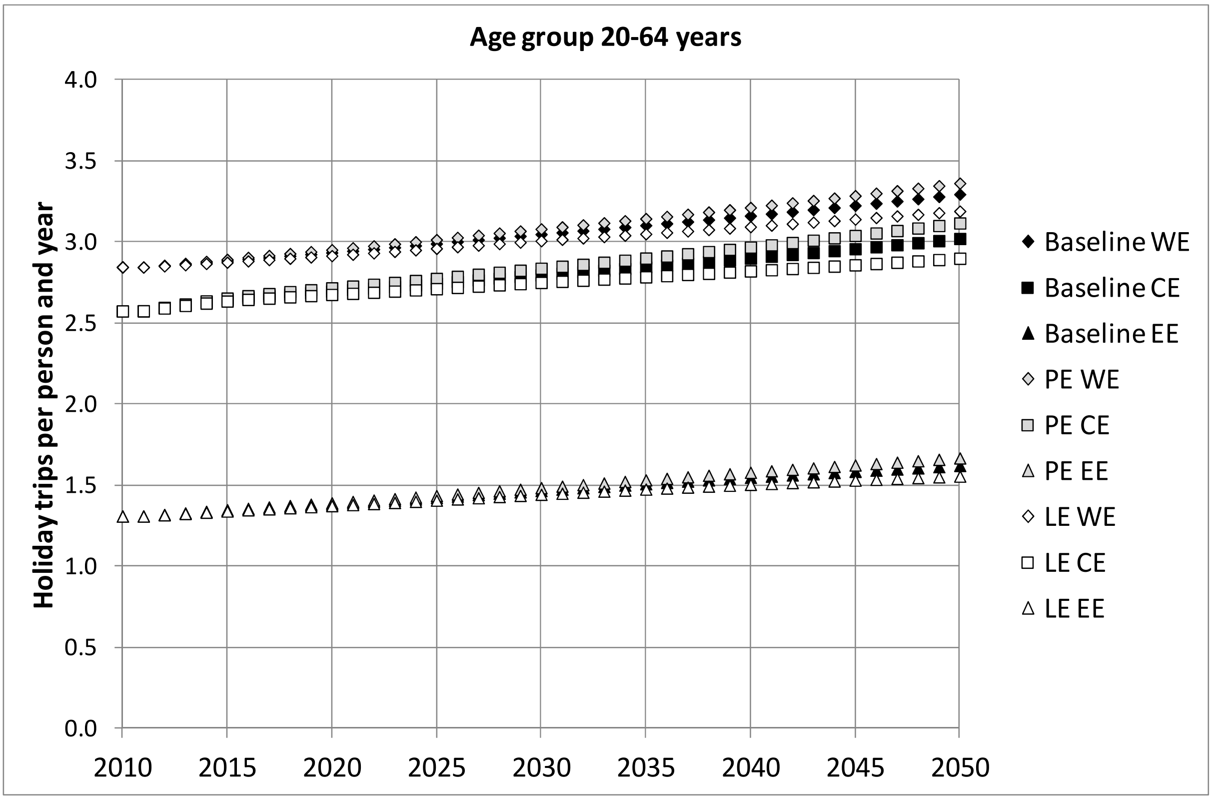


Figure 7-34 Annual holiday trips per person and year age group 20-64 years by region

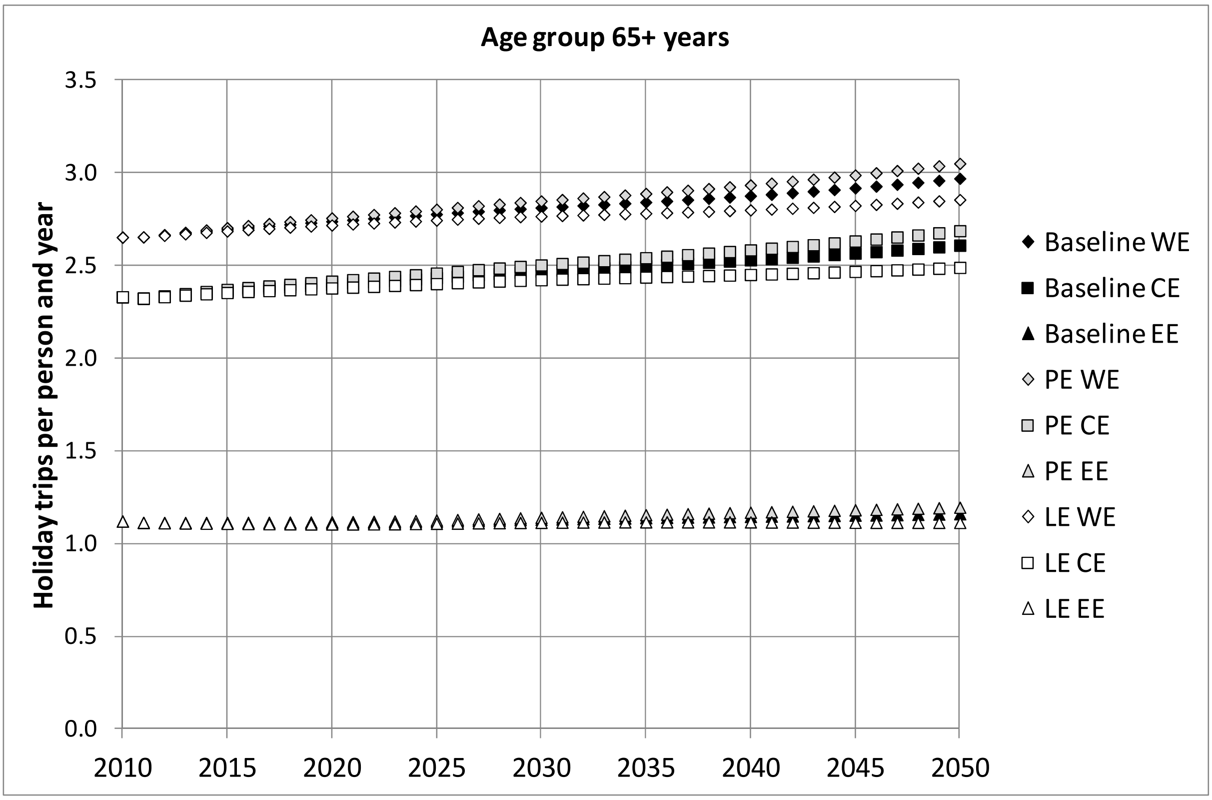


Figure 7-35 Annual holiday trips per person and year age group 65+ years by region

However, although the average differences between the three country groups are surprisingly clear cut, this still hides stark differences within each group.

Figure 7-36 shows the development of the holiday trips for each country. While the range of trips in the regional averages stretches for 2010, for instance for the middle-aged group, from roughly 1.3 for Eastern Europe to 2.8 trips for Western Europe, the range, for instance, within Western Europe stretches from 1.6 to 4.2 trips per person per year, so vary much stronger than the differences between the regional averages.

Within Western and Central Europe, there is a trend towards higher trip rates in Northern and lower ones in Southern Europe, although there are notable exceptions: Belgium has a particularly low holiday trip rate, while Switzerland has a particularly high one. In Eastern Europe it is Finland and Cyprus, who have the highest rates, while the countries on the Eastern Baltic coast have the lowest ones. In most cases it is the countries that start off with the highest trip rates that experience the largest further growth until 2050, but in Western Europe Ireland stands out with particularly strong growth, and in Central Europe it is Switzerland that starts off in third place and comes joined first with Norway in first place by 2050.

So in general, the disparities between social welfare in the different European countries, as measured by the holiday trip rate, increase over time.

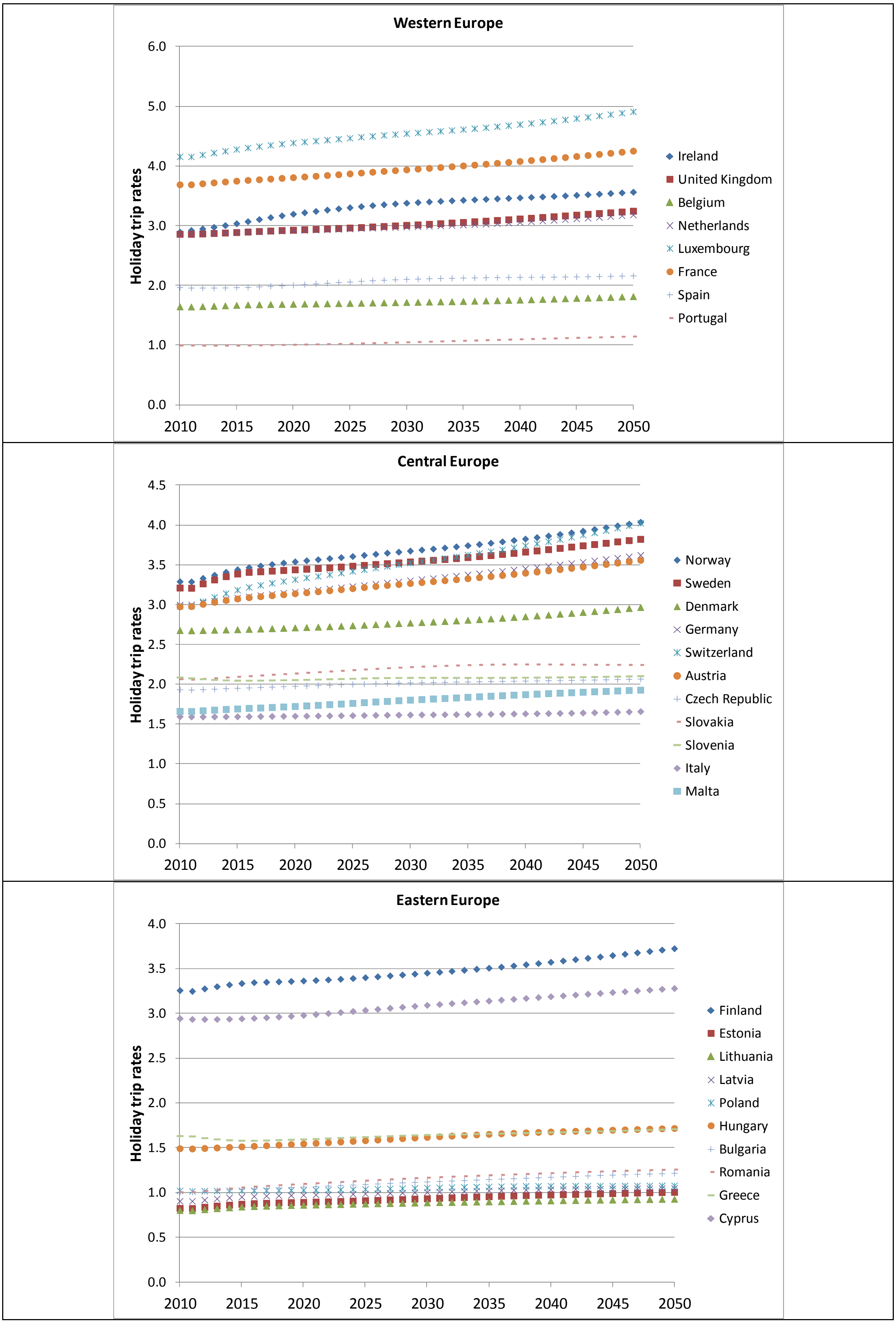


Figure 7-36 Annual holiday trips per person and year by country, Baseline

8 CONCLUSIONS

Scenarios 2030

The main findings from the scenarios 2030, as modelled by MOSAIC, are as follows:

- Total mobility measured in passenger kilometres changes slightly across different future scenarios, with some stronger local variations.
- Road will remain the main mode for passenger transport in Europe, but some degree of modal shift can be achieved depending on the policies applied. Rail has the highest growth potential, multiplying by 3 its share on scenario OR1.
- The most effective policy for lowering the number of cars on the roads is to increase the average vehicle occupation.
- New routing options appear when new infrastructure is developed. For new rail this usually causes trips to get a little shorter in distance to get to the rail station, although in some cases the distance can become longer when rail is used as part of an intermodal chain; but even then trips generally become shorter in total travel time.
- Global travelling time tends to decrease in all the scenarios as changes in transport costs and infrastructure lead to better routes. However, the most effective measure to improve it is increasing the speed on the road as in scenario OR4.
- In most scenarios with higher share of rail, trips tend to be more multimodal, mixing rail with road but also with air on the same trip. Mobility becomes more complex with lots of interchanges between modes. However in scenario OR4, the increase of rail does not result in an increase of multimodality, as the growth of air trips and the high increase in road speed compensates it.
- On the other hand, in some cases scenarios with a higher share of air mode tend to be more unimodal with long-distance flights, making mobility simpler (access/egress to airports from a very close location is not considered another mode), although scenarios OR4 and the Baseline are exceptions, as here the air trips are not so long, and road as a feeder mode becomes relatively more relevant.
- Fuel efficiency improves in all scenarios, but the most effective policy is the technological one. In scenario OR2, the vehicles are forced to consume less, resulting in a reduction of up to 40% compared to the Baseline.
- CO2 emissions also decrease in all the scenarios, with the technological scenario again being the one with the highest reduction. The Normative scenario achieves the White Paper target of reducing emissions by 20% by 2030.
- Accessibility measured as the accessible population weighed by the time of reaching this population tends to improve when new infrastructure appears, allowing for better transport chains. However, the pricing policy in some scenarios causes transport to get more expensive, thus lowering the accessibility in certain regions.

Scenarios 2050

The main findings from the scenarios 2050, as modelled by LUNA, are:

- Car ownership will be rising in the future, but least in a Prospering Europe scenario due to a combination of population growth, an increase in older population, rising household sizes and a decrease in GDP per person. The Normative Transport Policy curbs car ownership to a limited extent.
- The total number of cars will also rise, but here the population growth is the key factor, so that the number of cars rises highest in a Prospering and least in a Lagging Europe.
- The number of passenger kilometres grows in all scenarios from 2010 to 2050, by up to 52% in PE, mainly due to the increase in the number of trips and to a lesser extent due to a lengthening of air trips, and with the policy also rail trips. The number of trips is not affected by the Transport Policy.

- The strongest growth in passenger mileage comes in all scenarios from the growth in air travel, while growth in car travel depends much more on the socio-demographic and economic development. Neither is much affected by the Transport Policy, but the Policy does lead to an increase in rail travel, in the combination of the Policy with the assumptions of a Prospering Europe by up to 66%. Coach and maritime travel are both expected to grow continuously, slightly less with than without the Policy, but in terms of overall pax km, they will still remain less important than the other modes.
- The development of vehicle kilometres is, unsurprisingly, dominated by the car whose mileage is in 2010 27 times that of all collective modes together, and this relationship does not change much until 2050 in the Baseline scenario. But it is susceptible to both the socio-demographic and economic development and the assumptions about car occupancy in the Policy, and therefore its growth ranges from -6% in LE with the Policy to 39% in PE without the Policy. The fastest growth of all modes with 21% in LE to 41% in PE is that in the air travel mileage and the Policy only reduces that by less than 5% in all cases, while at the same time increasing the use of rail.
- The time spent on long-distance travel per person and year increases from 16.8 hours in 2010 to 21.0 hours in LE, 21.9 in the Baseline and 22.4 in PE, but the Transport Policy reduces this in all three again by one hour, mainly due to less time spent on air travel.
- User expenditure increases from €248 per person and year in 2010 to €410 to €440, depending on the scenario. The main factors are a doubling of the cost of car travel and a 60% increase in the cost of air travel, but differences between scenarios with or without Transport Policy are with a maximum of €25 per person per year between the lowest and highest value too small to make a factual difference for the users. Differences between richer and poorer countries increase, however, from €1,200 in 2010 to €1,900 in 2050.
- In all scenarios there is an initial decline in fuel consumption but then it is rising again and, except for LE with the Transport Policy, ends up in 2050 well above 2010 levels. This is largely driven by the large increase in air fuels, and the decrease in car consumption through the increase in car occupancy, while the impact of any changes in the other three modes is totally marginal.
- Greenhouse Gas emissions decrease with the Transport Policy in place by between 22% and 28% and without the Policy decline even much less. This is all well below the EU's GHG reduction target for 2050 of 60 %, and even a much more stringent Transport Policy than the one chosen in these scenarios could not possibly lead to results that come anywhere near that. Only a step change in propulsion technology would have any chance of producing a result that is approaching the EU target.
- The biggest absolute and relative decrease in particulate emissions in the three BAU scenarios from 2010 to 2050 comes from rail, based on the assumptions made about the electrification of rail. However, the biggest absolute decrease overall comes from the Transport Policy, and therein for the cars due to the change in the car fleet: the reduction in particulates for cars in the Baseline scenarios in 2050 from BAU to with Policy option on is significantly higher than the particulates the entire rail sector contributed in 2010.
- The indicator for social welfare available from LUNA is the holiday trip rate per country and age group. The number of holiday trips per year increases in all scenarios, though more in PE than in LE. The trip rate for young people is catching up with that of the middle-aged, but people of 65+ years fall further back as their level of car ownership does not increase at the same pace as their longevity. There are stark differences between holiday trips in different parts of Europe with that of Central Europe being – and remaining in the future – twice that of Eastern Europe, and Western Europe being another 10% ahead, even though there are strong differences within each of these three groups, in particular a very strong north/south divide. Moreover, the disparities between social welfare in the different European countries, as measured by the holiday trip rate, increase over time.

Overall conclusions

The two sets of scenarios for 2030 and 2050 start in many aspects from different premises, and it is therefore not straightforward to compare them and come to common conclusions. The key difference is that the 2030 scenarios are dealing with any travel between NUTS3 zones (or where no NUTS structure is available similar, if often somewhat larger, regions) within Europe plus Turkey, while the 2050 scenarios only look at travel that involves at least one overnight stay and, furthermore, also includes intercontinental journeys. One key resulting difference is that one of the core findings in the 2030 scenarios is that road is, and will remain, the dominant mode for long-distance travel in Europe, while the 2050 scenarios already start with air journeys entailing the largest share of passenger kilometres in Europe in 2010, and air even enlarging its lead in every scenario for 2050. Nevertheless the two sets of scenarios come to some common findings:

- The most effective way to decrease the number of cars, or at least the growth in the number of cars, is to increase vehicle occupancy with policy incentives.
- Investment in rail, in particular in High Speed Rail, and policies to reduce the cost of rail travel can significantly increase rail usage.
- Air travel will rise in all scenarios well above 2010 levels with the lowest assumption for 2030 being +36% to the highest of +66% by 2050 for a Prospering Europe.
- Both sets of scenarios foresee a decrease in fuel consumption for the nearer future, but in the 2050 scenarios consumption is rising again in later years, largely driven by the increase in air travel, and in most scenarios end up well above 2010 level. The most important factors in limiting fuel consumption are the assumptions for future propulsion technology.

Some further general conclusions can be drawn from the 2050 scenarios only, with the main one being that socio-demographic and economic changes can significantly influence the future of transport. The difference between a Prospering and Lagging Europe, based even on very reasonable rather than extreme assumptions, can be more 400 million trips per year. This equates to more than 200 billion passenger kilometres per year, or a difference of more than 25%. In contrast, the Transport Policy applied in these scenarios has a significant influence on mode choice, but very little on total mileage travelled.

What can be regarded as the key message from both sets of scenarios concerns the Greenhouse Gas emissions. They decrease in all scenarios, but while the Normative Transport Policy for the 2030 scenarios manages to meet the EU target of reducing GHG emission by 20% by 2030, the 2050 scenarios are much less optimistic and, even in the best case, only reduce emissions by 28% by 2050, far away from the EU target of a 60% reduction by that year. As for fuel consumption, the key factor is the future of propulsion technologies, but the assumptions made for 2050, that were assumed to be realistic, are still clearly not sufficient, and a real step change in technology is necessary to make transport and mobility sustainable in the future.

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