

living RAIL

Living in a Sustainable World Focused on Electrified Rail

Deliverable 5.1: The LivingRAIL Railmap 2050

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Executive summary

Preliminaries

The LivingRAIL project and this report

This document was produced by the research project LivingRAIL which is co-funded by the 7th RTD research programme of the European Commission. The Core objective of the LivingRAIL project is to develop a Vision for the future of the rail sector in Europe in 2050 supported by a roadmap of measures and policy actions to achieve the white paper targets of a 50% mode share of the railways in key passenger and freight markets by 2050. Detailed information on the project can be retrieved at: www.livingrail.eu.

The document describes the results of a visioning, roadmapping and impact assessment process towards a state of Europe in 2050, in which electrified rail caters the majority of passenger and freight trips. The Vision 2050 emerges from an interactive process with project partners and external experts resulting in four broad themes. By a backcasting process the LivingRAIL Vision 2050 also develops the story lines how to arrive there from today's situation. The Railmap 2050 is the result of a likewise interactive roadmapping exercise combined with analyses of numerous measure fact sheets from earlier works in this project. Finally, the impact assessment combines the application of the European System Dynamics simulation model ASTRA plus rough estimates of funding needs and financing options.

Background

Mobility styles and logistics processes emerge from a multitude of framework conditions. These start with peoples' lifestyles and the habits of companies. These further depend on the prevailing urban and regional settings, on mobility systems

available and of course on the attractiveness and services offered by the railways. These ingredients are all part of the LivingRAIL Vision and Railmap 2050. Accordingly, the concepts developed in this project are extremely broad going far beyond the sole description of transport market trends.

Why rail? The primary goal of forward-looking planning of our social environment shall be to preserve sufficient resources for future generations without compromising the present. These resources include economic strength, environmental quality and social justice, i.e. the three commonly listed pillars of sustainable development. It is here where collective transport modes need to be developed and used as high quality and low impact alternatives accessible by all parts of society. Public transport is more efficient in terms of energy use, environmental impacts and space consumption. No matter how far individual motorised transport closes up in terms of the first two issues, congestion and land use will remain their Achilles' heel even with advanced traffic demand management systems in place.

Alternative scenarios. Of course, technological development is not limited to the rail sector. Autonomous cars with emission-free electric or fuel cell propulsion may well compromise the railways' environmental and social advantage. Given the current developments in electric and hydrogen vehicles and the announcement of first commercial roll-outs of self-driving cars makes this development a real threat for public transport. A further threat for the railways is a persistent regime of financial constraints and austerity in Europe. The greatest threat of all, however, is probably the lacking commitment of policy of various levels as well as of the railways themselves to modal shift and customer orientation goals. The LivingRAIL

project underlines a positive scenario whilst acknowledging these threats and pitfalls on the way.

The 2050 Vision

The 2050 vision developed by the LivingRAIL team with the help of external experts from the transport sectors, from academia and public administration expresses a wishful future rather than an expected trend scenario. The Vision 2050 sets the changes which we believe need to take place in order to give the realisation of the White Paper mode shift targets set out by the Commission in 2011 a chance to become true.

As the targets are radical by demanding for a three to five fold increase of passenger and freight volumes by rail across the EU and even beyond an eightfold increase peripheral regions, the necessary changes in railway supply, policy, spatial structures and user preferences are alike. Accordingly, we do in no way believe the situation described in our 2050 Vision and on the way to then will happen automatically. Strong drivers and action on a variety of activity fields is needed; these measures will be described in later stages of the LivingRAIL project.

In this document we elaborate the main vision statements and the underlying storylines by four themes and 13 sub-themes from the 2050 perspective. While the detailed roll-out of the vision in this document goes from the prevailing situation in 2015 over short- and medium- to long-term developments, this summary concentrates on the 2050 vision statements. From the 2050 perspective the LivingRAIL Vision reads as follows:

Today, 2050, the majority of regional and long-distance passenger trips and medium to long distance freight movements are done by rail on mainly electrified networks. For high density areas the share of rail travel approaches 60% and even more in large agglomerations, while low density and peripheral regions with still more car dependence have achieved a 40% market share for the railways.

Passengers and industry put much value on sustainable lifestyles and enjoy seamless and high

quality Europe-wide rail services. For that purpose, planning standards have been reformed and the railways themselves have undergone a major re-definition, putting customer and market needs way above internal management issues. Thanks to the boost in demand, innovation cycles in the rail industry have shortened and cost efficiency and availability have increased such that the sector's attractiveness and competitiveness against air and road travel is considerable.

To serve the entailed doubling to tripling of freight volumes and the eightfold passenger volumes on Europe's rail networks, all means of capacity utilisation on existing lines, new investments and track upgrades and the use of high volume trains have been exploited to their limit. Information and management systems and automation have been expanded to the extent needed to maximise system reliability, efficiency and user attractiveness.

Although big investments have been indispensable to cater for this new rail based mobility culture, by 2050 completely alternative technology futures and new transport systems are not dominating the transport sector. The transformation of management cultures in railways, planning and financing authorities and the transformation of the 20th century railways – partly using 19th century technologies and concepts – to the 21st century was demanding enough. Moreover, the limits of big data, the all-embracing World Wide Web and the risks associated with mega investment projects became ever more visible. Thus, in line with the change in values of citizens and consumers, policy and economy habits re-focused on the doable and on the clever use of known and reliable concepts.

The 2050 Railmap

The LivingRAIL railmap is composed of 62 single measures, which partly describe larger activities and strategies, and partly refer to more detailed interventions. The measures are not elaborated in full detail as an important part of job if these two groups of players is to regularly reflect on their goals and their options and limitations for action.

Most of the measures need to be started in the short or at least in the medium run. Effectiveness

and efficiency considerations clearly points to network extension and upgrading measures to be fostered with most urgency, this is relevant to enable the rail system to cater the three to five fold demand increase expected by 2050. Second, however, come railway and policy reforms, integrated planning and services. Most relevant services are considerably higher train frequencies in all regions, door-to-door offers, guidance and information in passenger and freight, and Europe-wide logistics brokerage platforms. These themes are closely inter-linked as without a clear vision among all parties on where the transport sector shall develop to, and without open, market oriented and self-confident companies and institutions this enormous endeavour is at high risk.

Urban policies and mobility management together are targeted to impact peoples' and companies' perception of mobility. The remaining measures stations, rolling stock and regulation full important gaps in the policy and service landscape, but are

not alone capable to alter mode shift decisions in passenger and freight transport considerably.

Expensive investments into the rail sector are needed. However, flanking measures making railways and policy capable to act, and providing users with the right incentives to decide for rail, are equally important. International policy and the transport sector (rail and PT companies) play the most relevant role and need to push forward capacity and quality enhancing measures on the European passenger and freight rail networks. Low density countries are considered to have more time to act and erect their networks than high density areas.

Figure X1 summarises the main elements of the Vision 2050 and the top 25 measures identified for its realisation. However, it should be noted that this is only a snapshot. For realising the envisaged mode shift targets the full broadness of all 62 Railmap measures is required.

		Current status (2015)	Short term (2015 - 2020)	Medium term (2020 - 2030)	Long term (2030 - 2050)	Vision (2050)																																																			
Vision	Values and lifestyles of companies and people	Campaigns to promote environmental behaviour and sustainable policies often fail or progress slowly and are frequently dominated by business concerns.	A shift towards more sustainable behaviour of people and companies becomes visible. Work-life-balance and flexibility gains increasing importance for employees and employers.	Sustainability and sustainable quality of life has become element in general services like school curricula's or public administration. Attitudes towards car use have become largely pragmatic.	Consistent governance guarantees compliance with sustainability goals among all citizen groups and companies. Thanks to good PT services car use has dropped significantly even in low density areas.	People, companies and the public sector put high priority on sustainability, health and inclusion in decisions across all parts of society. Flexibility has reduced the need for travel and car use in particular.																																																			
	Spatial and urban concepts for a liveable and connected Europe	Consistent guidelines for sustainable urban, regional and large-scale planning and development are missing, coordination between regional bodies is low. Living standards differ in Europe.	Urban and regional sustainable development plans are in place all over Europe, planning power is devoted to local bodies and European gateways are well connected.	Agglomerations enforce PT-based green living and mobility, small to medium sized cities are fostered. European and national transport, energy and ICT plans integrated.	Strong European policy ensures open and competitive markets and sustainable rail-based global and continental logistics chains.	A consistent European to local transport and spatial policy creates liveable and well-connected cities and regions with powerful global gateways.																																																			
	Customer-oriented multi-modal passenger and freight services	Railways services are planned and managed with a bureaucratic approach without considering customers preferences and constraints. Services are slow, inflexible and expensive. Quality targets are rigid or non-existent.	Railways monitor customer needs along trip/shipment chains; quality targets for passenger and freight services across all modes are set and first steps towards customer orientation are taken.	Passenger rail stations get multi-modal and cultural hubs; freight services and intermodal terminals improve on efficiency and quality through automation and standardization. Costs of rail use decline considerably.	One-stop-shop services for trip and shipment chains enter markets. Multi-modal quality targets are met by most mobility service providers. Rising demand automation and standardization lowers costs considerably.	All railways have developed to integrated mobility alliances serving customer needs on all parts of mobility chains. Low cost, flexible and high quality door-to-door services are offered across all Europe.																																																			
	Network development, automation and train control	Expansion of HSR lines is slow; secondary and branch lines closed; network maintenance suboptimal in many countries; many lines not electrified. More than 20 different train control systems in Europe, all based on fixed blocks.	Separation of passenger and freight networks starts with adjusting each to future train weights, lengths and dimensions. All major rail companies have simplified and standardised their communication and train control systems.	Most networks have standardised communication and signalling. Autonomous trains are used for long-distance services. Increasing demand and for rail equipment reduces innovation cycles and cuts production costs.	Existing lines are electrified where suitable; non-electrified sections are served by hybrid locomotives. Comprehensive cross-border links are established. Moving block signalling for all railways. Trains are fully interoperable.	All agglomerations are connected to HSR; reliable, frequent and high quality direct passenger and freight services provide access to all European regions.																																																			
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Figure X1: 2050 Vision and top 25 Railmap measures

Impact Assessment & Funding

From the transport market, sustainability and financing assessment we can summarize a number of important key statements:

Demand:

- The overall mode split effect of more fast lines only ranges around two percentage points and less.
- Cheap tickets are found to have a visible impact on mode shares.
- the remaining 30% of mode share need to come from quality and from flanking policy measures.

Sustainability:

- Total transport THG emissions would fall by 40% with the Railmap measures and without any other technical measure.
- Similar reductions are envisaged from noise and – somewhat weaker – for accidents. Even more impacts are envisaged for the reduction of air pollutants.

Economic performance:

- Cost estimates (in net present values) arrive at total additional costs of €1345 bn. The most expensive single measures are the completion of the European high speed and freight networks with €416 bn.
- With a 400% to 500% growth in rail demand, passenger and freight customer revenues are expected to grow by €2522 bn. (NPV) despite a 50% fare reduction.

With road user charges across all Europe and an earmarking of 25% for railway projects, the Railmap could be fully financed. The excess availability of funds provides the freedom to take back some unpopular policy pricing measures. Even if we double costs and half pricing and rail charging incomes the received revenues can easily cover costs.

Final Recommendations

1. While re-emphasising the basic and necessary ingredients on railway futures advocated since long, the LivingRAIL vision strongly points on business and cultural frameworks. This broad view leads to a number of core policy recommendations in order to achieve the massive mode shift envisaged by the EC White Paper by 2050.
2. *Be aware of alternative futures.* Rail needs to address these by incorporating the new technologies as quickly as possible in its own system and by getting more cost efficient without compromising on customer orientation.
3. *Place users in the core of decision processes.* Without developing the mindset of customers, company managers, policy-makers and at last of railway staff, no substantial increase in rail mode share will happen.
4. *Immediate action is needed.* These actions need to happen quickly and decisively in order to have a sufficiently large effect in the decades ahead.
5. *Interventions need to be consistent.* Stakeholders and decision-makers need to co-operate and that steps taken towards more sustainability in transport need to be consistent in order not to risk achieving given sustainability goals.
6. *Re-think business and policy cultures.* Implementing the radical changes in railway investments, operations and customer care as well as in policy-making, regional and urban planning requires 21st century business and policy-making mentalities.
7. *Respect the limits of the railways.* But the flexibility of the system and its accessibility in sparsely populated areas are limited. Rail providers thus need to co-operate with other modes or integrate these into their core business models.
8. *Consider Europe's multiple faces.* The different economic and cultural conditions in Europe need to be taken seriously, but a strong coordination of national plans is unavoidable.

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Abbreviations

APS	Allianz pro Schiene e. V.	LNG	Liquid natural gas
CBD	Central Business District	mill.	millions
CIA	Central Intelligence Agency	MRF	Measure Reporting Form
CO	Carbon oxide	MS	Member State (of the European Union)
CO ₂	Carbon dioxide	n.r.	not relevant
dB (A)	Decibel, filter A	NGO	Non-governmental organisation
DB AG	Deutsche Bahn AG	NOx	Nitrogen oxides
EC	European Commission OR Euro-City train	NPV	Net present value
ERA	European Railway Agency	NUTS	Unified nomenclature for transport statistics
ERTMS	European Rail Traffic Management System	NUTS	Nomenclature of territorial unit for statistics
ETCS	European Train Control System	NUTS I	Nomenclature of territorial unit for statistics at level 1
ETICA	European Transport Investment and Service Co-ordination Agency	NUTS II	Nomenclature of territorial unit for statistics at level 2
ETS	Emission Trading System	OECD	Organisation for Economic Co-operation and Development
EU+	More or less undefined EU area ranging between EU27 to EU+	pkm	passenger kilometre
EU27	Borders of the European Union prior to 1 July 2013, i.e. excluding Croatia	PM	Particulate matter
EU30	EU territory as of 1 July 2013, i.e. including Croatia, plus Switzerland and Norway	PM10	Particulate matter < 10 µm diameter
GDC	Goods distribution centre	PSO	Public service obligation
GDP	Gross Domestic Product	PT	Public transport
GHG	Greenhouse gas	RTCA	Rail Technology Cluster Austria
HDA	High Density Area	RTD	Research and Technical Development
HGV	Heavy Goods Vehicle	SME	Small and medium sized enterprise
HS	High Speed	SNCF	Société nationale des chemins de fer français
HSR	High Speed Rail	SUMP	Sustainable Urban Mobility Plan
IC	Intercity (train)	SZZ	Savez za Željeznicu
IC/EC	Intercity / Euro-city	TGV	Train à Grande Vitesse
ICE	Inter-City Express OR Internal Combustion Engine	tkm	ton kilometre
ICT	Information and communication technology	TOD	Transit-oriented development
IPCC	Intergovernmental Panel on Climate Change	toe	Tonnes of oil equivalent
ISI	Fraunhofer Institute for Systems and Innovation Research	TRT	TRT Trasporti e Territorio
ITS	Intelligent transportation systems	UIC	International Union of Railways
IWW	Inland waterways	UN	United Nations
km/h	kilometres per hour	UNIFE	International Railway Association
LDA	Low Density Areas	UoB	University of Birmingham
		VDV	Verband deutscher Verkehrsunternehmen
		VOC	Volatile organic compounds

1 Preface

1.1 On this document

This document was produced within the framework of the research project LivingRAIL which is co-funded by the 7th RTD research programme of the European Commission. Core objective of the LivingRAIL project is to develop a roadmap of measures and policy actions to achieve the white paper targets of a 50% mode share of the railways in key passenger and freight markets by 2050. This task involves two challenges: First of all these targets are extremely ambitious and require decisive action by the transport sector as well as by the various policy levels. Second the time frame from now to 2050 is considerably long, corresponding to the development from the 1970s to the base year 2010.

Developing concepts for such an enormous endeavour over a long period of time requires a vivid picture of what this future could look like, how people actually live with the developments and how technologies, services, cities and lifestyles are linked. Such a picture shall be drawn by our Vision 2050 present in Chapter 4 of this document. But first, in order to get a better idea of how flexible some developments can be over that time horizon the 2050 Vision is introduced by going beyond today and moving through the decades from the 1970s to now in Chapter 3.

The full Railmap 2050 is presented in Chapter 5. This links concrete measures elaborated through several workshops and literature review to the story lines of the 2050 Vision to demonstrate more concretely by which suite of interventions the desired future could be addressed. The railmap regards the measures and their timing from different angles, i.e. types of region, actor or transport market.

Eventually in Chapter 6 we provide an impact assessment of both, the vision as it was becoming reality and the proposed measures as all of them involve small or large side effects. Contrasting the vision with the triggering measures and the impact assessment will finally provide the full picture. In particular we identify the more and the less helpful measures and the overall cost coverage and social impact evaluation.

Before embarking on the story telling process this document will introduce the LivingRAIL research project (Section 1.2), its mission (Section 1.3) and its framework (1.4). Chapter 2 will then introduce to the roadmapping methodology and approach applied by the LivingRAIL project.

1.2 The LivingRAIL Project

Within its 7th framework programme for research and technical development the European Commission is co-funding the LivingRAIL research project to explore by which strategic measures transport policy, spatial planning and the rail sector can maximise the market share of electrified rail and thereby contribute to a sustainable Europe 2050 with a high quality of life. In this context LivingRAIL has elaborated visions of the future role of the electrified railways not only within the general framework of mobility of people and goods but also by looking at the broader picture of the evolving demographic and economic structures, environmental challenges, energy issues, social and cultural values, living spaces, technological progress etc. in the long term.

The LivingRAIL project constitutes a joined endeavour of eight European research institutes, SMEs, railway alliances and industry undertakings.

The link to current decision-making processes within railway sectors and policies the research team is supported by an Advisory Board composed of representatives from European railways, user organisations, governmental bodies and NGOs. The project is co-ordinated by the Fraunhofer Institute for Systems and Innovation Research (ISI) and runs from December 2012 to May 2015.

The LivingRAIL project is organised along five scientific work packages (WPs):

- WP2: Framework Conditions
- WP3: Rail System Evolution
- WP4: Spatial Policy Design
- WP5: Vision and roadmap 2050
- WP6: Dissemination

This report presents the final results of Work Package 5: Vision and Railmap 2050. By building on work conducted so far in the project, it delivers the final output of the study.

- The 2050 vision, which was published earlier in Special Report 2,
- A roadmap for implementing action to move closer towards the vision and
- an economic and environmental impact assessment of the railmap.

Full information on the project's mission, partners and publications can be found on the LivingRAIL website at www.livingrail.eu.

1.3 Why Rail?

The primary goal of forward-looking planning of our social environment shall be to preserve sufficient resources for future generations without compromising the present. These resources include economic strength, environmental quality and social justice, i.e. the three commonly listed pillars of sustainable development. Transport (and other) sectors needs to contribute by efficiently reducing the need to travel, in particular motorised trips and goods movements, as far as possible. However, this panacea needs to be achieved without overly suppressing today's generation and it is here where collective transport modes need to be de-

veloped and used as high quality and low impact alternatives:

Environment. Even with current occupancy rates and fuel mixes, passenger and freight trains have four times less external costs than cars or trucks. With increasing load rates and further use of renewable energy sources, there is considerable potential for rail to lower air pollution, climate impacts, noise and accidents in the transport sector. Indeed, future strategies within rail and the EU envisage climate neutrality, zero air pollution and noise levels below disturbing thresholds in the coming decades. However, the efficient use of vehicle capacity through a considerable shift of demand from road to rail plays a key role for approaching these goals.

Social issues. Rail and public transport provide travel options for those who have limited or no access to a private car. This not only affects young, elderly, mobility restricted or poor people, but also people living in dense urban areas without parking facilities or simply travellers with heavy luggage, children or acutely immobile citizens. Moreover, collective transport opens the opportunity for sociable group travel, enjoying a glass of wine, working or simply meeting other people on the trip. In urban areas, high capacity rail modes bring about the advantage of freeing up urban space for cultural and leisure activities. No matter how far individual motorised transport closes up in terms of the first two issues, congestion and land use will remain their Achilles' heel even with advanced traffic demand management systems in place.

Economics. The economies of scale described for the environmental benefits of rail also hold for their financial viability. Provided capacity is available on the train, the marginal costs of each additional passenger or unit of cargo is small. Likewise, track infrastructure costs per train kilometre considerably decreases with more traffic on the network. Thus a shift of demand to rail, along with a better use of vehicle and network capacity, e.g. through virtual train control systems, will significantly reduce public sector contributions whilst increasing the rail sector's competitiveness with car and truck. Moreover, less car and truck transport reduces the costs for road expansion and maintenance. Along

with a reduction in road space, this cost saving can be considerable.

Other forms of collective transport (i.e. buses) may approach these sustainability targets in a similar way. However, they often lack the high capacity and quality and comfort offered by high frequency rail, especially in dense urban areas. However, both systems will need to integrate and co-operate in a strong environmental alliance to effectively reduce car travel as a preferred mode. As such, the LivingRAIL scenarios rather look at the potential for such a “sustainable mobility alliance” rather than on the isolated role of the railways.

1.4 Alternative Futures

Of course, technological development is not limited to the rail sector. Autonomous cars with emission-free electric or fuel cell propulsion may well compromise the railways’ environmental and social advantage. Given the current developments in electric and hydrogen vehicles and the announcement of first commercial roll-outs of self-driving cars makes this development a real threat for commercial transport.

This might in the end not be bad for customers. Calling a car or minivan that picks people up, maybe in groups, at where they are and gets them plus their luggage to their destination with no need for a driver’s licence will give freedom, flexibility and high quality of mobility, which rail or public transport can only offer in certain cases. Self driving trucks may serve remote regions for a fraction of the costs of today’s means of goods transport. In both cases, cars and trucks will be safer than manned vehicles as they are immune against fatigue and other human failures.

Perhaps the future will be a hybrid modal solution where autonomous vehicles board car trains for efficient long distance travel or even link together to form road trains running on a repurposed road network. A further threat for the railways is a persistent regime of financial constraints and austerity in Europe. Railways can eventually cater to a far

greater number of passengers and goods than today without asking for much more public contributions. But bringing the railways in a competitive position to cater way more passengers and goods requires financial commitment by the public sector. Reduced expenditure on modernisation, expansion and vehicle purchase means that the attractiveness of rail over other modes becomes limited. Global economic conditions, which can only partly or even not at all be controlled by the players will naturally have a strong impact here.

The greatest threat of all, however, is probably the lacking commitment of policy of various levels as well as of the railways themselves to modal shift and customer orientation goals. A future is not unlikely where policy makers continue down the traditional path of building new roads and airports to serve the assumed will of their constituents. In this scenario, railways need to focus on listening to travellers and goods forwarders as opposed to seeking subsidies and big investment projects. A desire to test new concepts to move with the times and attract new customers is crucial. After all, competing transport modes are doing just that.

Overall, the first thing the railways themselves need to do is to become self-confident of their role and capabilities. There is a need to develop products and services via intensive research of their potential customers’ needs and desires. Secondly, new technologies in the road sector need to be integrated into rail products and, where needed, co-operations with car, coach and air carriers are to be established. The positive story: Railway vehicles can benefit from certain technologies already in place when it comes to cars and buses. Many kinds of alternative fuels or hybrid vehicles as well as smaller and light weight vehicles can be used to consolidate rail leadership in eco-friendliness, energy and cost efficiency.

Finally, policy needs to pursue a transparent and consistent policy of sustainable development to support all green transport modes in their endeavours. The LivingRAIL project underlines this positive path forward whilst acknowledging the potential threats and pitfalls on the way.

2 Method of the LivingRAIL study

2.1 What is a Vision?

Generally a vision describes an idealized desirable future of a specific system that is substantially different from the status quo (Bezold et al. 2009). A vision is relevant to the actors concerned and thereby motivates, inspires and directs actions towards the vision. For policy maker and civil society communities, shared visions are increasingly recognized as highly relevant for initiating transition processes and achieving goals (Schultz et al. 1993). Even though different practitioners use different visioning approaches they share certain elements such as exploring individual and personal visions, investigating shared values, assessing the legacy of the past and exploring dreams for the future. Very often visions involve visual and other creative elements as a catalyst of expressing wishes and values. According to Bezold et al. (2009) a vision plays different roles:

- Describes the preferred future of a group
- Specifies a direction, which is described by ambitious goals
- It is based on the common values and goals of a group
- Supports the common take-off into the uncertain future

A vision provides a focus for collective activity. It addresses the question of *'where we are going'* (Bezold et al. 2009). Therefore it must be accepted as *legitimate*. This can be achieved by getting personally involved in creating the vision or including different values in the process. A vision only works when it is shared to enable a common contribution in moving toward the vision. Furthermore, it should express people's highest aspirations to create a "better" future. A vision should not be based on current realities and actual personal

limits; however, it should be achievable within a specific time frame, no matter how difficult that may be.

2.2 What is Roadmapping?

Roadmaps provide decision-makers from business, science and politics with a structured overview of framework conditions (e.g. political and societal) along with information on innovation developments (relevant actors, competitors, technologies) and their corresponding relationship. Unlike other operational planning tools, roadmapping was not developed from scientific theory, but from operating in practice in the late 60's. The term "roadmap", in analogy to a road or street map, refers to an arrangement of paths or connections between different developments over a certain period of time (Gordon 2009). Roadmapping is originally a method to support technology development by structuring technologies and identifying their linkages according to a timeline used by private and public institutions with their own specificities: subject, scope, field of research, target group, and orientation (explorative vs. normative; technology-oriented vs. problem-oriented) (Behrendt 2009).

The outcomes of a roadmapping process are graphical representations of objects, such as markets, technologies, products or resources and competences representing state of knowledge and their interdependencies which link the current development trends to the future. The most important benefits of roadmapping processes are:

- The roadmap is an ideal form to display a lot of complex and interrelated information in a single picture. All the information is visible at once, in chronological order, and

therefore conclusions can be drawn in a more substantial manner (Isenmann et al. 2010)

- Certain patterns of interpretation are typical and unique for a roadmap. The proper sequence of occurrence of expected developments can easily be checked here. If inconsistencies are detected solutions can be discussed directly, thus “hot topics” and “blind spots” become visible. All these interpretations allow to define actions and to design a strategy accordingly (Gordon 2009)

Roadmaps can take many forms, but the most general and flexible approach comprises a visual time-based, multi-layered chart which enables to show a variety of considered aspects as well as relationships between them and provides a structured framework to address two key questions (Phaal et al. 2008): *Where are we now and how can we get to the preferred future?*

2.3 The LivingRAIL Visioning Process

A proven best practice is to combine scenarios or visions with roadmaps by using *forecasting* and *backcasting* as a bidirectional approach. Forecasting is used to determine the possible implications of a particular hypothesis, certain conditions in terms of impact assessment; while backcasting determines the conditions that are necessary to achieve certain goals (Steinmüller 1997). Backcasting is often applied when a vision is created or when one or more scenarios describe desirable futures to work backwards and identify major *events* or *developments* as well as *decisions* or *measures* that support this future.

By taking the backward looking perspective we need to decide on a particular development path of framework conditions. By 2050 Europe could either be devastated by economic, financial and political crises, could have stabilised in a situation close to the current one, or could have entered a dynamic and prospering track. Although not the most likely

future, in this paper we have decided in favour of the dynamic case as suggested by the LivingRAIL framework conditions report (Fiorello et al., 2013). Nevertheless, we take some sideways glances at the alternative case of a “muddling through” scenario to 2050.

In this document we describe the results of a visioning and backcasting process performed by the LivingRAIL team. It builds on a set of framework conditions and transport sector targets set out by LivingRAIL Deliverable 2.3, and will feed into a roadmapping process generating the final output of the project: the LivingRAIL Railmap 2050. The 2050 vision gives the direction and the core field of action for the railmap measures proposed by this study. The process starts from a very general expectation on mode shares in regional, long distance passenger and freight transport. This is 50 % of regional trips, 50 % of long-distance passenger kilometres and 50 % of medium to long distance ton kilometres by public transport or rail.

As these targets are more than challenging, a broad and co-ordinated process of policy, industry and the transport sector is needed to approach them. A vision of the state of rail transport in 2050 thus needs to address the way our regions and cities will look like, how will people and companies behave, which mobility options are available and how the railways act. We thus break down the general 2050 vision into four main topics, and further diversity each of these topics into three to five sub-themes. Each of these 13 sub-themes tells a story-line from where we are today to the state of regions, cities, mobility and railways to their final shape in 2050.

After these story lines of a desirable future development had been told, a set of measures to realize them is defined. The main elements of the vision, the measures and the related collection of good practices are shown in Figure 1. Figure 2 then presents the hierarchy of vision and measures elements of the LivingRAIL railmap and their very principal interdependency.

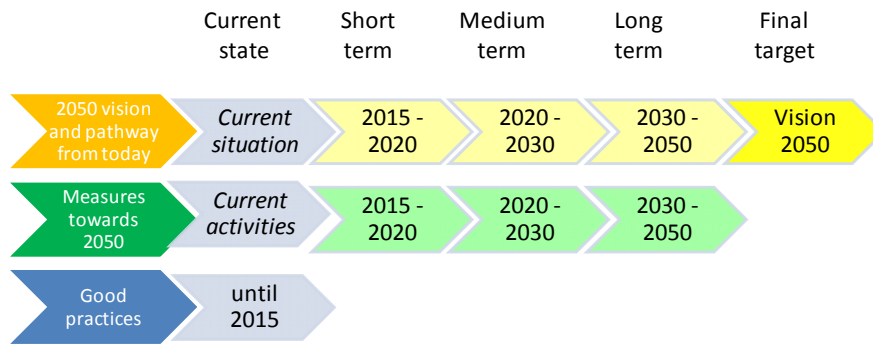


Figure 1: Elements of the LivingRAIL 2050 vision

The roadmap pyramid depicted in Figure 2 shows the hierarchical structure of its elements. The lit is formulated by the very general mode shift targets for 2050, which are inspired by the EC Transport White Paper 2011. Below these we find the four general vision statements for values & lifestyles, spatial and urban concepts, mobility systems and the rail sector. These are considered direct necessities for achieving the mode shift targets.

But again, the four main vision statements need further precision. These are given by the 13 sub-themes represented by the third layer of the pyramid. These are structured where necessary by focus area as work in the project has strongly indicated the different starting points, development speeds and preferences of European regions and rail or PT markets. Further, these 13 sub-themes are broken down in story-lines over time.

The lower-most part of the pyramid finally represents the measures which need to be taken by several actors to achieve the vision elements. Again, this is structured into a broad level of intervention fields, which mainly relate to the group of actors in charge of implementing the detailed measures: the rail sector and related entities on the one hand and the public policy, legal and administration sector on the other hand. The lower-most layer of the pyramid finally represents the single measures proposed by this project.

The interventions are further detailed in packages of measures, represented by the second lower level of the pyramid, and single interventions forming the very bottom of the graph. The packages had been proposed by LivingRAIL Deliver-

ables 3.2 and 4.2. As for the detailed vision statements, the interventions (or measures) are allocated to focus areas and time lines to provide more detailed information what has to be done when and where by who to approach the overall vision goals.

We can formulate two principal links between the measure and the vision statement layer of the roadmap. On a more general level we can link the technology or policy packages of interventions to the broad vision themes. This strategic relationship, which is depicted by the dotted arrow in Figure 2 provides a more quick and easy-to-read summary of the overall story line.

The more tricky and complex link of the two areas finally is formed from the detailed measures or interventions to either the single elements of the vision or directly to the mode shift layer, i.e. the core goal of the LivingRAIL vision.

This means that there are direct as well as indirect ways to address the utmost goal of the LivingRAIL roadmap. The direct way is to address peoples' or shippers' decision framework by altering prices, availability or quality of the modes. The indirect way rather addresses long-term decision pathways by forming social, economic, legal, infrastructure and built environments such that attitudes towards transport and mobility shift over time. But of course these two impact channels are highly inter-connected. Most likely we need to exploit both to their full extent to comply with the White Paper mode share targets even over a time horizon of 35 years from now.

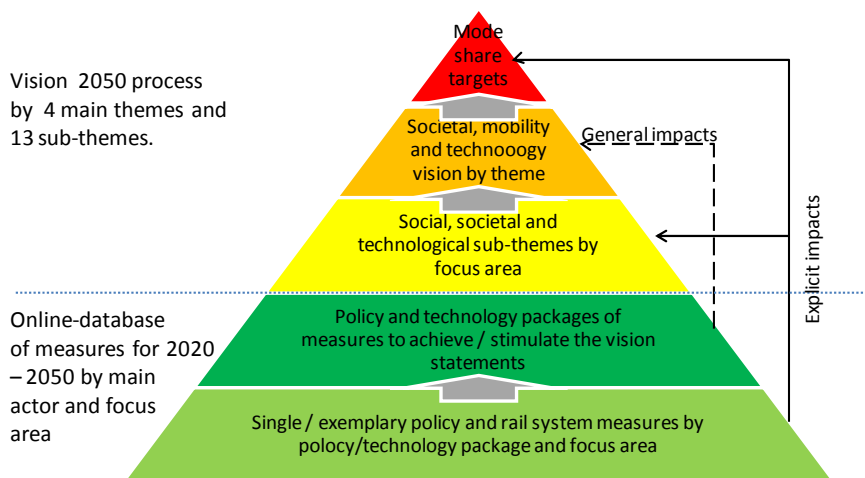


Figure 2: Hierarchical structure of the LivingRAIL Railmap 2050

After a short review of the visioning methodology the document discusses the four core fields of the vision and summarises the main concepts. The thematic areas of the LivingRAIL Vision 2050 are:

1. Values and lifestyles
2. Regions and cities
3. Mobility services
4. Rail system

Each of these thematic areas is characterised by one or two core statements which express what the LivingRAIL team expects the future in 35 years' of time to look like.

- Compared to 2050 people put much more value on healthy and sustainable lifestyles.
- All cities and regions are strictly developing according to sustainable planning principles.
- The majority of people and firms all over Europe have easy access to high quality and secure passenger and rail freight services.
- Europe has completed a high quality and dense rail network connecting all cities and regions.
- The European rail industry is a global leader in innovative and user-oriented system solutions.

Developments and the description of social, political and technical structures are of course far more complex than can be expressed by a handful of statements. Thus, the four topic areas are subdivided into several statements of the future. In the course of this document we elaborate these details of the story lines by different geographical areas in Europe and by following the trace spanning over four decades from today to the target year of the Vision 2050.

Our experiences from diverse visions or scenarios based on roadmapping projects show various advantages of participatory approaches:

- Development of shared ideas about the future in a short time (away from daily business) and generating more ideas due to synergy effects (alternative concepts, different possibilities);
- Including different temporal perspectives and aims of the involved actors which support the acceptance of applied methods and results;
- Positive side effects, e.g. expansion of the own perception or network building;
- Raising awareness of technological, environmental and societal changes, including long-term changes;

- Intensive discussions of alternative developments and mapping the changes in the markets;
- Characterization of required competences and planning business activities.

For the fact finding missions and roadmapping exercises in the LivingRAIL project stakeholder involvement through workshops with external participants was extremely important. Only the identification of relevant framework conditions and the drafting of a future vision of rail-based transport in Europe are designed as internal processes. This is

because particularly the Vision 2050 touches the very core objectives of the LivingRAIL project, providing only little space for external participants to contribute and design the vision.

By involving all project partners the process was organised in form of a virtual workshop. Through a multi stage input and feedback process, project partners brought in their ideas by activity field, and later commented and prioritised the compiled set of elements. Only in the very final stage the vision was discussed during a physical meeting of all partners.

3 Casting back into the Future: the General Picture

Now we are placing ourselves into the middle of the 21st century. Looking back we see a world that has been changing rapidly in some respects, but has remained reluctant to change or innovate in other areas. After a first look across today's situation in 2050 we look back 80 years into history to understand the decision background of early 21st century policy-makers and railway planners.

Over this nearly century-long time line we see cities turning green and service-oriented, borders falling, information technologies emerging and the rise of high speed and container trains. But we also see the basic principles of rail system organisation remaining stable and the global political and economic landscape getting ever more complex.

In the following paragraphs we elaborate some of these story lines from our point of view in 2050. We will conclude on the flexibility and the stability of certain conditions between 1970 and 2010. These patterns then shall provide the basis for interpreting the more recent evolution of transport markets between 2010 and 2050.

3.1 Living in the Mid 21st Century

Now, in the year 2050, thanks to multiple drivers and active fostering, an economic, social and cultural environment in Europe has emerged, where a high degree of flexibility in lifestyles and working conditions meet high standards of reliability and social security. Arriving at this balanced societal state has neither emerged as a matter of course, nor has it been easy to achieve. Outlooks on 2050 from the early 20th century and in particular from after the economic crises around 2010, were more depressing and opened a number of less favourable pathways Europe could have taken. But we managed to take the right turns.

The period of globalisation and rapid economic growth 70 to 100 years ago until the turn of the century must

be characterised as prosperous, but overly resource consuming and naively believing in market mechanisms. The series of economic and financial crises, social cuts and rising unemployment in the 2000s then initiated a paradigm shift in peoples' preferences. Today, in 2050, economics, living and working conditions across Europe are thus far more comparable than they were in the early 21st century.

After the world economic crises and the armed conflicts along the Russian border three decades ago transnational, European and national institutions have adopted a new policy style, which has put the citizens before companies' and state interests.

After the topic of climate mitigation and energy security had partly lost attention during the early 21st century economic crises they were pursued with even more intensity after 2015 by the EC and by national and local governments.

Within this positive development Europe has taken, we focus on the role of electrified rail and public transport services to cater for the mobility needs of people and the transport needs of companies. We can look back on a positive and very successful re-vitalisation of the sector, which has seen a rapid decline in the second half of the 20th century due to massive road network extension financed by public money and, as a consequence, supporting the rise of the private car and the liberalisation of the road haulage sector.

3.2 Time Travel from the 1970s to 2015

The changes of society, technology and economy we have seen in the past four decades are significant, but are not particularly unique in history. When looking at a more distant time line from the 1970s to the first decade of the 21st century much more dramatic changes, including path-breaking technologies like the mobile phone as well as more lazy movements, such

as the shape of passenger cars or non high speed rail technologies are revealed.

1970s: In post World War II years heavy industrial production dominated economic markets and most countries in central Europe were mining hard coal and cooking steel. Transport was characterised by the mass production of cars and roads, while the railways rapidly started losing market shares. City planning centred around the car by sacrificing walking space, historic town centres and natural habitats to streets and motorways. Following the 1970s oil crisis, the publication “Limits of Growth” by the Club of Rome gained international attention as it made the finiteness of natural and environmental resources visible. This may have been the first sign for the public that the unlimited freedom promised by the car, as fully dependent on petrol, had some pitfalls.

1980s: In the 1980s GDP growth rates fell to 2% and traditional industries were shut down: France, the Benelux countries and the UK withdrew from coal mining, forcing mining areas to find new ways of creating income. Developments in the transport markets were interesting in all modes. As legislation and technology made cars safer, truck sizes and dimensions were expanded and road building continued, roads’ market share kept on rising at the expense of rail. In the 1980s air transport started to become affordable also for leisure purposes. In France the railways, however, started attacking road and air with their train concept “Train à Grande Vitesse” (TGV). Following the nuclear catastrophe of Chernobyl (Ukraine, 1986), the Exxon Valdez oil spill (Canada, 1989), acid rain and further devastating pollutions to soil, waters and air, the 1980s can be marked as the starting point of environmental activism and peace movement.

1990s: Undoubtedly the most profound change of our social, economic and political environment in the 1990s was the opening of the Berlin Wall and the fall of the Iron Curtain in November 1989. The 1990s were then marked by forecasts and speculations of a glorious future of a border-free Europe. Another game changing development was the steep rise of computer and mobile communication technology. Although invented in the 1980s, World Wide Web applications and email communication were commercialised in the early 1990s. In the 1990s the downward trend of rail market shares began to slow down when road congestion became a serious threat to the economy and cities and the awareness for the environment and safety rose rapidly. By then the European Union im-

plemented political action to liberalise rail markets and to regulate road traffic.

The early 2000s: The greatest technical revolution in daily life in the recent past was maybe the development of smart phones and their unprecedented speed of market dispersion. Which took stationary computers before was now possible everywhere: the retrieval of real-time information on locations, retail, transport, leisure, etc. The turn down of the rail market share had been stopped, but in general the dominating role of cars and trucks remained. Thanks to strong environmental regulations road vehicles became much cleaner and fatality rates declined to only a fraction of their level in the 1970s. And progress continued: after powerful driver assistance systems in trucks and premium cars and the installation of driverless metro systems and people movers, global players like Google and universities worked on fully autonomous cars. Emerging new technologies, services and business models for rail and public transport in some western European and Asian countries, the re-vitalisation of tramways in large cities and the extension and improvement of public transport supply and – most important – a paradigm shift in urban planning have shown effect on mobility behaviour.

3.3 Lessons for the second Period from 2015 to 2050

In the early 2000s several foresight, visioning and roadmapping studies on the state of transport and the environment in a future Europe were conducted. Many of these took 2050 as a popular target year. But in many cases the recipes, technologies and services known – or at least visible – at that time were projected into the future without major adaptation.

In retrospective we go through a number of the above introduced key developments and formulate statements on their rigidity and predictability over time. On the one hand we observed early visions of the future which have not become true or – if changes occurred – turned out more bad than good. We may have called these developments “great flops”. Candidates for that category were the traditional transport systems and the evolution of the global economy and policy. The glorious future which could have been expected from the stable growth patterns of the 1970s was dismissed in many respects although not in all.

The other extreme was marked by so-called “game changers”. These technologies or developments were

completely off the radar of contemporary forecasts and included internet, telecommunication, the success of multi-modal mobility services or the implementation of renewable sources for power generation in some countries. ICT technologies undoubtedly imposed the most profound, though not only positive, impulse on peoples' and companies' way of living and interacting.

Then we had a number of partly predicted developments, which finally were implemented. The trends between Game Changers and the Grand Flops were foreseeable and had been long planned and prepared. Prominent examples are high speed rail or some mega projects like the Swiss Alpine rail tunnels, the Channel Tunnel or the Oresund crossing.

In the opposite corner of our model, however, we can identify some trends of long term changes to societies and economy, which were identifiable from the 1970s perspective. One of these "oil tanker like trends" is the demographic change of societies. Baby boomer times were over and birth rates dropped dramatically in western societies. But besides statistical offices the consequences were largely denied by planners and policy makers. Only in the 1990s they were adopted in planning manuals.

In our mental model depicted in Figure 3 we find the unpredictable development in the upper left corner: game changers or unforeseen quick changes. In contrast, high hopes which were or only slowly realised can be found in the lower right corner, the grant flops, of this collection of illustrative examples.

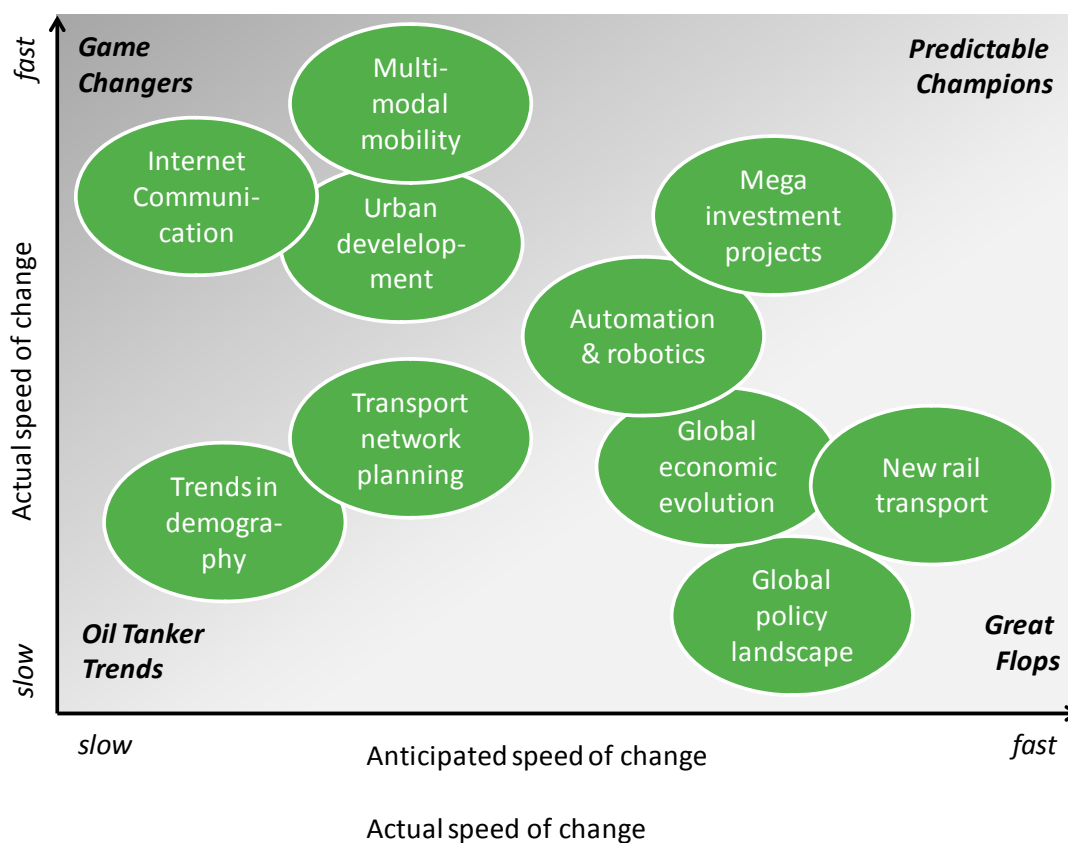


Figure 3: Mental model on the predictability of social trends

3.4 Key prospects for the Second Period 2015 - 2050

But what could we have learned from these observations for formulating visions in the mid 2010s towards now, i.e. the mid 21st century? First, we tend to expect today's technology or style of living to move gradually

to something similar, but just better, smarter, faster, cheaper or more reliable.

Two other ways of thinking of the future can be found in utopian or science fiction literature. Some stories develop futures of "returning back to pre-industrial forms of living", while others advocate the advantages brought about by technological and societal progress.

This progressive or “techy” vision on social, economic or technical development then leads to the second theme we can identify in sci-fi literature. Dark pictures of societies controlled by machines and computers have a long-standing tradition in books about our long term future. In these, individual people struggle – and often fail – to lead a self-determined life.

By having analysed the social and technical trends so far, in the mid 2010s it was recognised that neither of these extreme visions on the future is likely. Technologies have always had, and always will have, good and bad sides.. Another lesson for the early 21st century vision developers was that important changes often do not advertise themselves long in advance. Some game changers did, like the automobile in the 1950s, but others did not. Here we take again the

example of ICT technologies, but also the fall of the Iron Curtain in 1989 or – on the negative side – the terrorist attacks of 9/11.

Thirdly analysts could see that policy interventions, if done decisively, had impacts. Good examples from the late 20th century are the reduction of industry and transport exhaust emissions simply by regulating new technologies and by setting prices right. Of course policy cannot impact on all areas equally well. The impact of interventions may be incredibly difficult to predict when leaving the local level or simple markets; the struggle in getting hold of financial markets or armed conflicts were telling examples.

4 Vision by Themes

In this section we present the vision statements and the story lines for each of the four main thematic areas in more detail: values and lifestyles, urban and regional development, mobility services and rail system. These themes are further broken down into sub-themes, each of which leads to a final 2050 vision statement.

The story lines behind each of these sub-themes start with the far distance situation in 2010 and describe the state of things from there in the short run (to 2020) the medium run (to 2030) and finally the long run, i.e. today (2050). The elements which each story line is composed of further distinguish between transport sectors (urban and regional passenger, long distance passenger and regional and long-distance freight) and between type of area (high density areas HDA, low density areas LDA or general). This allows a subsequent de-composition of story lines by the six LivingRAIL focus areas (as done in Section 5).

4.1 Overall Vision Statement

Today, 2050, the majority of regional and long-distance passenger trips and medium to long distance freight movements are done by rail on mainly electrified networks. For high density areas the share of rail travel approaches 60% and even more in large agglomerations, while low density and peripheral regions with still more car dependence have achieved a 40% market share for the railways.

These ambitious market share targets are inspired by the 2011 transport White Paper issued by the European Commission. Given the market shares of 8% in inter-urban passenger, 18% in intra-urban freight and around 15% in urban public transport prevailing at the time of compiling the White Paper, this vision seemed to be far from realisation. However, looking back in history demonstrated that such a market structure is in principle feasible and well able to maintain or even increase economic and social wealth with minimal environmental impacts.

Passengers and industry put much value on sustainable lifestyles and enjoy seamless and high quality Europe-wide rail services. For that purpose, planning standards have been reformed and the railways themselves have undergone a major re-definition, putting customer and market needs way above internal management issues. Thanks to the boost in demand, innovation cycles in the rail industry have shortened and cost efficiency and availability have increased such that the sector's attractiveness and competitiveness against air and road travel is considerable.

To serve the entailed doubling to tripling of freight volumes and the eightfold passenger volumes on Europe's rail networks, all means of capacity utilisation on existing lines, new investments and track upgrades and the use of high volume trains have been exploited to their limit. Information and management systems and automation have been expanded to the extent needed to maximise system reliability, efficiency and user attractiveness.

Although big investments have been indispensable to cater for this new rail based mobility culture, by 2050 completely alternative technology futures and new transport systems are not dominating the transport sector. The transformation of management cultures in railways, planning and financing authorities and the transformation of the 20th century railways – partly using 19th century technologies and concepts – to the 21st century was demanding enough. Moreover, the limits of big data, the all-embracing World Wide Web and the risks associated with mega investment projects became ever more visible. Thus, in line with the change in values of citizens and consumers, policy and economy habits re-focused on the doable and on the clever use of known and reliable concepts. Figure 4 illustrates the elements of the overall Vision 2050 and the four sub-themes.



Norms, Values and Lifestyles

Spatial and urban planning, poly



Mobility services

Rail technologies and operations



Figure 4: Vision 2050: overall picture and sub-themes (credit: Heyko Stöber 2014)

4.2 Norms, Values and Lifestyles

Rail transport needs social acceptance. This is in particular the case as not only rail and public transport, but also its competitors implement new technologies for improving travel experience, universal availability and simplicity. Areas where changes in favour of rail have been achieved include the awareness of people and companies on the individual and social benefits of sustainably lifestyles and business models, the attitudes towards transport modes and in particular the requirements in business travel and commuting.

4.2.1 Green and healthy lifestyles

In 2015, people and companies were largely focussing on short term profits. A moderate level of environmental awareness was already apparent in society, but apart from those individuals with a greater level of involvement in the issue, it generally played a minor role in many decisions and behaviours and for the majority of the population.

Since 2015, more and more new scientific findings about the knock-on effects of global warming and the increased and ever more rigorous reduction efforts of the international community have led stepwise to an increasing readiness to make relevant changes to their own behaviour. Beliefs that a green economy is both needed and possible have increased among stakeholders and in the population. More and more companies have begun to realise that alternative business models can be successful, and in the long run will be superior to business models neglecting environmental criteria, and begin to act accordingly. In the medium term, topics dealing with environmental and sustainable behaviour and technology have been firmly embedded in schools as part of the curriculum. In the long run, with growing pressures from environmental and various stakeholder groups, increased costs of energy and resources as well as consequences of environmental damages, efforts from policymakers, companies and individuals have become more and more coordinated and consistent.

The 2050 vision: In 2050, a high level of environmental awareness and sustainable behaviour, but also personal health and well-being, are inseparable parts of peoples' lifestyles. A much greater priority is put on green issues in politics, public services, business and

private decisions. Sustainability awareness influences the behaviour of citizens, firms and institutions:.

4.2.2 Change of status symbols

In 2015, the majority of the population still considers cars as important to fulfil daily needs. Positive affective and symbolic values were strongly associated with cars. New mobility concepts, IT technologies, platforms and infrastructure which encourage and ease the combination of various transport means started to appear and to gain attractiveness. However, due to still widespread car ownership and strong habits of using cars and of considering mainly usage costs and absolute trip time, car usage was very dominant.

In the generation born since 1980, the car has lost its standing as a status symbol. In the medium term, in urban areas, people have increasingly preferred mixed and green urban spaces which are pedestrian and cyclist friendly and promote and enable diverse and varied multimodal mobility options instead of urban areas and cities where cars are omnipresent and allowed to park or go everywhere. Thus, acceptance of urban policies to restrict car use has increased. In the long term, alternatively fuelled cars have become widely spread, but have not been considered as the solution to all transport problems. The improvements to local public transport and urban design have significantly reduced both the attractiveness of cars and the necessity to use them for shorter distances. Thus, car use and car ownership have decreased significantly..

The 2050 vision: In 2050, the car is not seen as a status symbol anymore and is used pragmatically according to needs and available transport options. Thus in high density regions, the car has clearly lost its dominant popularity, while in low density regions, the car is still an important part in every day mobility when there are less alternatives available..

4.2.3 Commuter and business travel

In 2015, mobility and work patterns were largely determined by relatively inflexible school, work and public service times. Mobility management by companies was not widespread. Vehicles played a major role as transport means for commuter travel, while for business travel planes played a significant role for medium to long distance trips.

In the Short term work-life-balance has become increasingly important for employees and employers due to increasing requirements of work, family and leisure which individuals need to reconcile. In the medium term, people have gained much flexibility to organise their work time and place according to their individual needs. This has had the effect of reducing some of the peak traffic periods. Increasing decentralisation of work and technical possibilities as well as high acceptance of home office and phone and video conferences have lessened the necessity to commute to work from one agglomeration to another. In the long term, it has become common to use phone and video conferences whenever possible or travel by rail if personal meetings are necessary.

The 2050 vision: In 2050, flexibility of school, work and public service times as well as IT technologies and

measures (such as, e.g. commuter rooms, telecommuting, mobile workplaces, telephone and video conferences) are used to reduce the need for travel, to avoid traffic peaks and enjoy daily life without having to travel a lot.

Figure 5 finally gives an overview of the three story lines and their elements. Most developments which took place are universal across area types and transport sectors. Main differences between central and high density areas on the one hand and peripheral and low density regions on the other hand are the speed of acceptance for shared mobility options and for interventions restricting car use. Due to the more dispersed settlement structure the car will most likely remain an important means of ensuring mobility in low density areas by 2050.

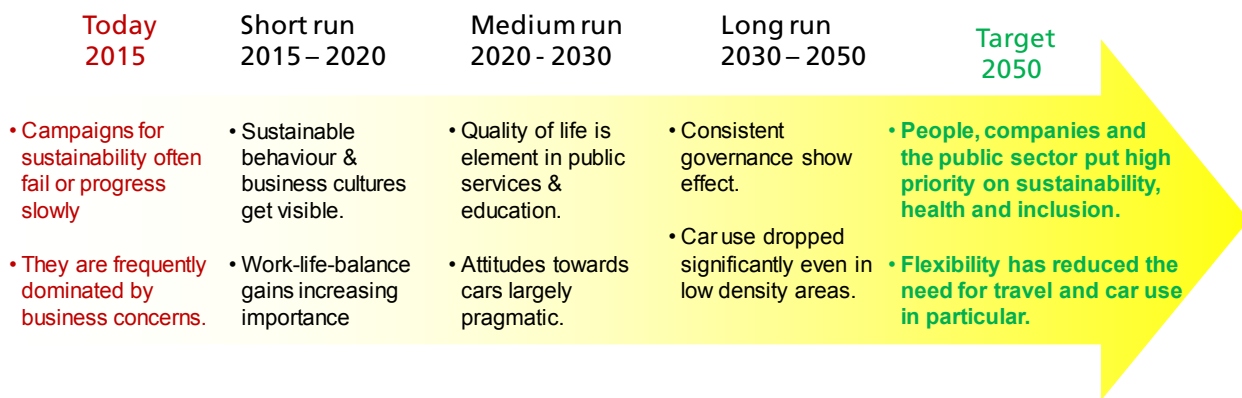


Figure 5: Pathways to Vision 2050: values, lifestyles and attitudes

4.3 Spatial planning, urban development and policy

4.3.1 Compact and liveable settlements

In 2015, in particular small towns in the EU's periphery, but increasingly more and more cities in the European core area, are struggling with funding constraints and cars are still considered an essential necessity by citizens in the periphery. The acceptance of policies shifting budget from financing roads to public transport often lacks public acceptance.

In the short term large cities push forward in improving SUMP's and innovative funding instruments. New generations of town planners have improved co-operation between different planning authorities.

This trend was to a large extent pushed by citizens' movements as people increasingly rejected being stuck in traffic jams and seeing parked cars occupying valuable urban space. As cities and planning institutions across Europe acknowledged the preferences of citizens which are undergoing major changes, new planning tools and guidelines have been implemented. Small and medium sized towns make efforts to become largely self-sustaining entities, which are less dependent on one particular sector such as services, culture, etc. provided by nearby agglomerations. This reduced the need for travel and at a later stage attracted work places to these regions. Beyond 2030 altered planning habits show their effects in all major cities. Monocentric structures were broken open and migrated towards polycentric forms. This supports the

walkability of neighbourhoods and reduces car- and energy dependency.

The 2050 vision: 2050 is characterised by fully integrated spatial and urban planning practices all over the Union. Most people live in compact towns, cities or city neighbourhoods.

4.3.2 Accessible regions

In 2015 transport infrastructure planning is primarily a national business. Although the EC has introduced European corridors, investment decisions are taken nationally. This causes international links to be under-evaluated and consequently cross border rail connections have been lost throughout the decades.

In the short term planning and investment powers became widely strengthened for regions and communities. Local areas thus received a great deal of autonomy in designing their transport system, although national and European institutions provided strong guidelines and support with funding. Approaching 2030 attention turned more towards cross border projects. To strengthen border regions and European integration a European Transport Investment and Service Co-ordination Agency (ETICA) was established. In the long term, due to the increasing ridership in public transport and rail systems, private investments started to earn profits all over Europe.

The 2050 vision: In 2050 national transport investment plans are rail-based. A general strategic framework vision developed jointly by the European Member States serves as a guideline.

4.3.3 Open and connected Europe

In local and regional transport tendering of services was encouraged and has been implemented more or less successfully since the early 2000s. However, by 2015 we needed to constitute that some of the big new players withdrew from the markets as profit margins were too low to sustain business even in generally high volume markets.

Later in high density areas regions and cities have pursued and extended tendering of local and regional transport services. Incentives were installed to link service providers' profits to quality and market success. In the medium term high density areas have opened all rail networks for horizontal and vertical competition. While market opening and tendering processes had been completed in the 2030s for high

density areas, low density countries followed in opening their networks for international and private competition. However, care was taken to preserve the national carriers in order not to create market monopolies in European rail travel with the strong carriers from central countries as market dominating forces. Therefore, the network opening has started gradually with high volume international corridors. Some sensitive networks remain partly closed to free competition.

The 2050 vision: Following the developments of the past 35 years, railway markets in Europe are now open to multiple levels of competition. Passengers and goods forwarders have gained from this development by more attractive products and services and by better price structures.

4.3.4 Location of companies

In the early 2000s the accessibility of urban areas for delivery traffic and the competition of communities for companies still provided more incentives for companies to adopt dispersed patterns of location, often in the country side. Under these location patterns the use of rail was rather difficult and trucks still constituted the means of choice for most forwarders.

With sustainable urban and regional planning becoming more popular, high density areas have re-discovered the concept of concentrating goods flows at the city border to provide greater efficiency for urban deliveries. This brought about a wave of re-vitalisation, of urban goods distribution centres (GDCs) and similar concepts. By 2030 most cities and many delivery branches adopted this system. All centres have been linked to nearby rail terminals or have even been arranged around them. Beyond 2030 virtually all goods movements from and to agglomeration areas pass through urban GDCs for minimising local commercial traffic. For transport from and to and between the GDCs, rail transport is highly competitive. Although there was no direct pressure for companies to alter location policies, access to the important markets in large agglomerations and in central countries incentivised them to ship by rail. Firms then increasingly started to move closer to rail stations and transshipment terminals.

The 2050 vision: Partly triggered by policy incentives, and by autonomous decisions, industrial and retail companies are now mostly located around freight railway stations or terminals.

4.3.5 Standards, regulation and prices

A unique platform for price information and booking of tickets or cargo shipments did not exist in European passenger and freight rail services by the early 21st century due to different data standards. These services and their prices remained opaque to the end user and this put cars, trucks and airplanes into a privileged position although rail might have been the better choice. Certification processes for new rolling stock or trading of used locomotives and wagons was extremely difficult as national standards blocked the evolution of a functional second life market. This and the small size of the rail equipment market raised rolling stock costs extremely high. Furthermore, the railways suffered from different labour and safety standards between the modes.

Basic booking standards had been unified by 2020. This enabled passengers to see prices and to reserve tickets for trans-European journeys on a variety of booking portals. The European Railway Agency (ERA) pushed forward the unification and simplification of the jungle of national admission and licence rules for rolling stock. By retrofitting existing rolling stock most

locomotives and railcars are capable and certified to operate under the train control systems of neighbouring countries. The cost difference between road and rail was levelled out for the benefit of rail services. After 2030 the standardisation of train control systems moved forward, development and licensing costs for rolling stock declined and the capacity of the network increased due to the standardisation.

The 2050 vision: Thanks to the clear guiding principles jointly formulated and pursued by European and national institutions and the rail sector, data standards and information transparency are now unified across Europe where such unification creates value for the end user. This might be passengers as well as goods forwarders.

Figure 6 highlights the three most relevant trends identified for spatial planning, urban design and transport policy. From the local to the European and trans-European level

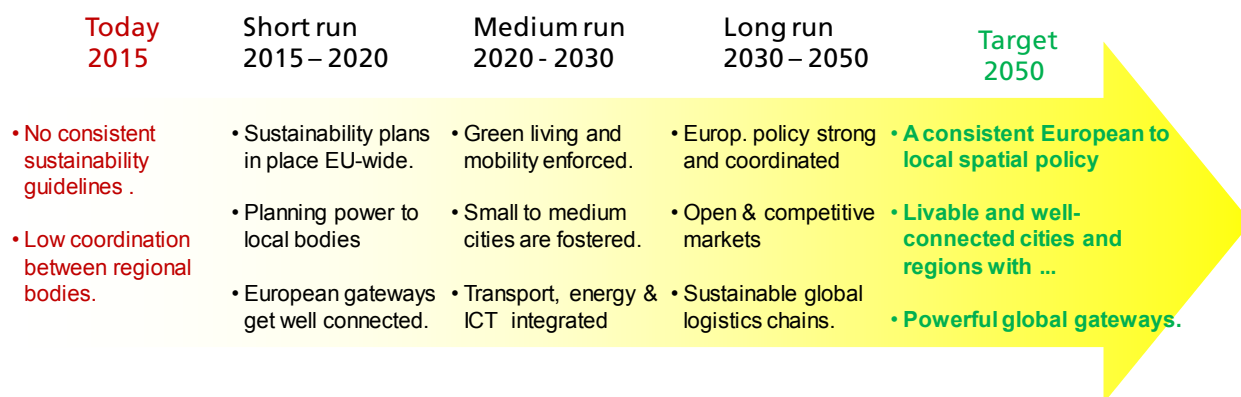


Figure 6: Pathways to Vision 2050: spatial and urban development and policy

4.4 Mobility Services

Mobility solutions can be manifold and of course we can always dream of fancy contradictions such as faster but more reliable, convenient but cheaper, more flexible but simpler and so on. But as we are now in 2050 and have far more satisfied and relaxed customers than four decades ago, the demand for ever faster and cheaper mobility services has become less pressing.

Instead flexibility and reliability, convenience, good information and affordability have emerged as the most important qualities expected from the transport systems. This has led to highly multi-modal urban transport systems for seamless access to long distance services, to powerful personalised and privacy-protecting information systems and to all-inclusive platforms for freight bookings. The backbone of these services however was and still is the reform of all European rail carriers to customer oriented mobility and service providers.

4.4.1 Customer orientation

Railways of 2015 already were able to offer competitive cross-border freight services on many corridors, but when it came to passenger services, one found a mixed picture.

Having recognised the negative loop of low service quality, market volumes and profitability of certain services, rail carriers re-thought their internal decision processes and conducted serious market research to get closer to their customers. A shift in market behaviour and higher quality standards was demanded and appreciated by many, but in particular by the growing number of elderly passengers.

Towards 2030 rail carriers came up with innovative customer services such as instant door-to-door or station-to-station luggage services which to a large extent solved the ever growing space problem on inter-city connections. Passenger satisfaction polls, compensation payments and constant service improvements became common and were well received by passengers as well as by freight forwarders.

After 2030 the attention of railway marketing and market development efforts turned towards multi-modality. As quality issues had largely been improved by all railways, towards the middle of the century passengers asked more for additional or value added services on board and in stations. The railways reacted to that by providing recreation, infotainment, retail and other services on board of trains as well as in stations..

The 2050 vision: Highly customer-oriented railways value user satisfaction and affordability as important as operational efficiency and cost savings. Railways have managed to find a good balance of operational efficiency to keep prices low, and direct customer care.

4.4.2 Passenger intermodality

Outside the big metropolitan areas – and sometimes even there – rail stations were often perceived as uninviting, grey or even scary locations, solely designed for getting on and off trains.

By 2020 all rail stations in large cities become fully accessible, more lively and attractive through the increased presence of helpful and well-trained staff, WiFi availability and commercial facilities. In small and medium sized cities rail stations became better connected and more accessible from the outside simply by

improving and securing parking lots, facilities for bikes and the connection to public transport.

By 2030 all medium and long distance rail stations developed into multi-modal hubs providing access to PT, sharing and rental systems. .

The 2050 vision: Rail and major PT stations are multi-functional hubs for fully integrated mobility systems and for economic, social and cultural urban life.

4.4.3 Intermodal freight

Back in the late 20th century the forwarders had to organise demanded planning of the actual shipment if a scheduled container train was not used..

Short term: In the short run rail companies all across Europe developed tailored logistics products and marketed them by directly approaching industry companies. This proactive behaviour by the railways managed to convince some industry branches of the feasibility and benefits of shipment by rail. Especially in high density areas railways developed and introduced rail quality targets. Besides punctuality, reliability and safety these referred to environmental, customer care and information issues.

In the medium term the big rail carriers have managed to offer one-stop-shops for all trans-European rail movements with the option of short-term booking or cancellation. These included not only the haul by freight rail, but the entire logistic chain.

Towards 2050 independent booking agencies managed the organisation of multi-modal freight transport chains for railways, haulage companies, shippers and airlines. Thus the final customer no longer needed to choose a transport mode, but received the most suitable service available for its specific purpose. Rail freight largely profited from that trend as the complexity of its use was finally hidden from the forwarder. Consequently the system became more efficient and freight rates dropped significantly.

The 2050 vision: Multi-modal service entities organize highly reliable and cost-efficient trans-European logistics chains of any complexity for all industry sectors..

4.4.4 Always informed

By the early 21st century travelling by rail in Europe in most cases was more an adventure than a smooth

travel experience. Announcements in national languages only, different information systems and company philosophies and the use of non-compatible IT standards turned passenger rail more into an insider system. In freight the missing connection of senders to their cargo via tracking systems as in road or sea transport caused many forwarders to go for these options.

In the late 2010s the railways pursued to publish more and more on-trip information on smart phones, computers, screens in trains, announcements, etc. By 2030 multi-modality had long outgrown its market niche and was widely used by citizens all over Europe. The entailed information needs were satisfied by multi-functional info systems connecting rail / PT to other modes and other services. Also in freight transport the information base for pre and on trip

information was widely improved. Electricity-connected freight wagons provided the option of installing sensors to monitor cargo conditions and to locate the wagons across all Europe.

Beyond 2030 multi-modal transport planning and on-trip information were more and more embedded in general personalised information platforms.

The 2050 vision: By 2050 fully personalized information on all aspects relevant to trip planning and traveling is available anywhere in real time via multiple channels for passengers and freight forwarders..

Figure 7 the major steps on the pathway to 2050 for these three sub-themes.

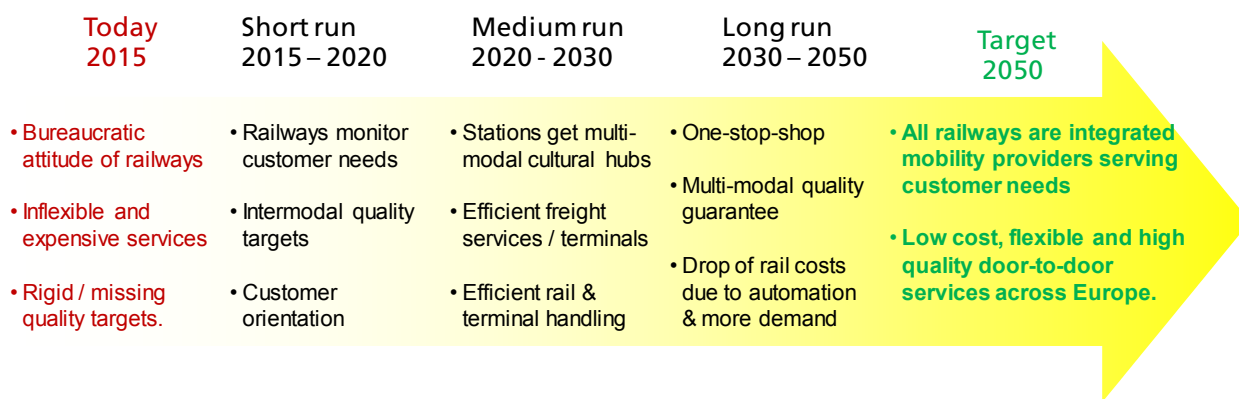


Figure 7: Pathways to Vision 2050: mobility services

4.5 Rail System

From the early 2000s until today, we have seen major paradigm shifts in the sector. During that period many rail companies focussed on defending domestic markets, cost control by staff and service reduction and on high speed solutions for premium markets. Only a few companies recognised the shift in passengers' and freight customers' expectations and shifted resources from internal process management to customer care. Accordingly, low cost air carriers, car and truck continued to gain market shares, particularly in peripheral and low density countries. Network Development

In 2015, the European rail network was composed of a bewildering and contradicting patchwork consisting both of world-leading high-speed rail lines, dense and well connected urban and regional networks using high-capacity and energy-efficient rolling stock, as well as poorly-connected networks with notable national and international gaps, using ageing rolling stock.

Although EU member states possessed one of the most extensive high-speed rail networks in the world, the required connectedness between countries were largely lacking.

However, the seeds of future change could be seen. As well as the large scale reopening of viable lines on

a regional and urban basis, a large number of well-known gaps in the European network were filled.

In the medium term major lines between agglomeration areas are upgraded to 250 km/h through a combination of new rolling stock and improved infrastructure. Feeder lines to the HSR network have also been expanded. High speed rail with airports have now been integrated better. Increasing separation of passenger and freight rail traffic, as well as the benefits of more reliable passenger timetables, has also led to a reduction of maintenance costs.

In the long term almost all existing lines have been electrified. Coupled with a radical shift to renewables in the energy sector this has led to a large reduction in transport-related GHG emissions in the European Union.

The 2050 vision: There has been a three- to eightfold expansion in rail system capacity for both passenger and freight. A well maintained and high quality electrified European rail network allows fast and reliable operations to all major and medium sized destinations across the continent.

4.5.1 Automation and train control

In 2010 Europe consisted of more than 20 different train control systems, six different power systems and several gauges, profiles and train length restrictions. Train paths had to be booked far in advance, additional traffic or disturbances often led to heavy knock-on delays and – because of that – the physical capacity of the networks was inefficiently utilised.

Major rail companies and infrastructure managers started to modularise and standardise their communication systems. More and more countries implemented the European Train Control System (ECTS) Level 2. At the same time, specifications for a cost-effective, completely flexible block-free train remote control system (ERTMS Level 3 or similar) were developed by the rail industry. A common European freight wagon standard for automatic coupling and uncoupling was developed and approved.

By 2030 all major networks used the same communication and signalling standards and functions. On major freight lines automated coupling technologies were introduced. This increased line capacity by 40% and cut costs by simpler operations and rolling stock.

By 2050 all networks in central countries of the Community have replaced all track side signalling equipment by the standardised European satellite and ICT based train control system. All freight trains use automated coupling for faster shunting operations.

The 2050 vision: Today, organising rail paths through Europe is as easy as booking flight slots from one airport to another. Thanks to a fully implemented and jointly improved ETCS Level 3+ train paths can be added, altered or removed almost in real time on large parts of the European network. Track capacity has tripled thanks to these flexible control and allocation systems.

4.5.2 Rolling stock and rail industry

Rail vehicles were very safe, but heavy and expensive. New rolling stock took a long time to achieve authorisation for use, but then had a lifetime in service of up to 50 years. Rail vehicles are very safe, but heavy and expensive.

Agreement between the national administrations was reached to extend the remit of the EU standards authority for rolling stock for international use. Rapid retrofitting of passenger and freight vehicles quickly improves user acceptance.

EU standards for rolling stock construction have been defined. The design of rolling stock is changed to provide comprehensive ICT for wagon monitoring and control and personalised infotainment in coaches. All passenger coaches are comfortable and well designed for working and recreation.

Thanks to drastically increased demand the European rail industry has accelerated its development processes. Coaches and wagons are modular, with major upgrades or full replacement every 10-15 years helping the latest technology to enter markets quickly, supported by the adoption of common EU standards for rolling stock for international traffic, adopted for many vehicles for leasing.

Lightweight rolling stock has reduced energy requirements, enabling goods trains in particular to achieve faster transit times with smaller locomotives and much lower energy costs..

The 2050 vision: Highly innovative, modern and energy efficient rolling stock provide passengers and goods forwarders with low costs, high comfort and latest ICT services. Coaches and wagons are modular,

with major upgrades or full replacement every 10-15 years helping the latest technology to enter markets quickly.

4.5.3 Timetables and rail services

A concern of railway customers in the early 2000s was that long-distance intercity and night trains were removed from time tables, became less attractive or were badly connected to high speed or local services. Headways between main line departures were generally perceived to be too long and prices of rail services compared to air fares were considered too high in particular by non-business travellers. The expansion of high speed international networks was slow and was limited to a relatively restricted number of routes.

By 2020 passenger rights provisions motivated the railways to make major improvements in punctuality and reliability. On-time arrivals exceed 95% on all networks, which is achieved by the conventional measures of more time buffers and by compromising on overall travel times. Long-distance night trains have been re-established between many European metropolitan areas and major cities in low density areas

have been connected to the European high speed network.

Learning from the night train success story and following low cost airline business models, more and more private investors engaged in running rail services. The emerging “low cost railway” model finally regained considerable numbers of passengers formerly lost to coaches and low cost airlines.

The 2050 vision: All large and medium sized cities across Europe are connected by reliable, very frequent, high quality services. The rail system is now set up so that there is a cost-effective and attractive service for low cost, business and premium market segments.

Figure 8 presents the vision topics on the theme “Rail System” which have been selected most relevant including their development from 2015 to 2050.

In the following chapter the measures which were taken to achieve today’s powerful state of the railways are presented. After first going through the four vision

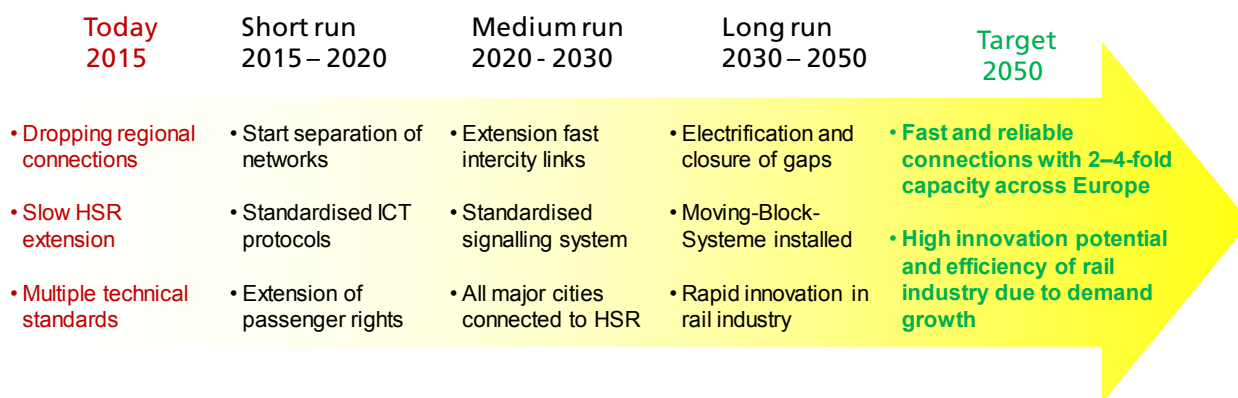


Figure 8: Pathways to Vision 2050: rail system

5 The LivingRAIL 2050 Railmap

5.1 Review of Measures for 2050

In this section we give a brief summary of the suit of measures developed in the fields of policy and spatial development as well as in rail technology and organisation. For details on the respective measures please consult the respective Deliverables 3.2 (Jaroszweski et al, 2015) and 4.2 (Biosca et al., 2015) as well as the databases on current practices and 2050 measures developed by the project team. All of these materials are available through the LivingRAIL website at www.livingrail.eu.

There is not a single measure dominating all others. The achievement of the mode share targets defined by the LivingRAIL framework scenarios (Deliverable D2.3, Fiorello et al., 2013) thus needs to take into account a multitude of push and pull actions to provide good services with high accessibility and to stimulate peoples' mode choice behaviour.

5.1.1 Rail technology and operation

The measures included under the 'rail system and technology' theme (as covered in Deliverable 3.2) describe activities which can be performed by players within the railway business to support the sector. These measures have a strong technological and infrastructural element, but also include 'soft' pull factors emanating from within the rail sector designed to make the railways more attractive to passenger and freight customers. The major themes are grouped as 'stations, services and customer relations', 'design and traction' and infrastructure. Each of the themes is further structured in three to four topics. The stations, services and customer relations breaks down further into specific measures relating to customer relations, services and ticketing, and stations. Design and traction includes specific measures for the sub-areas of rolling stock design, emerging solutions and future concepts, which cover ideas which are currently in their infancy but show the potential of being adopted in the medium to long-term, and finally freight rolling stock measures. Infrastructure measures include

capacity and coverage, signalling, control and maintenance technology and freight infrastructure.

The type of measures and the way that they are applied is determined by the intended market. In LivingRail we focus on three markets: medium-distance passenger rail, urban passenger rail and freight. To achieve the White Paper targets of 50% modal share for rail over medium to long distances within Europe an expansion of both national and international routes must be made. Measures to increase greatly expand the European High Speed Rail Network and to reopen closed railways are intended to expand the coverage of rail across the Union. Measures to increase the line capacity and reliability of the network include moving block signalling, automated trains and remote conditioning. Measures focusing on higher capacity passenger and next generation trains contribute both to increased capacity and greater competition with air transport over longer distances.

A strong element of achieving a substantial modal shift from car to rail transport in urban areas will come through better service provision and marketing, acting as pull factors. Here we see the measures of taking soft factors seriously, quality of commute, tariff/mobility associations, integrated mobility platforms and improved onboard information provision as highly important and linked. Similarly to intercity passenger transport, higher capacity passenger trains is an important measure here. Urban environments are likely to continue to be the areas where new signalling and control systems such as moving block and automated trains are introduced first.

For freight transport, we again look at increasing capacity and coverage through dedicated freight lines and reopening closed railways. However, we also look at the logistical structures and processes that could help rail compete with road freight including intermodal hub control and intermodal freight terminals. It has to be conceded that road transport has an almost insurmountable advantage to rail over shorter distances, and that road-based freight will always have some

role in the last leg of journeys. Hence we advocate an expansion of rolling motorways/trucks on trains, which will confer many of the benefits of rail (speed, lower carbon consumption) to road freight for the majority of the consignment's journey.

5.1.2 Policy and spatial development

Mobility management and information in urban as well as in long-distance travel plays a key role in altering daily routines and informing people on the services offered by rail and public transport. However, this will only work if tailored to people's actual needs and if rail and PT services are multi-modal, accessible and of sufficiently high quality.

Urban and regional mobility behaviour plays a decisive role for mode choice in inter-urban mode choice. Transit oriented development concepts fostered by powerful authorities and mobility associations appear as promising strategies supporting the positive development of many cities in Europe and worldwide.

Pricing of competitors to rail and public transport, namely trucks and cars, have the potential to directly impact mode choice behaviour. However, pricing measures may impose considerable social impacts. We thus consider soft forms, such as parking management in cities and the regulation of social standards to be applied to their full extent first. Advanced pricing regimes are then considered most suitable for large cities and high density regions.

Reforming the market orientation of the railway sector and the decisiveness of transport policy is found to be of ultimate importance for the achievability of the White Paper targets. The installation of powerful incentives towards the customer orientation of rail and PT companies as well as the co-ordination of regional to European transport planning is needed to erect a mature and self-confident railway sector.

5.1.3 The complete measure database

In total 62 measures were considered relevant for realising the LivingRAIL vision 2050. These consist of 24 policy and spatial development measures, 25 railway sector measures and 12 measures which were added during the final consistency checks of the roadmap. All measures were labelled by the following attributes:

- *Package* denotes a particular policy or technology package to group the measures by their nature (infrastructure, rolling stock, stations, services, mobility management, etc.).
- *Market*: type of transport (urban mobility, inter-urban passenger transport, freight).
- *Actor*: sector or institution in charge of action (international / national policy, local policy, transport sector (service & infrastructure providers), transport industries, users and customers, SP ??)
- *Effectiveness*: the measure reporting forms provided estimates of the likely increase of rail and PT shares by type of region. By relating these to a 20% increase we defined a score value normalised around 1.0.
- *Affordability*: Cost values have been estimated by some reporting forms. Additionally we have used expert votes on effectiveness in terms of mode shift (Special Report SR1) to define a score value between zero and 1.00.
- *Rank*: Internal discussions set the effectiveness : affordability weight to 60 : 40. With a final score computed accordingly, the 62 measures were ranked from 1 (highest priority) to 62 (lowest priority).

The measures which have been selected for the final Railmap 2050 are presented in Table 1. The internal selection process of measures for the Railmap has ruled out a number of candidates which are of low mode share relevance, expensive or come along with major negative side effects. One example are inter-urban truck, car and air charges. Due to their potential disturbing impact on social equity, which may fall back on peoples' attitudes towards rail, it was decided not to list them in the Railmap.

However, later in this report funding options are discussed. Here we will find that cost advantages of the railways matter a lot for mode share in case their quality is of an acceptable level. Furthermore we will find that funding a high quality rail system requires some portion of cross-funding from road and air, at least in the coming decade. So the indirect impact of road and air pricing on the railways' funding condition plus the competitive advantage are important reasons for bringing this instrument back into play as a financing tool.

Table 1: Overall set of measures

Measure Short Title	Package	Actors	Markets	Short run	Med. run	Long run	Effec- tiveness	Afforda- bility	Rank
				2015-2020	2020-2030	2030-2050			
Freight network design	Networks	IP, TS	F	LDA+HDA	LDA+HDA	LDA+HDA	2,93	0,43	1
Incentives for customer orientation	Rail reform	IP, TS	U, I, F	HDA	LDA+HDA	LDA	2,07	1,00	2
European HSR network	Networks	IP, TS	I	LDA+HDA	LDA+HDA	LDA	2,40	0,15	3
Inclusive multi-level mobility planning	Planning	IP	I, F		LDA+HDA		1,87	0,94	4
Close network gaps	Networks	IP, TS	I, F	LDA+HDA	LDA+HDA	LDA+HDA	1,75	0,75	5
High train service frequencies	Services	TS	I		HDA	LDA+HDA	1,70	0,50	6
Urban car pricing	Urban policy	LP, IP	U		LDA+HDA		1,39	0,83	7
Multi-sector rail funds for remote regions	Funding	IP, LP	U, I, F	LDA+HDA	LDA+HDA	LDA	1,67	0,33	8
European logistics brokerage platforms	Services	IP, TS	F	LDA+HDA	LDA+HDA		1,20	1,00	9
Mobility & accessibility plans	Urban policy	LP	U		LDA+HDA		1,22	0,86	10
Networks for longer / wider trains	Networks	IP, TS	I, F		HDA	LDA+HDA	1,20	0,87	11
On-trip internet access	Services	TS	U, F, U	LDA+HDA	LDA		1,00	1,00	12
Door-to-door logistics info systems	Services	TS	F	LDA+HDA	LDA+HDA		1,21	0,67	13
Market research on customer needs	Rail reform	TS, TI	U, I, F	LDA+HDA			0,98	1,00	14
Mobility management for employers	M. Managem.	LP, UC	U, I	LDA+HDA	LDA+HDA		1,13	0,77	15
Intermodal freight facilities	Stations	IP, TS	F	LDA+HDA	LDA+HDA		1,48	0,23	16
Slow zones in cities	Urban policy	LP	U		LDA+HDA		0,90	1,00	17
Passenger stations to urban centres	Stations	LP, TS	I, U		LDA+HDA	LDA+HDA	1,16	0,60	18
Re-vitalise rail stations	Stations	LP, TS	U, I		LDA+HDA		1,27	0,43	19
Rolling stock modernisation	Rolling stock	TS, TI	I, F	LDA+HDA	LDA+HDA	LDA+HDA	1,27	0,40	20
Urban parking policy	Urban policy	LP	U	LDA+HDA			0,91	0,93	21
European track access standards	Regulation	IP	I, F, U	HDA	LDA+HDA		1,07	0,65	22
Regular freight shuttles	Services	TS	F		HDA	LDA	1,30	0,30	23
European interoperability standards	Regulation	IP, TI	I, F	LDA+HDA			1,03	0,68	24
Fully autonomous trains	Rolling stock	TI, TS	U		LDA+HDA	LDA+HDA	0,93	0,80	25
Car free residential areas	Urban policy	LP	U		LDA+HDA		0,85	0,90	26
Simplify rolling stock specifications	Regulation	IP	I, F	LDA+HDA	LDA+HDA		0,78	1,00	27
Green and walkable cities	Urban policy	LP	U	HDA	LDA+HDA	LDA	1,02	0,64	27
Upgrade intercity rail lines	Networks	IP	I		LDA+HDA		1,20	0,33	29
Mobility associations	M. Managem.	TS, LP	U	HDA	LDA+HDA		1,13	0,40	30
Multi-modal PSOs in all remote regions	Funding	LP	U	LDA+HDA	LDA		1,27	0,20	31
Simplify time tables & ticketing	Services	TS	U, I	LDA+HDA	LDA		0,73	1,00	32
Freight customer rights	Rail reform	IP, TS	F		LDA+HDA		0,90	0,70	33
Key performance targets	Rail reform	IP, LP, TS	U, I, F	LDA+HDA			0,93	0,60	34
ETCS Level 3 Moving Blocks	Networks	TS, IP	I, F		HDA	LDA+HDA	1,03	0,40	35
Emotionalise rail	M. Managem.	TS, TI	U, I	LDA+HDA	LDA+HDA		0,74	0,83	36
Standards guide for regional planning	Planning	IP, LP	U	LDA+HDA			0,62	1,00	37
Green mobility in education	M. Managem.	IP, LP	U, I, F	LDA+HDA	LDA+HDA		0,60	1,00	38
Sustainable company networks	M. Managem.	UC, LP	I, U	LDA+HDA	LDA+HDA		0,58	1,00	39
ICT tools to replace travel	M. Managem.	IP	I	LDA+HDA	LDA+HDA		0,58	1,00	39
Customer advisory boards	Rail reform	TS, LP, UC	U, I, F	LDA+HDA	LDA+HDA		0,57	1,00	41
Approach swing users	M. Managem.	LP	U	LDA+HDA	LDA+HDA		0,67	0,85	41
Powerful TOD authorities	Planning	LP	U	HDA	LDA		0,83	0,60	41
Quality and availability guarantee	Rail reform	TS, IP	I, U	LDA+HDA	LDA+HDA		0,90	0,50	41
Sustainable business travel	M. Managem.	LP, IP	U, I	LDA+HDA	LDA+HDA		0,82	0,60	45
Harmonise fiscal governance in Europe	Funding	SP	U, I, F		LDA+HDA		0,62	0,80	46
Open networks for test applications	Regulation	TS, IP	I, F	LDA+HDA			0,54	0,90	47
Electrify all major lines	Networks	TS, IP	I, F	LDA+HDA	LDA+HDA	LDA	0,73	0,60	48
Advanced maintenance & risk planning	Planning	TS	I, F	LDA+HDA	LDA+HDA		0,62	0,70	49
Regional logistics concepts	M. Managem.	LP, TS, IP	F	HDA	LDA+HDA	LDA	0,85	0,30	50
Green logistics label	M. Managem.	IP	F	LDA+HDA			0,35	1,00	51
Health & sustainability in public procedures	Planning	LP, SP	U, I, F	LDA+HDA	LDA+HDA		0,54	0,70	52
Reform national accounting systems	Planning	SP	U, I, F			LDA+HDA	0,54	0,65	53
Feeder services to rail on demand	Services	TS	U	LDA+HDA	LDA+HDA		0,50	0,67	54
Revitalise urban / regional light rail	Networks	IP, LP, TS	U	LDA+HDA	LDA+HDA	LDA+HDA	0,77	0,25	55
Inter-modal master plans	Planning	IP	F		LDA+HDA	LDA+HDA	0,44	0,73	56
LCA decision guidelines	Planning	IP, TS	I, F, U	LDA+HDA			0,29	0,85	57
Car-free tourism	M. Managem.	IP	I, U		LDA+HDA	LDA	0,36	0,60	58
Rail based hybrid modes	Rolling stock	TI	I, F			LDA+HDA	0,42	0,40	59
Vehicle re-design processes	Rolling stock	TS, IP	U, I, F	LDA+HDA	LDA+HDA	LDA+HDA	0,28	0,60	60
Modular train concepts	Rolling stock	TI, TS	I, F			LDA+HDA	0,35	0,45	61
Alternative fuel trains	Rolling stock	TI, TS	I, F, U			LDA+HDA	0,21	0,45	62

Legend: HDA: high density areas, LDA: low density areas, IP: (inter)national policy; LP: local policy; TS: transport sector; TI: transport industry; UC: users/consumers;

Figure 9: Landscape of measures according to mode shift efficiency and fiscal affordability

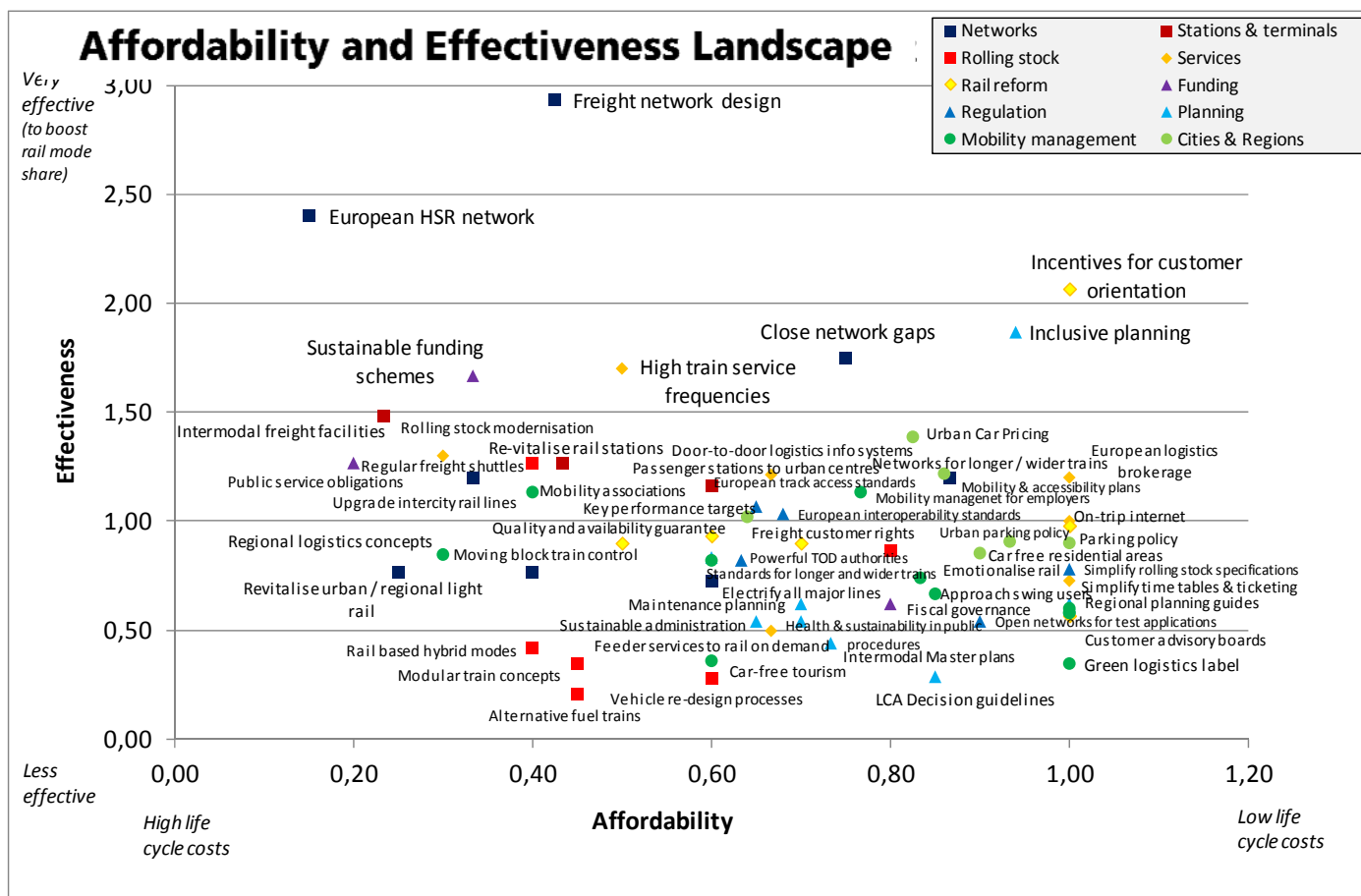


Figure 9 presents a plot of the 62 measures according to their scores in affordability (x axis) and their effectiveness to shift demand towards rail modes (y axis). In the centre top we see the heavy network investment measures, i.e. the completion of the European high speed network and the installation of high capacity freight corridors. Closer, but still on top of the cloud of measures is the closure of network gaps, which appears way more affordable but still very effective compared to the above mentioned investments.

Least cost and most effective are two measures located at the right upper corner of the landscape: incentivising customer orientation of the railways and inclusive planning processes. Both measures are addressed to policy and the rail sector and aim at pulling the railways into a position where they can and must actively shape and address their business environment. This is turning passive and process oriented state owned bureaucracies into vital market players.

The remaining measures are clustered in a dense cloud in the medium to low effectiveness part of the landscape. In the right upper sector of the cloud we find several urban interventions plus measures on IT platforms and standards.

5.2 Railmap in a nutshell

The LivingRAIL railmap is composed of 62 single measures, which partly describe larger activities and strategies, and partly refer to more detailed interventions. This suite of measures gives an indication which areas need to be looked in case the EC White Paper targets are taken seriously by rail companies and policy institutions. The measures are not elaborated in full detail as an important part of job if these two groups of players is to regularly reflect on their goals and their options and limitations for action.

We gave the measures a broad start and end time, differentiated by the two area types defined in LivingRAIL: Low density, peripheral and low income areas

(LDA) and high density, central and high income areas (HDA). Some of the measures, e.g. network investments or regulations, need to be pursued over the entire period from now (2015) to 2050, while others remain in one of the time slots (short, medium and long term). As the goal of 50% market share of rail and PT is extremely ambitious, most of the measures need to be started in the short or at least in the medium run. A frequent regional pattern is that HDA countries start with activities and LDA follow or take more time for completion.

The rank of the measures, reflecting effectiveness and efficiency, clearly points on network extension and upgrading measures to be fostered with most urgency, this is relevant to enable the rail system to cater the three to five fold demand increase expected by 2050. Second, however, come railway and policy reforms, integrated planning and services. Most relevant services are considerably higher train frequencies in all regions, door-to-door offers, guidance and information in passenger and freight, and Europe-wide logistics brokerage platforms. These themes are closely inter-linked as without a clear vision among all parties on where the transport sector shall develop to, and without open, market oriented and self-confident companies and institutions this enormous endeavour is at high risk.

Urban policies (rank 5) and mobility management (rank 7) together are targeted to impact peoples' and companies' perception of mobility. Although the single measures appear rather detailed (mobility management for employers, mobility and accessibility plans, etc.), in total they should provide a stable basis for the railways' service initiatives to be accepted. Between them, funding options play a major role for getting the above (and below) investment measures on track. What is needed are flexible instruments in the short to medium run, while in the long run the railways' income from passengers and freight customers will pay back all investments. The remaining measures stations, rolling stock and regulation fill important gaps in the policy and service landscape, but are not alone capable to alter mode shift decisions in passenger and freight transport considerably.

To each of the measures potential actors from policy, the transport sector or private players are assigned. From the ranking of measures we see that the most important are to be carried out jointly by international policy and the transport sector. Local policy (LP) follows with urban and mobility management measures and thus likewise plays a decisive role. Transport industry only appears from rank 20 downwards when talking about user-friendly equipment design, interoperability and ETCS level 3 standards, etc. Users and companies as *actors* only appear in the lower part of the list. However, as those parties finally taking the decision how to travel and move goods, they may eventually play the most relevant role of all.

Looking at the three transport markets we see no particular one concentrating in the upper part of the ranking of measures. Top ranks are being held by freight (F) networks, HSR and inter-urban (I) train frequencies and urban (U) car pricing. But we also see general ones like incentives for customer orientation, inclusive planning and network gap closure. There is only a slight tendency that inter-urban measures are ranked a bit higher as here higher volumes of traffic (in pkm / tkm) are reached compared to urban measures.

For the first quick overview we can conclude that of course expensive investments into the rail sector are needed. However, flanking measures making railways and policy capable to act, and providing users with the right incentives to decide for rail, are equally important. International policy and the transport sector (rail and PT companies) play the most relevant role and need to push forward capacity and quality enhancing measures on the European passenger and freight rail networks. Low density countries are considered to have more time to act and erect their networks than high density areas.

The following set of roadmaps presents the measures by timing and region. Market sectors and players are indicated by respective labels. Most obvious is that nearly half of all measures needs to start now in order to achieve the White Paper targets in 2050.

		Current status (2015)	Short term (2015 - 2020)	Medium term (2020 - 2030)	Long term (2030 - 2050)	Vision (2050)
Vision	Values and lifestyles of companies and people	Campaigns to promote environmental behaviour and sustainable policies often fail or progress slowly and are frequently dominated by business concerns.	A shift towards more sustainable behaviour of people and companies becomes visible. Work-life-balance and flexibility gains increasing importance for employees and employers.	Sustainability and sustainable quality of life has become element in general services like school curricula's or public administration. Attitudes towards car use have become largely pragmatic.	Consistent governance guarantees compliance with sustainability goals among all citizen groups and companies. Thanks to good PT services car use has dropped significantly even in low density areas.	People, companies and the public sector put high priority on sustainability, health and inclusion in decisions across all parts of society. Flexibility has reduced the need for travel and car use in particular.
	Spatial and urban concepts for a liveable and connected Europe	Consistent guidelines for sustainable urban, regional and large-scale planning and development are missing, coordination between regional bodies is low. Living standards differ in Europe.	Urban and regional sustainable development plans are in place all over Europe, planning power is devoted to local bodies and European gateways are well connected.	Agglomerations enforce PT-based green living and mobility, small to medium sized cities are fostered. European and national transport, energy and ICT plans integrated.	Strong European policy ensures open and competitive markets and sustainable rail-based global and continental logistics chains.	A consistent European to local transport and spatial policy creates liveable and well-connected cities and regions with powerful global gateways.
	Customer-oriented multi-modal passenger and freight services	Railways services are planned and managed with a bureaucratic approach without considering customer preferences and constraints. Services are slow, inflexible and expensive. Quality targets are rigid or non-existent.	Railways monitor customer needs along trip/shipping chains; quality targets for passenger and freight services across all modes are set and first steps towards customer orientation are taken.	Passenger rail stations get multi-modal and cultural hubs; freight services and intermodal terminals improve on efficiency and quality through automation and standardization. Costs of rail use decline considerably.	One-stop-shop services for trip and shipment chains enter markets. Multi-modal quality targets are met by most mobility service providers. Rising demand automation and standardization lowers costs considerably.	All railways have developed to integrated mobility alliances serving customer needs on all parts of mobility chains. Low cost, flexible and high quality door-to-door services are offered across all Europe.
	Network development, automation and train control	Expansion of HSR lines is slow; secondary and branch lines closed, network maintenance suboptimal in many countries; many lines not electrified. More than 20 different train control systems in Europe, all based on fixed blocks.	Separation of passenger and freight networks starts with adjusting each to future train weights, lengths and dimensions. All major rail companies have simplified and standardised their communication and train control systems.	Most networks have standardised communication and signalling. Autonomous trains are used for long-distance services. Increasing demand for rail equipment reduces innovation cycles and cuts production costs.	Existing lines are electrified where suitable; non-electrified sections are served by hybrid locomotives. Comprehensive cross-border links are established. Moving block signalling for all railways. Trains are fully interoperable.	All agglomerations are connected to HSR; reliable, frequent and high quality direct passenger and freight services provide access to all European regions.
Measures	Current (2015)	<ul style="list-style-type: none"> U I IP TS Freight network design (1) I IP TS European HSR network (3) I F IP TS Close network gaps (5) U I F IP LP Multi-sector rail funds for remote regions (8) U I F IP TS European logistics brokerage platforms (9) U I F IP On-trip internet access (12) U I F IP Door-to-door logistics info systems (13) U I F TI TS Market research on customer needs (14) U I LP TS Mobility manager for employers (15) I F IP TS Intermodal freight facilities (16) I F TI TS Rolling stock modernisation (20) U LP Urban parking policy (21) I F IP TI European interoperability standards (24) U LP Simplify rolling stock specifications (27) U LP Multi-modal PSO's in all remote regions (31) U LP Simplify time tables & ticketing (32) F I U IP LP TS Key performance targets (34) I U TI TS Marketing to emotionalise rail (36) F I U IP LP TS Planning tool for sustainable regions (37) F I U IP LP Green mobility in education (38) I U TS Sustainable company networks (39) I U TS ICT tools to replace travel (39) U I F TS TS Customer advisory boards (41) U LP Approach swing users (41) U I IP TS Quality and availability guarantee (41) I U IP LP Sustainable business travel (45) I F IP TS Open networks for test applications (47) I F IP TS Electrify all major lines (48) I F IP TS Advanced maintenance & risk planning (49) F IP Green logistics label (51) I F U IP LP Health & sustainability in public procedures (52) U TS Feeder services to rail on demand (54) U IP LP Revitalise urban / regional light rail (55) U I F IP TS LCA decision guidelines (57) U I F IP TS Vehicle re-design processes (60) U I F IP TS Incentives for customer orientation (2) F I U IP European track access standards (22) U LP Green and walkable cities (27) U LP Mobility associations (30) U LP Powerful TOD authorities (41) F IP LP TS Regional logistics concepts (50) 				
	Medium term (2020 - 2030)	<ul style="list-style-type: none"> U I IP Inclusive multi-level mobility planning (4) U IP LP Urban car pricing (7) U LP Mobility & accessibility plans (10) U LP Slow zones in cities (17) I U LP TS Passenger stations to urban centres (18) I U LP TS Re-vitalise rail stations (19) U TI TS Fully autonomous trains (25) U LP Car free residential areas (26) I IP Upgrade intercity rail lines (29) F IP TS Freight customer rights (33) F I U IP Harmonise fiscal governance in E-Funding (46) F IP Inter-modal freight master plans (56) U I IP Car-free tourism (58) U I F TI TS Alternative fuel trains (62) I TS High train service frequencies (6) I F IP TS Networks for longer / wider trains (11) F TS Regular freight shuttles (23) I F IP TS ETCS Level 3 Moving Blocks (35) 				
	Long term (2030 - 2050)	<ul style="list-style-type: none"> U I F IP Reform national accounting systems (33) I F IP TS Rail based hybrid modes (59) I F IP TS Modular train concepts (62) 				

Legend

Vision statement steps forward

Vision statements 2050

relevant for LDA and HDA

relevant for HDA

relevant for LDA

Relevant for

- U Urban / local
- I Inter-urban passenger
- F Freight
- IP (Inter-)national policy
- LP Local and urban policy
- TS Transport sector
- TI Transport Industry
- UC Users & citizens

Figure 10: Complete Railmap

5.3 Railmap by theme

In the following sections we go through the 10 themes of the railmap and draft the line of action by type of region.

Theme A: Networks

Focus: International policy and transport sector; inter-urban freight and passenger markets.

2015 – 2050: Establish high capacity trans-European freight corridors by starting with high volume routes in, from and to central Europe. By 2030 in HDA and by 2050 in LDA the European High Speed network (+10 000 km) shall be completed by new investments and line upgrades.

From 2020 on in HDA and later in LDA networks shall be capable to carry longer and wider trains and be equipped with ECTS level 3 (or higher).

Theme B: Rail and policy reforms

Focus: International to local policy and transport sector; all transport markets

Short term: Railways to conduct intensive market research on the needs and desires of their customers and freight and passenger market and to set binding performance targets in all markets.

Short to medium term: Define freight customer rights similar to passenger rights, set quality and availability guarantees for passengers with respective technical and organisational measures along inter-modal trip chains and set in passenger advisory boards for all markets and services.

Theme C: Inclusive planning

Focus: International to local policy and transport sector; all transport markets

Short run: first, the numerous activities for urban, regional and project planning shall be condensed into practical guidebooks, standards and assessment tools for cities, regions and international co-operation projects. With somehow longer perspective the installation of powerful TOD authorities first in HDA and later in LDA shall carry holistic and inclusive planning procedures.

In the medium run the EC in co-operation with national governments and the major transport associations and undertakings is to set up an integrative European planning procedure. Of utmost importance here is the connection of networks at national borders. In co-operation with the transport sector the framework shall ensure the efficient use of investment funds to maximise passenger and freight customer value.

Theme D: Services for customers

Focus: Transport sector, all transport markets

In the short to medium run one of the basic needs of customers in passenger and freight transport needs to be addressed: the establishment of European, inter-modal booking and brokerage platforms for travel and shipment opportunities. These measures for market transparency will simplify the rather complex rail production system for the customer and partly approach the simplicity of using cars and truck. Such systems do not need to be set up by the railways, but the railways as well as other transport providers have to provide timely and reliable information. In parallel, on-trip door to door information systems have to be provided and physical access to rail stations and terminals have to be organised.

In the medium to long run, when network capacity expansion measures (Theme A) show effect, service frequencies in passenger and freight markets are to be increased. Depending on city size, 1 hour to 30 minutes headways for high speed passenger services and 15 to 30 minutes headways for medium speed inter-city trains are potential goals. In freight transport regular shuttle services between important hubs and terminals shall ease shipment procedures.

Theme E: Urban and regional policies

Focus: Local policy, urban and regional transport.

In the short run systematic parking policies including parking pricing shall be exploited in all cities. Parking pricing can be used as a cost-effective and flexible form of congestion charging while raising money for green mobility projects. Large cities shall pursue and intensify a development towards green and cycling and walking friendly environments with attractive PT services. Smaller and more remote cities will take more time for the transformation, which shall be largely concluded for large agglomerations by 2030.

In the medium term the bulk of transformation processes needs to fully unfold with impact on behavioural patterns until 2050. These include the implementation of sophisticated road pricing systems for fund raising and road transport demand control, the replacement of current demand for parking spaces by compulsory mobility and PT accessibility plans for all large traffic generators and the rapid expansion of slow zones and car free city areas.

Theme F: Funding instruments

Focus: mainly national and international policy, all transport markets.

Funding is partly coming from the several pricing and taxation schemes proposed, and partly arises through the envisaged three to five times increased rail demand. But the unfolding of these measures takes time and will not arrive at equal levels in all parts of the Union. Thus, supportive measures are required in the early stages of the railmap and need to sustain probably for good in low demand areas.

In the short run, existing contractual arrangements for rail financing, e.g. public service obligations (PSO) need to be developed in a way which provides rail undertakings maximum incentives to attract passengers while allowing to test and implement creative instruments without unnecessary contractual barriers. These advanced PSOs could be funded through businesses profiting from them and / or from other transport modes via multi-sectoral transport funds.

In the medium term the unification of fiscal governance rules across the EU would be needed to make the transport funds truly inter-regional. By that way remote regions will profit from demand growth in core markets. This is justified as increased accessibility of high density areas from peripheral regions by rail promises extra ticket earnings for both sides.

In a final stage, GDP-based national accounting systems and project assessment principles are to be replaced by evaluation criteria oriented at societal development goals.

Theme G: Mobility management

Focus: mainly local policy and the transport sector with support of (inter)national policy; all transport markets.

Mobility management is the largest, and probably most inhomogeneous theme of measures in the LivingRAIL railmap. 10 out of these measures are ranked 11 and 12 (multiple assignment) in the applied effectiveness-affordability scale. Thus, and because the measures embraced by this theme directly target peoples' mode choice behaviour, mobility management constitutes a core element of the railmap.

All measures need to be set on track in the short to medium run to fully unfold by 2050. Various forms of mobility management by municipalities, company networks, employers (including the use of ICT tools for reducing business trips), by education at various levels, by multi-modal regional mobility associations, through campaigns should jointly create an atmosphere of conscious travel decisions. Young people and the large group of non-captive swing users are to be targeted most intensively.

Particularly for the logistics sector green labels should help customers to make informed decisions on the ecological footprint of products and the re-vitalisation of urban logistics centres should help to bundle transport flows to make rail more competitive on the main haul.

In the medium term the still booming tourist industry are to develop business models and markets for car free tourism.

Theme H: Stations

Focus: mainly local policy and the transport sector; all transport markets.

Thematically stations are located between network infrastructures (theme A) and urban and regional development (theme E). As the gateways to the railway system they are of particular relevance.

In the short term the railmap suggests concentrating of core freight hubs as mode shift decisions in freight are way more long-term than with passengers.

In the medium to long term passenger stations in remote areas need to be re-vitalised with staff and commercial services. In urban areas the former function of rail stations as commercial and cultural hubs as integral part of city life needs to be re-gained.

Theme I: Rolling stock

Focus: transport industry and railway undertakings; all transport markets.

Starting in the short run and persisting for good the railmap mentions two standard activities: the rapid replacement of rolling stock in particular in passenger transport every 15 years and their rapid re-design. The latter is required to link cost efficiency to quickly developing customer taste and expectations.

In the medium to long run the automation of trains and transshipment facilities will further help declining system costs and improve on capacity and reliability. Trains powered by renewable energy sources will replace diesel trains wherever electrification is not possible.

In the long run rail based hybrid road rail vehicles will enhance system accessibility in remote regions. Modular train sets will allow instant retrofitting of trains to adapt to actual needs and expectations of passengers and freight customers.

Theme J: Regulation of the railways

Focus: International policy; long-distance passenger and freight markets.

An overwhelming number of national and international standards and rules, partly more than 100 years old, is

restricting market activities and increasing costs of the railway sector. Without targeting the fundamental rights of railway staff and the safety of rail operations, the LivingRAIL railmap foresees a drastic simplification of regulations on many levels.

The process starts in the short run. First, as advocated by numerous studies, European interoperability standards need to be further unified and simplified by national and international railway agencies. The European Railway Agency ERA therefore shall take over decision power from the national agencies. Further, the EC enforces the network opening in all countries and markets for free access under fair conditions.

In the short to medium run national track access charges shall be harmonised and simplified. Also all other requirements for the international registration and use of rolling stock shall be harmonised by a strong ERA.

Table 2 summarises the 10 themes of measures and gives an indication of the main actors involved, the most affected transport markets and the overall time line. This summary emphasised, as was indicated before, that there is no specific sequence of timing, but all activities have to start now and run in parallel to have a chance of meeting the White Paper targets in 2050.

Table 2: Summary of themes of measures

Theme of Measures	No. / ranks of measures	Main actors	Main markets	Short run 2015-2020	Med. run 2020-2030	Long run 2030-2050
A - Networks	8 / 1 - 55	IP, TS	I, F	LDA+HDA	LDA+HDA	LDA
B - Railway and policy reforms	6 / 2 - 41	IP, LP, TS	U, I, F	LDA+HDA	LDA+HDA	
C - Inclusive planning	8 / 4 - 57	IP, LP	U, I, F	LDA+HDA	LDA+HDA	LDA+HDA
D - Services for customers	9 / 6 - 54	TS	U, I, F	LDA+HDA	LDA+HDA	LDA
E - Urban policies	6 / 7 - 27	LP	U	HDA	LDA+HDA	LDA
F - Funding Instruments	4 / 8 - 53	IP	U, I, F	LDA+HDA	LDA+HDA	LDA+HDA
G - Mobility management	11 / 15 - 58	LP, TS, IP	U, I, F	LDA+HDA	LDA+HDA	LDA
H - Stations	3 / 16 - 19	LP, TS	U, I, F	LDA+HDA	LDA+HDA	LDA+HDA
I - Rolling stock	6 / 20 - 62	TI, TS	U, I, F	LDA+HDA	LDA+HDA	LDA+HDA
J - Regulation	4 / 22 - 47	IP	I, F	LDA+HDA	LDA+HDA	

5.4 Railmap by type of region

None of the 62 measures selected for the LivingRAIL Railmap 2050 is exclusively designed for high or for low density areas. But from the discussion on themes of measures above we can deduct that high density areas in the European centre need to move first, and

that consequently low density areas at the European periphery may take some more time. We indicated this pattern for themes A (networks), D (services), E (urban policies) and G (mobility management).

For the single measures as well as for the themes of measures we can identify three types of patterns in timing:

- Measures or themes have the same start and end time for LDA and HDA. This does, however, not mean that the intensity of the measure is the same in all types of regions.
- Same start period, but a later end period for LDA. In this case we assume that peripheral and low density regions or smaller cities take more time to accomplish the measure.
- Later start and later end period for LDA compared to HDA. In this case HDA countries are in a more advanced starting position and are able to accomplish earlier.

We will look deeper into the latter two cases in turn.

5.4.1 Shifted implementation periods

In Theme A (Networks) we assume low density areas to start later with the implementation of networks for longer, wider and heavier trains and with the implementation of ECTS / ERTMS level 3 or higher. This is because these measures involve considerable investments, but are not decisive for running traffic.

As flexible train control systems and higher track standards are required to cater higher train frequencies, LDA countries also start later with increasing passenger train frequencies and with providing regular freight shuttle services (Theme D). We assume these measures to start in LDA only after 2030.

Expert consultations and literature work further suggested that low density areas start later with reforming railways (Theme B), with installing local and regional agencies to foster transit oriented development (Theme C) and with organising regional transport undertakings to multi-modal mobility associations (Theme G).

Finally, smaller cities in sparsely populated areas are not that much under pressure to develop and implement regional logistics concepts. To what extent LDA countries should postpone the standardisation of their network access conditions can of course be questioned, but as their networks cater lower traffic volumes the economic relevance of doing so is somewhat limited.

5.4.2 Later accomplishment in low density areas

We consider peripheral countries taking more time for the hard investment measures. This is first due to funding, and second because central countries are

often in a better starting position concerning infrastructure endowment. Both lines of argumentation are true with the completion of the European high speed network and the electrification of all major rail lines. The HSR network is virtually non-existent yet in the whole of eastern Europe and many peripheral countries still operate with diesel equipment apart from the main lines.

As concerns customer services (Theme D) we see this pattern for the installation of internet services or the organisation of door-to-door logistics solutions. Both can be wrong as internet solutions for rail passengers (or for the connected freight train) by new technologies covering all Europe and freight solutions will most likely be brought into the market by third party players other than the railways. But the sheer density of demand makes peripheral markets less attractive for private investors and thus will delay the establishment of such services.

The same line of argumentation indicates that funding solutions need to sustain way longer in low density regions compared to high demand areas. In the latter we can well assume that the mix out of more demand for the railways (and for PT) plus pricing incomes from road and air will bring the rail sector closer to cost coverage.

5.5 Railmap by sector

5.5.1 Urban and rural mobility

Out of the 62 railmap measures identified, 37 are fully or partly relevant for urban and regional mobility markets. Urban traffic is less relevant for Theme A (networks) and Theme J (regulation). In all other themes urban measures are prominently contained. This characteristic of the LivingRAIL railmap is not surprising as urban areas are the start and end point of most passenger trips – as well as the final destination of a high share of freight movements.

The six measures defining the activity theme E (urban policy) are exclusively designed for that transport market. But eight further urban measures are part of other themes: planning standards for sustainable regional planning and TOD authorities (Theme C), mobility associations (Theme G), flexible PSOs (Theme F), network re-vitalisation (Theme A) and fully automated PT systems (Theme J).

Urban areas are the main implementation platform for all measures impacting peoples' mobility behaviour as part of future lifestyles, and values. And more: cities are the object of evolution themselves. Given the on-going urbanisation trend in Europe and all over the globe the importance of cities for mobility management will even rise.

5.5.2 Inter-urban passenger transport

39 measures are exclusively or partly relevant for inter-urban passenger transport markets. These go across all action themes besides Theme E (urban policy). Exclusive measures include the European HSR and inter-city networks (A), train frequencies (D), multi-level mobility plans (C) and business travel management (G). All other measures for inter-urban passenger transport are either common network issues for passenger and freight or mobility management measures which as well work in urban areas. In other words: a concentration of only one aspect of the LivingRAIL or White Paper mode shift targets appears to be way less efficient than supporting all sustainable transport modes at the same time.

5.5.3 Freight transport

Although we have stated earlier in this report that freight was treated less intensively in the LivingRAIL

railmap, even 35 measures are identified as being relevant for this market segment. The large investment measures are priority corridors for freight (A) and intermodal terminals (H). But also general network measures like upgrading for longer, wider and heavier trains, will have a great impact on the sector. On the organisation side Freight master plans (C), Logistics brokerage platforms and respective door-to-door services (D), Freight shuttles (F), logistics labels and regional logistics concepts (G) show the broadness of potential solutions.

Some measures like passenger advisory boards or passenger rights have been re-defined to be applicable to the freight sector as well. In particular we stress the point that reforming railways and market orientation does not only refer to passengers, but also – and maybe even more urgently – to freight markets. Here the railways have to actively offer solutions which meet the actual needs of shippers and forwarders. Freight measures should have sufficient attention and priority as rail still has a better market share in freight than inter-urban passenger travel, but ideas of leaving freight markets seem to get more popular among incumbents. The increasing standardisation through containers will help the railways, but the sector definitively needs more automation and supportive services for the customers.

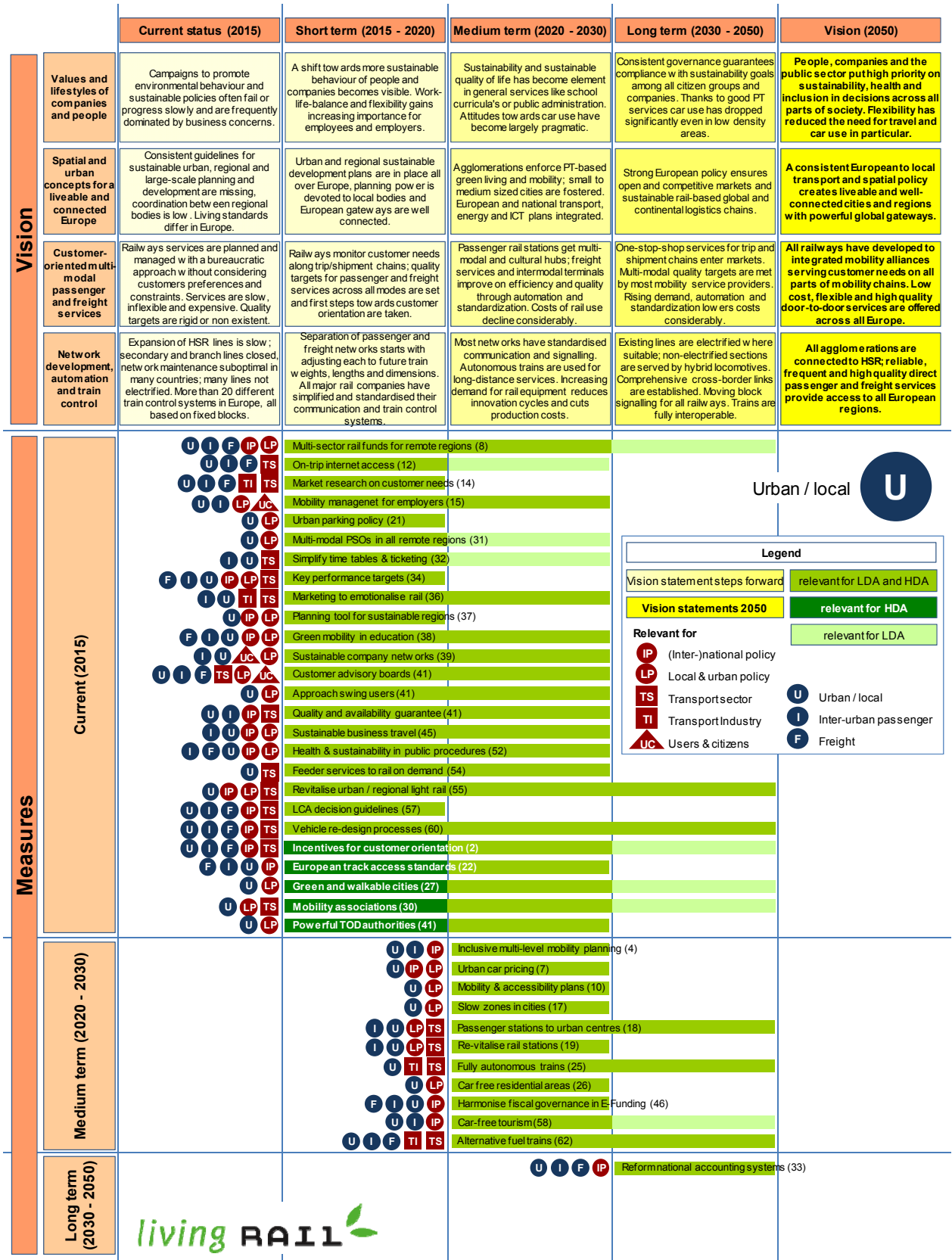


Figure 11: Railmap for urban and regional transport

		Current status (2015)	Short term (2015 - 2020)	Medium term (2020 - 2030)	Long term (2030 - 2050)	Vision (2050)
Vision	Values and lifestyles of companies and people	Campaigns to promote environmental behaviour and sustainable policies often fail or progress slowly and are frequently dominated by business concerns.	A shift towards more sustainable behaviour of people and companies becomes visible. Work-life-balance and flexibility gains increasing importance for employees and employers.	Sustainability and sustainable quality of life has become element in general services like school curricula's or public administration. Attitudes towards car use have become largely pragmatic.	Consistent governance guarantees compliance with sustainability goals among all citizen groups and companies. Thanks to good PT services car use has dropped significantly even in low density areas.	People, companies and the public sector put high priority on sustainability, health and inclusion in decisions across all parts of society. Flexibility has reduced the need for travel and car use in particular.
	Spatial and urban concepts for a liveable and connected Europe	Consistent guidelines for sustainable urban, regional and large-scale planning and development are missing. Coordination between regional bodies is low. Living standards differ in Europe.	Urban and regional sustainable development plans are in place all over Europe, planning power is devoted to local bodies and European gateway areas are well connected.	Agglomerations enforce PT-based development plans; small to medium sized cities are fostered. European and national transport, energy and ICT plans integrated.	Strong European policy ensures open and competitive markets and sustainable rail-based global and continental logistics chains.	A consistent European to local transport and spatial policy creates liveable and well-connected cities and regions with powerful global gateways.
	Customer-oriented multi-modal passenger and freight services	Railways services are planned and managed with a bureaucratic approach without considering customers preferences and constraints. Services are slow, inflexible and expensive. Quality targets are rigid or non-existent.	Railways monitor customer needs along trip/shipment chains, quality targets for passenger and freight services across all modes are set and first steps towards customer orientation are taken.	Passenger rail stations get multi-modal and cultural hubs; freight services and intermodal terminals improve on efficiency and quality through automation and standardization. Costs of rail use decline considerably.	One-stop-shop services for trip and shipment chains enter markets. Multi-modal quality targets are met by most mobility service providers. Rising demand, automation and standardization lowers costs considerably.	All railways have developed to integrated mobility alliances serving customer needs on all parts of mobility chains. Low cost, flexible and high quality door-to-door services are offered across all Europe.
	Network development, automation and train control	Expansion of HSR lines is slow; secondary and branch lines closed, network maintenance suboptimal in many countries; many lines not electrified. More than 20 different train control systems in Europe, all based on fixed blocks.	Separation of passenger and freight networks starts with adjusting each to future train weights, lengths and dimensions. All major rail companies have simplified and standardised their communication and train control systems.	Most networks have standardised communication and signalling. Autonomous trains are used for long-distance services. Increasing demand for rail equipment reduces innovation cycles and cuts production costs.	Existing lines are electrified where suitable; non-electrified sections are served by hybrid locomotives. Comprehensive cross-border links are established. Moving block signalling for all railways. Trains are fully interoperable.	All agglomerations are connected to HSR; reliable, frequent and high quality direct passenger and freight services provide access to all European regions.
Measures	Current (2015)			<p>European HSR network (3)</p> <p>Close network gaps (5)</p> <p>Multi-sector rail funds for remote regions (8)</p> <p>On-trip internet access (12)</p> <p>Market research on customer needs (14)</p> <p>Mobility management for employers (15)</p> <p>Rolling stock modernisation (20)</p> <p>European interoperability standards (24)</p> <p>Simplify rolling stock specifications (27)</p> <p>Simplify time tables & ticketing (32)</p> <p>Key performance targets (34)</p> <p>Marketing to emotionalise rail (36)</p> <p>Green mobility in education (38)</p> <p>Sustainable company networks (39)</p> <p>ICT tools to replace travel (39)</p> <p>Customer advisory boards (41)</p> <p>Quality and availability guarantee (41)</p> <p>Sustainable business travel (45)</p> <p>Open networks for test applications (47)</p> <p>Electrify all major lines (48)</p> <p>Advanced maintenance & risk planning (49)</p> <p>Health & sustainability in public procedures (52)</p> <p>LCA decision guidelines (57)</p> <p>Vehicle re-design processes (60)</p> <p>Incentives for customer orientation (2)</p> <p>European track access standards (22)</p>		
	Medium term (2020 - 2030)			<p>Inclusive multi-level mobility planning (4)</p> <p>Passenger stations to urban centres (18)</p> <p>Re-vitalize rail stations (19)</p> <p>Upgrade intercity rail lines (29)</p> <p>Harmonise fiscal governance in EU Funding (46)</p> <p>Car-free tourism (58)</p> <p>Alternative fuel trains (62)</p> <p>High train service frequencies (6)</p> <p>Networks for longer / wider trains (11)</p> <p>ETCS Level 3 Moving Blocks (35)</p>		
	Long term (2030 - 2050)			<p>Reform national accounting systems (33)</p> <p>Rail based hybrid modes (59)</p> <p>Modular train concepts (62)</p>		
					<p>Legend</p> <p>Vision statement steps forward relevant for LDA and HDA</p> <p>Vision statements 2050 relevant for HDA</p> <p>Relevant for relevant for LDA</p> <p>IP (Inter-)national policy</p> <p>LP Local & urban policy</p> <p>TS Transport sector</p> <p>TI Transport Industry</p> <p>UC Users & citizens</p> <p>U Urban / local</p> <p>I Inter-urban passenger</p> <p>F Freight</p>	

Figure 12: Railmap for inter-urban passenger transport

		Current status (2015)	Short term (2015 - 2020)	Medium term (2020 - 2030)	Long term (2030 - 2050)	Vision (2050)
Vision	Values and lifestyles of companies and people	Campaigns to promote environmental behaviour and sustainable policies often fail or progress slowly and are frequently dominated by business concerns.	A shift towards more sustainable behaviour of people and companies becomes visible. Work-life-balance and flexibility gains increasing importance for employees and employers.	Sustainability and sustainable quality of life has become element in general services like school curricula's or public administration. Attitudes towards car use have become largely pragmatic.	Consistent governance guarantees compliance with sustainability goals among all citizen groups and companies. Thanks to good PT services car use has dropped significantly even in low density areas.	People, companies and the public sector put high priority on sustainability, health and inclusion in decisions across all parts of society. Flexibility has reduced the need for travel and car use in particular.
	Spatial and urban concepts for a liveable and connected Europe	Consistent guidelines for sustainable urban, regional and large-scale planning and development are missing, coordination between regional bodies is low. Living standards differ in Europe.	Urban and regional sustainable development plans are in place all over Europe, planning power is devoted to local bodies and European gateways are well connected.	Agglomerations enforce PT-based green living and mobility; small to medium sized cities are fostered. European and national transport, energy and ICT plans integrated.	Strong European policy ensures open and competitive markets and sustainable rail-based global and continental logistics chains.	A consistent European to local transport and a spatial policy creates liveable and well-connected cities and regions with powerful global gateways.
	Customer-oriented multi-modal passenger and freight services	Railways services are planned and managed with a bureaucratic approach without considering customers preferences and constraints. Services are slow, inflexible and expensive. Quality targets are rigid or non-existent.	Railways monitor customer needs along trip/shipment chains; quality targets for passenger and freight services across all modes are set and first steps towards customer orientation are taken.	Passenger rail stations get multi-modal and cultural hubs; freight services and intermodal terminals improve on efficiency and quality through automation and standardization. Costs of rail use decline considerably.	One-stop-shop services for trip and shipment chains enter markets. Multi-modal quality targets are met by most mobility service providers. Rising demand, automation and standardization lowers costs considerably.	All railways have developed to integrated mobility alliances serving customer needs on all parts of mobility chains. Low cost, flexible and high quality door-to-door services are offered across all Europe.
	Network development, automation and train control	Expansion of HSR lines is slow; secondary and branch lines closed, network maintenance suboptimal in many countries; many lines not electrified. More than 20 different train control systems in Europe, all based on fixed blocks.	Separation of passenger and freight networks starts with adjusting each to future train weights, lengths and dimensions. All major rail companies have simplified and standardised their communication and train control systems.	Most networks have standardised communication and signalling. Autonomous trains are used for long-distance services. Increasing demand for rail equipment reduces innovation cycles and cuts production costs.	Existing lines are electrified where suitable; non-electrified sections are served by hybrid locomotives. Comprehensive cross-border links are established. Moving block signalling for all railways. Trains are fully interoperable.	All agglomerations are connected to HSR; reliable, frequent and high quality direct passenger and freight services provide access to all European regions.
Measures	Current (2015)		<ul style="list-style-type: none"> Freight network design (1) Close network gaps (5) Multi-sector rail funds for remote regions (8) European logistics brokerage platforms (9) On-trip internet access (12) Door-to-door logistics info systems (13) Market research on customer needs (14) Intermodal freight facilities (16) Rolling stock modernisation (20) European interoperability standards (24) Simplify rolling stock specifications (27) Key performance targets (34) Green mobility in education (38) Customer advisory boards (41) Open networks for test applications (47) Electrify all major lines (48) Advanced maintenance & risk planning (49) Green logistics label (51) Health & sustainability in public procedures (52) LCA decision guidelines (57) Vehicle re-design processes (60) Incentives for customer orientation (2) European track access standards (22) Regional logistics concepts (50) 			<div style="text-align: center;"> </div> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Legend</p> <p>Vision statement steps forward</p> <p>Vision statements 2050</p> <p>relevant for LDA and HDA</p> <p>relevant for HDA</p> <p>relevant for LDA</p> <p>Relevant for</p> <ul style="list-style-type: none"> Urban / local Inter-urban passenger Freight (Inter-)national policy Local & urban policy Transport sector Transport Industry Users & citizens </div>
	Medium term (2020 - 2030)		<ul style="list-style-type: none"> Freight customer rights (33) Harmonise fiscal governance in Europe (46) Inter-modal freight master plans (56) Alternative fuel trains (62) Networks for longer / wider trains (11) Regular freight shuttles (23) ETCS Level 3 Moving Blocks (35) 			
	Long term (2030 - 2050)		<ul style="list-style-type: none"> Reform national accounting systems (33) Rail based hybrid modes (59) Modular train concepts (62) 			

Figure 13: Railmap for freight transport

5.6 Railmap by actor

As mentioned at multiple places in this document, the implementation of the Railmap and thus the achievement of the White Paper mode shift targets requires the co-operation of various policy levels and the transport sector.

5.6.1 The policy sector

We simplify the landscape of public actors by distinguishing two policy levels: national and European policy versus local and urban actors. When it comes to detailed discussions on implementation this systematic is of course too coarse. Here we need a fine distinction between legislative and operative institutions. The role of the European Railway Agency would need to gain special attention here. However, in a time line of 35 years institutions can well be established, reformed or abolished. We do thus not directly refer to a particular body within this higher level of decision making.

Nevertheless, important remains the role and legal decision making power of member states. The railways constitute one of the final areas of national influence sphere. To implement a European railway area, this dominance of member states either needs to be weakened for the benefit of larger scale planning and decision making bodies or a stronger coordination of national activities on European level needs to be enforced.

International and national policy (IP) plays a major role with implementing the large investment programmes providing the necessary capacity in the European railway networks to cater the envisaged demand shift. Further they are needed to simplify and unify rolling stock standards and to enable and to enforce railway reforming processes.

On the local and urban level decision making powers are more limited. Although the LivingRAIL Railmap envisages devoting more power to cities and regions, the higher policy level will most likely dominate funding and investment decisions still towards 2050.

However, urban areas and their surrounding regions are the start and end point of most journeys and of goods flows. Re-organising transport flows where will have a profound impact on long-distance trips and shipments too. The re-design of cities and regions contributes a large portion to the local as well as the

inter-urban modal shift. Transit oriented local and regional development, urban car pricing and parking management, cycling friendly cities and the re-activation of closed rail lines are some examples where local bodies can and must get active.

5.6.2 The transport sector

Also the transport sector is far from being a homogeneous body. In first place we need to distinguish infrastructure managers, rail and PT operators and the transport industry. In this research we considered the first two as one entity, which reflects the reality still in many national rail markets and local PT systems. It is not fully clear whether the separation of track management and train operations constitutes a decisive factor to the success of the railways. We thus do not advocate one or the other model here and thus leave these a single entity in the Railmap.

The most decisive role of infrastructure providers is ensure to provide the necessary network capacity in cooperation with international and national planning authorities, and to open up track access towards a fair competition. For railway companies getting closer to their customers and providing services along entire trip and logistics chains is of utmost importance.

Astonishingly, transport industries are given a rather small role in the Railmap. This is first because we argue to work with current or foreseeable technologies. However, a second look across the measures unveils that industries are required, though not directly mentioned, in many aspects. This is the enforced development of ERTMS Level 3 and beyond, the low cost provision of infrastructures and the development of cheap retrofitting options for rolling stock. Finally, bringing innovative products on the market not foreseen by this research should be done way more intensively compared to current innovation cycles.

5.6.3 The civil society

Under the term UC (users and companies) we subsume passengers and their organisations as well as firms shipping freight. They are mentioned only once in the 62 Railmap measures concerning mobility management for employers. Users are, however, the final decision makers of mode choice decisions. Through customer organisations and lobby groups they should constantly give the railways and PT undertakings feedback of their activities, service levels and market appearance.

6 Impact Assessment

6.1 Methodological approach

The following sections report about the use of the ASTRA model for estimating impacts of changes in the transport conditions consistent to the implementation of the LivingRAIL railmaps. We do not talk of a full assessment of the railmaps as their complexity cannot be reflected in the aggregated parameters of a simulation model like ASTRA. The railmaps include a number of measures and technical improvements sometimes tailored to specific local circumstances such as detailed analyses of local markets and areas would be needed for a full assessment.

This exercise has the less ambitious goal of providing indications of the magnitude of the changes that could be expected on some relevant indicators when the railmaps are implemented. The indicators cover four different domains: transport, energy, environment and safety.

The results of the application of ASTRA are presented below for three different scenarios. The first scenario concerns the simulation of a modification of transport costs. The purpose of this case is to show what can be expected from a modification of the relative costs of transport modes of the size reasonably associated to the implementation of the railmaps all other things being equal.

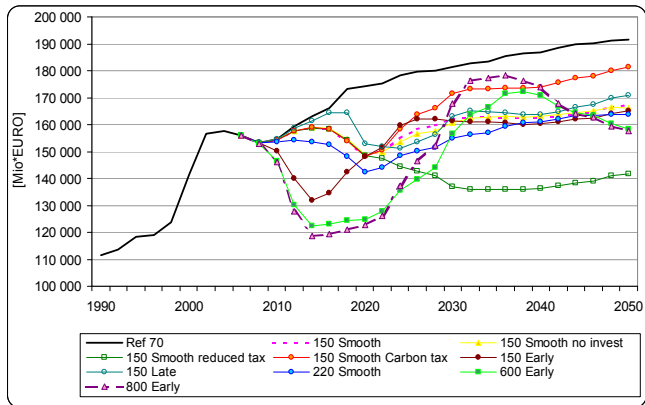
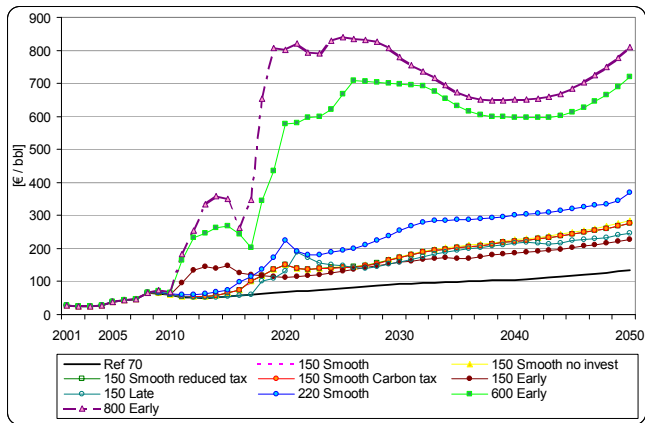
The second scenario concerns the simulation of a modification of transport speed. The purpose of this case, similarly to previous one is to show what can be expected whether only the speed of transport modes (mainly rail) is modified.

Finally, the third scenario is a sort of backcasting exercise where the ASTRA model implement the cost and time changes of the two scenarios and then is further forced to modify the mode split to simulate the achievement of the mode shift towards rail entailed by the railmaps. Assuming this mode shift the transport impacts are pre-determined but the modelling exercise provides result for the other indicators (energy, environment and safety).

In the remaining of this section some methodological details are given. In section 6.1.1 the ASTRA model is presented, while in section 6.1.2 the input used for the changed costs and changed speed scenarios are described.

6.1.1 The ASTRA model

The ASTRA model is based on System Dynamics methodology. System Dynamics does not focus on the analysis of specific fields like economy or transport, but is a general methodology that can be applied to any kind of system meeting some basic conditions. In brief, a System Dynamics model consists of a set of hypotheses on the relationship between causes and resulting effects. Relationships are represented by equations that are written and solved by mathematical simulation. In other words, a System Dynamic model does not have a specific set of unknown parameters or variables whose value is estimated as a solution of the model. Instead, most of the model variables change dynamically over time (see examples in Figure 14 related to oil price projections and fuel tax revenues forecasts under alternative scenarios) as an effect of the interaction of positive or negative feedback loops. This can be considered as the most important characteristics of any complex systems.



Source: Schade et. al. 2008

Figure 14: Examples of dynamic behavior in complex systems

The ASTRA model is therefore focused on the investigation of functional cause-and-effect relationships

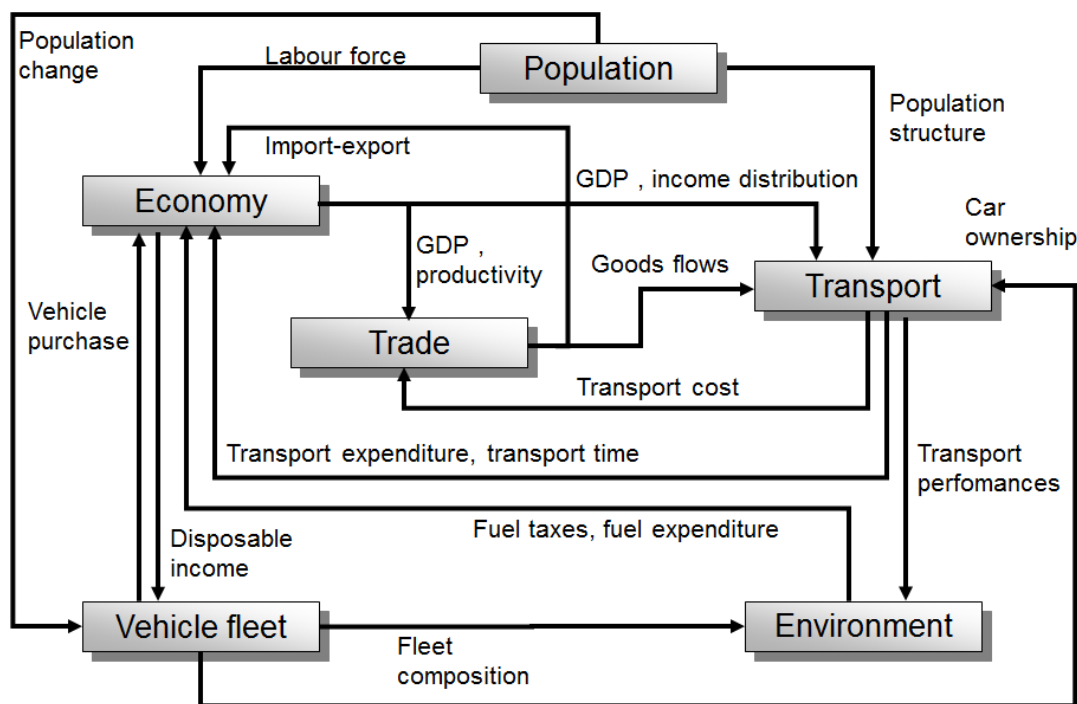
between the systems represented (transport, economy, environment) and connected through several feedback loops.

Overview of ASTRA

The model covers the time period from 1995 until 2050. Results in terms of main indicators are available on a yearly basis. Geographically, ASTRA covers EU27 member states plus Norway and Switzerland. Croatia is not in ASTRA yet as the latest revision of the model structure started before Croatia joined the EU

ASTRA consists of different modules, each related to one specific aspect, such as the economy, the transport demand, the vehicle fleet. The main modules cover the following aspects:

- Population and social structure (household types and income groups),
- Economy (including input-output tables, government, employment and investment),
- Foreign trade,
- Transport (including demand estimation, modal split, transport cost and networks)
- Vehicle fleet (road),
- Environment (including pollutant emissions, CO2 emissions, fuel consumption).



Source: TRT - Fraunhofer-ISI

Figure 15: Overview of the linkages between the modules in ASTRA

A key feature of ASTRA as an integrated assessment model is that the modules are linked together. Changes in one system are thus transmitted to other systems and can feed-back to the original source of variation. An overview on the modules and their main linkages is presented in Figure 15.

Different levels of spatial categorizations are applied in parallel in ASTRA (see Figure 16):

- The first categorization is based on the **country level** spatial differentiation, applied in all the modules of the model;
- The second categorization is founded on the **NUTS I zones level** (zones within each country represented with the same colour nuance in Figure 16), which is applied in the transport module to represent national trips;
- The third categorization is built on the **NUTS II zones level** (zones within each country separated by thin borders in Figure 16), applied in the transport modules (for trips generation) as well as for population and for a few selected socio-economic indicators;

NUTS I and NUTS II is not a very detailed level of spatial segmentation for transport demand, but it is consistent with the scale of the tool.

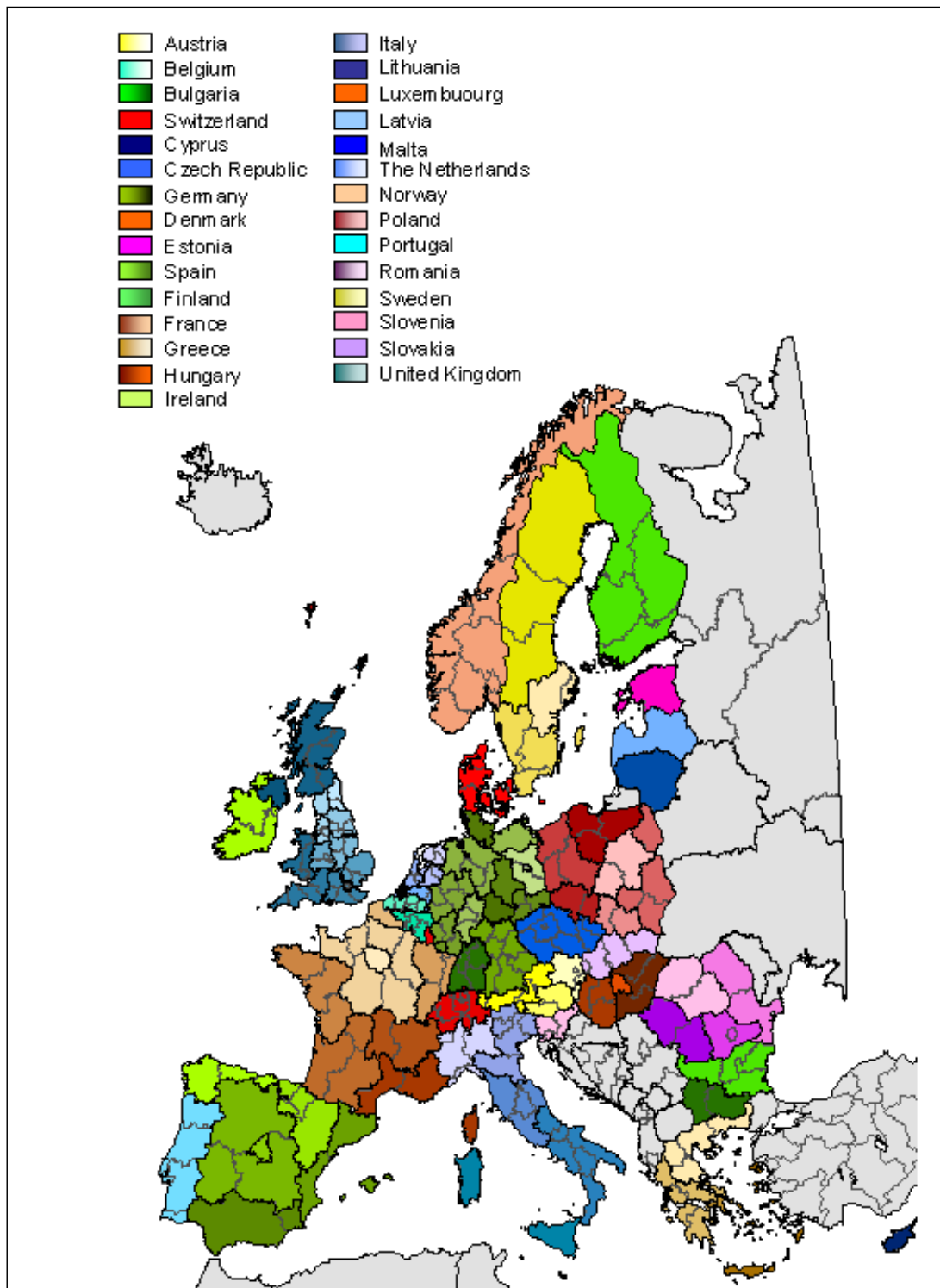
The modeling of transport in ASTRA

The transport component of the ASTRA model consists of adapted classical 4-stage transport models both for passenger and freight transport. While the first three stages – generation, distribution and modal split – are modelled state-of-the-art in a detailed way, the last step – the assignment stage – is not modelled in ASTRA, due to the geographical scope implemented.

The model considers endogenous reactions in all four stages i.e. there is no fixed generation and no fixed OD matrix. It adjusts the estimation of the generation, distribution and modal split phases on the basis of parameters differentiated by demand segments.

Passenger transport demand is generated at NUTS II level and then segmented in the distribution phase. National passenger demand at **intra NUTS II** level is further divided into:

- **Local distance** (intra NUTS III level with travelling distance lower than 3 km);
- **Very short distance** (intra NUTS III level with travelling distance between 3 and 50 km);
- **Short distance** (extra NUTS III level or intra NUTS III with travelling distance higher than 50 km);



Source: TRT - Fraunhofer-ISI

Figure 16: Zoning system in ASTRA

In terms of transport mode availability, ASTRA models different options for passenger:

- Slow modes (pedestrian and cycling),
- Car (including also 2-wheelers and passenger LDV),
- Bus/Coach,
- Train (including tram and metro),

- Air.

Instead, for freight the following modes are available:

- Truck,
- Train,
- Inland Waterways (modelled in a simplified way),

- Maritime.

Give the strategic nature of the model the transport modes are not described in detail. For instance, rail is not described in terms of services (with routes, timetables, stops, train types, etc.). Basically transport modes are represented by a transport cost and a transport time for a specific spatial domain (e.g. for a trip between two countries). Also, intermodality is not modelled explicitly, e.g. freight combined transport is considered “rail” and truck feeder services to and from intermodal centres are not represented.

Transport costs are computed on operating costs per vehicle-km (e.g. for cars) and/or on tariffs per passenger-km or tonne-km (e.g. for air services). There are some segmentation of tariffs by trip purpose (e.g. cost of public transport is assumed lower for commuting trips than for personal business trips) or by commodity category (e.g. cost of rail for unitised goods is not the same as for bulk goods).

Transport times are based on average speeds by mode plus, where relevant, fixed times (e.g. for transshipment or for loading/unloading).

The modal split process is calculated separately for each spatial domain (intra-NUTS II local, intra- NUTS II very short, etc.). Direct and cross elasticities to cost variation and time variation (implemented separately) are used.

Additional parameters are also implemented to reflect the contribution of other significant determinants of modal split. For instance, one parameter controls for the trend of motorisation rate, which affects preferences for car. Other parameters are instead used for calibration purposes and can be interpreted as the contribution of qualitative elements of transport (e.g. reliability, frequency of service, comfort). These elements are therefore not explicitly modelled and can be considered only implicitly by adjusting these additional parameters or by assuming that a change of one qualitative aspect equates to a given change of travel cost or travel time.

The modelling of transport impacts in ASTRA

The environment module of ASTRA uses input from the transport module (in terms of vehicle-kilometers travelled per mode and geographical context) and from the vehicle fleet module (in terms of the technical composition of vehicle fleets), in order to compute fuel consumption, greenhouse gas emissions and pollutant

emissions from transport. Also accidents are estimated.

The estimation of fuel consumption is based on consumption factors taken from HBEFA (2010). They are composed to reflect the different traffic situations in the various distance bands. Fuel consumption factors evolve over time due to different aspects: increased use of air conditioning, speed influence, etc.

ASTRA computes emissions for CO₂, NO_x, CO, VOC and PM for all transport modes. Tank-to-wheel CO₂ emissions depend directly on fuel consumption. Instead polluting emissions are simulated on the basis of emission factors per vehicle category, emission standard and, again, different traffic situations depending on distance band.

Accidents are estimated in ASTRA on the basis of accident rates by mode, implemented with reference to transport demand performances. Accidents are differentiated in categories (fatality, serious, light, material) according to their severity. Accident rates are distinguished by urban and non-urban context, in order to take into account different traffic conditions.

6.1.2 The modelling input

Changed travel cost scenario input

One of the effects expected from the implementation of the railmaps is a significant change of the transport costs with respect to the reference ones. Reference costs are those part of the base scenario developed in the ASSIST project (Kraib at. al. 2013), i.e. the most recent project where the ASTRA model was updated and recalibrated to meet the trends published by the latest release of the EU energy and transport trends to 2050 (European Commission, 2013).

Rail costs would be affected of course thanks to technology and organisational measures. But also costs of other modes would be modified because of regulation measures (e.g. road charging). The size of the variations have been estimated in the course of the project for other purposes and used here as input for the ASTRA model.

Table 3 and Table 4 show the change of passenger travel costs by mode for dense areas and, respectively, non-dense areas at the horizon of the year 2050. In ASTRA these changes are implemented progressively from the year 2015 onwards.

Rail costs (meaning rail user costs, i.e. fares to use rail transport services) are supposed to be significantly reduced in the range of 20% - 40%. The larger reduction is expected for regional trips in dense areas, while lower reduction margin is expected for short trips (mainly urban trips) and for international trips.

Car costs are expected to increase slightly for regional trips and more for national and international trips because of road charging measures.

Air costs are expected to grow up to 50% - 60% once regulatory measures (e.g. taxation of kerosene but also stricter safety measures, passenger rights enforcement and a much tighter cap on Emission permits in the ETS) are in force.

Table 3: Change of average passenger travel costs by mode in the year 2050 with respect to the reference scenario - Dense areas

Transport mode	Short trips	Regional trips	National trips	International trips
Rail	-20%	-40%	-25%	-20%
Car	0%	5%	15%	15%
Bus	0%	0%	0%	0%
Air	n.r.	n.r.	60%	50%

Source: Elaboration of ASTRA results

Table 4: Change of average passenger travel costs by mode in the year 2050 with respect to the reference scenario – Non-dense areas

Transport mode	Short trips	Regional trips	National trips	International trips
Rail	-20%	-30%	-25%	-20%
Car	0%	5%	15%	15%
Bus	0%	0%	0%	0%
Air	n.r.	n.r.	60%	50%

Source: Elaboration of ASTRA results

In Table 5 the assumptions about the change of freight costs are reported. Here the separation between dense and non-dense areas does not apply as average distance of freight shipment is usually long enough to cross different region types. Again rail costs

are supposed to decrease by 20%-30% with larger improvements for international trips. Truck as well as maritime costs are expected to increase by some 15%. No changes are assumed for inland navigation costs.

Table 5: Change of average freight travel costs by mode in the year 2050 with respect to the reference scenario

Transport mode	Short trips	Regional trips	National trips	International trips
Train	n.r.	-20%	-20%	-35%
Truck	0%	15%	15%	15%
Ship	n.r.	n.r.	15%	15%
IWW	0%	0%	0%	0%

Source: Elaboration of ASTRA results

Changed travel speed scenario input

In the second scenario the impact of the railmaps is translated in terms of improved travel speed for rail,

while other modes are not affected as most of the speed improvements stem from technical and organisational progress rather than from regulation meas-

ures. However, when short trips are considered, local and urban public transport systems are considered therefore including also modes like tram, metro and also buses.

As shown in Table 6, a 15% improvement of rail speed is assumed. The progress is not dramatic but it should be noted that the input makes reference to commercial speed (i.e. including stops at stations) rather than to the maximum technical speed. Also, although within railmaps the expansion of high speed networks and services as the railways' "premium product" is considered, the focus is put much more on cost efficient

EC/IC services connecting regions and agglomerations (Doll et.al. 2015). In other words, railmaps are supposed to improve availability and reliability of rail connections more than their speed. This aspect is not fully reflected in the modelling input: here is an example of the limitations of this exercise mentioned in the introduction.

For short trips the speed improvement assumed is slightly larger as there is more room for the contribution of organisational measures such as the integration of services.

Table 6: Change of average passenger travel speed by mode in the year 2050 with respect to the reference scenario - Dense areas

Context	Short trips	Regional trips	National trips	International trips
Rail passenger(*)	20%	15%	15%	15%
Rail freight	n.r.	15%	15%	15%

(*) Include local public transport for short trips

Source: Elaboration of ASTRA results

Target rail share scenario input

In the third scenario the input of both the two previous scenarios were implemented and furthermore it was assumed that the target mode share for rail is reached (Table 7). In ASTRA the mode split depends mainly on elasticities to travel costs and travel speed but there also other parameters available for controlling the share of demand attracted by each mode. These other parameters are used for calibration purposes in order to take into account that the trends of travel costs and travel speed by mode are usually unable to explain the trend of mode split (e.g. the market share of one mode can remain constant or even increase despite its cost becomes higher or speed is depleted because of congestion). These parameters can be interpreted as reflecting the contribution of qualitative elements (e.g.

frequency of service, reliability, safety) to mode choice. However, in the model there is not any direct equivalence between the value of the parameters and the level of the qualitative elements. For instance, there is no ground to say that when the frequency of service is increased by 20% the value of some parameters should be changed of an amount X. The parameters can be used only to push the model towards a target mode split, i.e. the expected model result should be known and the parameters are changed accordingly.

For this scenario, the parameters have been adapted in order to fill the gap between the mode shift obtained by means of costs and speed improvement and the 50% model share target.

Table 7: Rail share targets in LivingRAIL

Variable	EU average	Low density areas	High density areas
Passenger urban			
Mode share 2010	17	10	30
Target 2050	50	44	60
Passenger interurban			
Mode share 2010	8	4	15
Target 2050	50	35	70
Freight			
Mode share 2010	18	14	25
Target 2050	50	42	60

Source: Fiorello et. al. (2013)

6.2 Results for transport and environmental impacts

In this section the impact of the modelling input on various indicators is reported for the three scenarios. Two elements should be considered while looking at the results shown below. First, as mentioned in the previous section, the zoning system of the ASTRA model is mainly based on countries with NUTS I and NUTS II regions used for some variables. Therefore dense and non-dense areas can be recognised only in coarse terms. In order to provide the most representative results for dense and non-dense areas available from ASTRA, three densely populated NUTS II regions in different countries and three non-densely populated NUTS II regions in different countries have been taken and the results provided below are the average computed for these regions.

Second, since the purpose of this exercise is to show the magnitude of the effects rather than to provide exact estimations, all figures provided below are rounded and approximated.

6.2.1 Changed travel costs scenario

Transport impacts

In the first scenario, where travel costs of rail are reduced and travel costs of competing modes is increased passenger mode split is modified as shown in Table 8. In dense areas the mode share of rail is increased by 50% and in non-dense areas it is even doubled. In both cases the competitor losing more share is air whereas car share is diminished in dense areas but not in non-dense areas. In dense areas also bus and slow modes gain some mode share in the railmap scenario.

Table 8: Modelled passenger mode split in the year 2050 in the travel costs scenario compared to reference scenario (%)

Transport mode	Dense areas		Non-dense areas	
	Travel costs scenario	Reference scenario	Travel costs scenario	Reference scenario
Rail	15	10	10	5
Car	65	70	70	70
Bus	7	5	5	5
Air	5	10	10	15
Slow	7	5	5	5
Total	100	100	100	100

Source: Elaboration of ASTRA results

The impact on freight transport is similar (Table 9): train share is some 50% larger. However, given the initial shares, this means just a 10% reduction of truck share. Maritime transport share is not expected to change significantly.

Table 9: Modelled freight mode split in the year 2050 in the travel costs scenario compared to reference scenario (%)

Transport mode	Travel costs scenario	Reference scenario
Train	15	10
Truck	45	50
Maritime	35	35
IWW	5	5
Total	100	100

Source: Elaboration of ASTRA results

These results show that considering only the cost changes induced by the railmaps, rail is unable to reach the target 50% market share. Also the results suggest that road modes remain preferred despite a wider cost gap compared to rail. In the passenger market, rail seems more able to subtract market shares from air than from cars. However, part of the reduction of the air market share as well as the slight increase of bus and slow modes share is not the result of a mode shift towards rail but rather of a modification

of the demand pattern: some long distance trips are suppressed while local mobility is increased. This is another reason why the market share loss of road modes is limited.

Looking at the amount of demand for different types of mobility, the big improvement for rail comes from regional trips, where the competitiveness of passenger rail is at the top (see Table 10 and Table 11). Especially in non-dense areas the costs changes generated by the railmaps could allow tripling the number of rail trips. Quite significant demand gains could be achieved also for national and international trips. It can be noted that for national and international trips also car and bus are expected to gain demand. This is the result of the large loss of competitiveness of air transport. For short trips the growth is lower in relative terms. As already noted, it is especially air to lose demand.

It is worth mentioning that the larger impacts of costs changes on rail demand in non-dense areas is not due to the fact that the measures are more effective (as shown in section 6.1.2, the assumption is the same of it is even assumed a smaller cost reduction in non-dense areas). Instead the reason is that the starting point is different: in the reference case the rail demand in non-dense areas is quite low, so it is sufficient to shift a relatively small number of trips to rail to see a large change in terms of mode share.

Table 10: Change of passenger demand by mode in the year 2050 with respect to the reference scenario - Dense areas

Transport mode	Short trips	Regional trips	National trips	International trips
Rail	30%	175%	60%	60%
Car	-5%	-15%	-10%	10%
Bus	0%	-10%	10%	50%
Air	n.r.	n.r.	-60%	-35%
Slow	0%	n.r.	n.r.	n.r.

Source: Elaboration of ASTRA results

Table 11: Change of passenger demand by mode in the year 2050 with respect to the reference scenario – Non-dense areas

Transport mode	Short trips	Regional trips	National trips	International trips
Rail	45%	200%	100%	150%
Car	0%	-5%	-10%	40%
Bus	0%	-5%	20%	30%
Air	n.r.	n.r.	-65%	-30%
Slow	0%	n.r.	n.r.	n.r.

Source: Elaboration of ASTRA results

The role of the initial conditions is visible also in Table 12, regarding the demand changes for the freight market. Train demand is significantly larger than in the reference case, but the demand for other modes is not drastically reduced. This happens because the initial mode split is very favourable to truck and maritime, so when a limited share of tonnes are shifted to rail the demand for this mode is widely increased.

Table 12: Change of freight demand by mode in the year 2050 with respect to the reference scenario

Transport mode	Demand change
Train	45%
Truck	-5%
Maritime	-5%
IWW	0%

Source: Elaboration of ASTRA results

Energy consumption impacts

The mode shift towards rail (and also the contraction of average trip distances) bring about a reduction of

energy consumption in the range of 5%-10% (the reduction is larger in non-dense areas, see Table 13). For rail alone there is of course an increase of the energy consumption.

Table 13: Change of transport fuel consumption (toe) in the year 2050 with respect to the reference scenario

Transport mode	Dense areas	Non-dense areas
All modes	-5%	-10%
Rail(*)	35%	65%

(*) Passenger and freight rail

Source: Elaboration of ASTRA results

Environment impacts

The impacts on greenhouse gas and polluting emissions are correlated to those on energy consumption. As a whole CO₂ emissions are reduced by 10% while polluting emissions are up to 30% lower than in the reference scenario (Table 14). Larger reductions are expected for CO and VOC whereas PM emissions are only marginally reduced. Of course, rail emissions are increased proportionally to the larger rail demand.

Table 14: Change of GHG and polluting emissions in the year 2050 with respect to the reference scenario

Emission type	All modes		Rail(*)	
	Dense areas	Non-dense areas	Dense areas	Non-dense areas
CO ₂ (tank to wheel)	-10%	-10%	35%	65%
NO _x	-10%	-15%	35%	50%
CO	-30%	-25%	35%	45%
VOC	-30%	-25%	35%	45%
PM	-2%	-5%	35%	60%

(*) Passenger and freight rail; Source: Elaboration of ASTRA results

Safety impacts

Another effect of mode shift towards rail is the reduction of road accidents. As shown in Table 15 the ASTRA model estimates that in the changed travel costs scenario the number of road accidents could be slightly reduced especially in dense areas.

Table 15: Change of road accidents in the year 2050 with respect to the reference scenario

Impact	Dense areas	Non-dense areas
Road accidents	-5%	-2%

Source: Elaboration of ASTRA results

2.2 Changed travel speed scenario

Transport impacts

In this scenario we assume that only rail travel speed is improved as effect of the railmaps. As reducing rail travel time is not the major goal of the measures included in the railmaps, the effect on transport demand is significantly smaller in this scenario than in the previous one. In particular, only a very limited mode shift is expected such as we do not show figures for this indicator.

Actually only a limited modification of demand by mode is estimated by the model as shown in Table 16 and Table 17. Rail demand is estimated to be no more than 5% larger for short and regional trips. For national and international trips, where time reductions are more consistent in absolute terms, the demand gains can be of 15% or 20% in non-dense areas where the initial conditions are less favourable to rail and so even limited absolute numbers correspond to higher relative shares.

Table 16: Change of passenger demand by mode in the year 2050 with respect to the reference scenario - Dense areas

Transport mode	Short trips	Regional trips	National trips	International trips
Rail	2%	5%	15%	15%
Car	0%	0%	-2%	-2%
Bus	0%	0%	0%	0%
Air	n.r.	n.r.	0%	0%
Slow	0%	n.r.	n.r.	n.r.

Source: Elaboration of ASTRA results

Table 17: Change of passenger demand by mode in the year 2050 with respect to the reference scenario – Non-dense areas

Transport mode	Short trips	Regional trips	National trips	International trips
Rail	0%	5%	20%	15%
Car	0%	0%	-1%	0%
Bus	0%	-1%	0%	0%
Air	n.r.	n.r.	0%	0%
Slow	0%	n.r.	n.r.	n.r.

Source: Elaboration of ASTRA results

While in the changed costs scenario rail demand increased mostly at the expense of mode air, in this scenario is car to lose some trips or, in non-dense areas, it can be bus to be replaced by rail.

On the freight side the simulations with the ASTRA model show that a reduction of the rail travel time of the size assumed here (15%) does not give rise to a significant increase of rail demand. Of course con- signment time is relevant for freight transport but to appreciate its effect aspects like reliability should be taken into account rather than pure travel time reduc- tion in order to see effects. These aspects cannot be simulated with ASTRA however.

Energy consumption impacts

As expected given the limited changes on the trans- port demand side, the effects of this scenario on en- ergy consumption are minor. Only marginal reduction of transport fuels use is forecasted (Table 18).

Table 18: Change of transport fuel consumption (toe) in the year 2050 with respect to the reference scenario

Transport mode	Dense areas	Non-dense ar- eas
All modes	-1%	0%
Rail(*)	3%	2%

(*) Passenger and freight rail

Source: Elaboration of ASTRA results

Environment impacts

Also the impacts on greenhouse gas and polluting emissions are in line with the small changes on the demand side. Marginal reduction of total emissions are expected, mostly in dense areas (Table 19). Rail emissions are instead slightly higher.

Table 19: Change of GHG and polluting emissions in the year 2050 with respect to the reference scenario

Emission type	All modes		Rail(*)	
	Dense areas	Non-dense areas		Dense areas
CO2 (tank to wheel)	-1%	0%	3%	2%
NOx	-1%	0%	2%	0%
CO	-2%	-1%	1%	0%
VOC	-3%	-1%	1%	0%
PM	0%	0%	3%	1%

(*) Passenger and freight rail

Source: Elaboration of ASTRA results

Safety impacts

Given the minor demand shift from road modes also safety impacts are very small, with only a marginal reduction of road accidents expected in dense areas (Table 20).

Table 20: Change of road accidents in the year 2050 with respect to the reference scenario

Impact	Dense areas	Non-dense ar- eas
Road acci- dents	-1%	0%

Source: Elaboration of ASTRA results

6.2.2 Target rail share scenario

Transport impacts

In this scenario, besides implement cost and time changes as in the first two scenarios, the parameters of ASTRA have been modified in order to achieve the rail share target of the railmaps (see

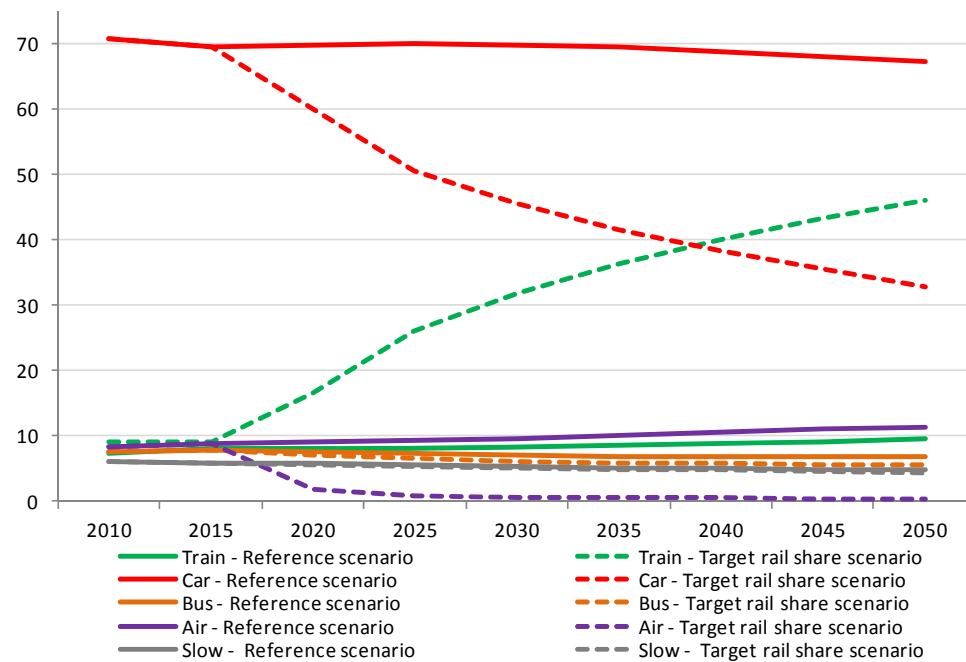
Table 7 in section 6.1.2). It is therefore not surprising that under this scenario, both passenger mode split (Table 21) and freight mode split (Table 22) are drastically changed in comparison to the reference case.

As for passengers, a 50% rail share corresponds to a situation where car share is progressively halved and air has basically disappeared as transport alternative (Figure 17). Bus and slow modes maintain their share.

Table 21: Modelled passenger mode split in the year 2050 in the target rail share scenario compared to reference scenario (%)

Transport mode	Dense areas		Non-dense areas	
	Rail target scenario	Reference scenario	Rail target scenario	Reference scenario
Rail	55	10	50	5
Car	35	70	40	70
Bus	5	5	5	5
Air	0	10	0	15
Slow	5	5	5	5
Total	100	100	100	100

Source: Elaboration of ASTRA results



Source: Elaboration of ASTRA results

Figure 17: EU27 Passenger Modal Split (based on passenger-km)

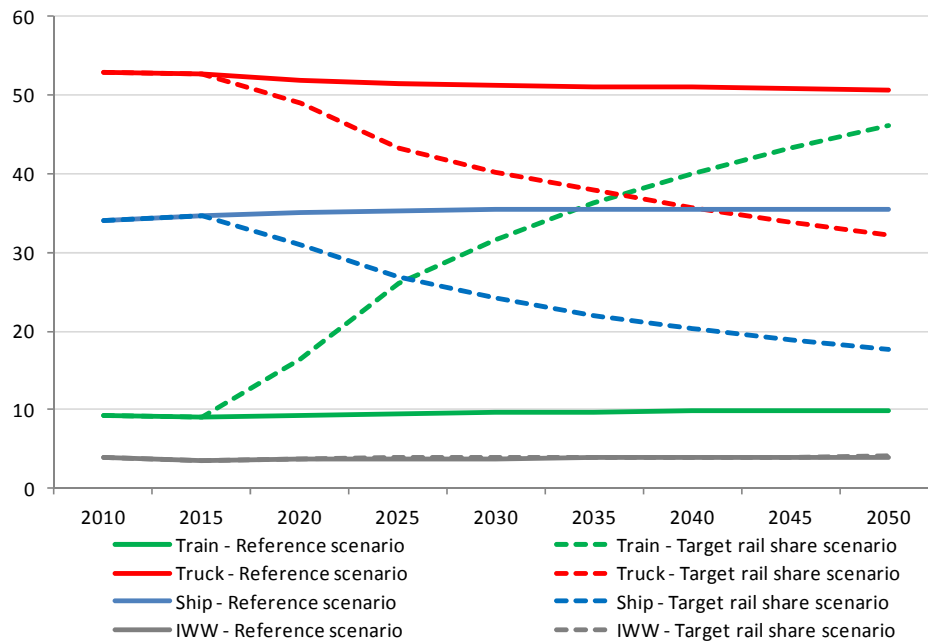
As for freight the 50% share is obtained by subtracting demand from both trucks and maritime shipping (Figure 18). In relative terms, maritime shipping is

reduced more than road freight transport: its modal share is more than halved.

Table 22: Modelled freight mode split in the year 2050 in the target rail share scenario compared to reference scenario (%)

Transport mode	Travel costs scenario	Reference scenario
Train	50	10
Truck	30	50
Maritime	15	35
IWW	5	5
Total	100	100

Source: Elaboration of ASTRA results



Source: Elaboration of ASTRA results

Figure 18: EU27 Passenger Modal Split (based on tonnes-km)

The rate of change of mode shares as determined by the ASTRA model appears highest in the coming years, while the model predicts declining rates towards 2050 (Figure 17 and Figure 18). An explanation for this behaviour of the model is surely the utilisation of low hanging fruits, i.e. passenger campaigns, service initiatives and the installation of powerful information services. In this early phase spare capacity in the networks is used and new capacity is made available through ongoing investments in key bottlenecks of the European rail network. Growth rates are then slowed down as infrastructure capacity can only slowly follow demand.

Given the initial level, the change of rail demand is huge. In dense areas, where the demand in the reference scenario is higher, reaching the 50% share means multiplying the demand by 5 – 7 times with the only exception of short trips where the increase is 'only' of 80% (Table 23). In non-dense areas, the increment is even more dramatic, up to 5000% for regional trips (Table 24). It is quite understandable from these figures how challenging to reach the rail-maps target is. It should be always considered that this is not a forecast, but a backcasting exercise to analyse the consequences in terms of energy consumption, emissions and safety IF the targets were met.

Table 23: Change of passenger demand by mode in the year 2050 with respect to the reference scenario - Dense areas

Transport mode	Short trips	Regional trips	National trips	International trips
Rail	80%	750%	500%	800%
Car	-5%	-50%	-70%	-90%
Bus	-5%	-65%	-50%	-90%
Air	n.r.	n.r.	-95%	-95%
Slow	0%	n.r.	n.r.	n.r.

Source: Elaboration of ASTRA results

Table 24: Change of passenger demand by mode in the year 2050 with respect to the reference scenario – Non-dense areas

Transport mode	Short trips	Regional trips	National trips	International trips
Rail	250%	5000%	1000%	3500%
Car	-5%	-70%	-80%	-95%
Bus	-5%	-55%	-65%	-95%
Air	n.r.	n.r.	-95%	-100%
Slow	0%	n.r.	n.r.	n.r.

Source: Elaboration of ASTRA results

To reach the 50% mode share in the freight market rail demand should increase by six times. As shown in Table 25 maritime demand would be halved whereas road freight demand reduction would be more limited.

Table 25: Change of freight demand by mode in the year 2050 with respect to the reference scenario

Transport mode	Dense areas
Train	500%
Truck	-15%
Maritime	-50%
IWW	0%

Source: Elaboration of ASTRA results

Energy consumption impacts

Assuming that in passenger freight transport markets rail is able to achieve a 50% market share the benefit in terms of energy consumption would be as large as 35% of the reference value at the year 2050 (Table 26). In the rail sector the energy consumption would be drastically increased but nevertheless the transport sector as a whole would become much more efficient.

Table 26: Change of transport fuel consumption (toe) in the year 2050 with respect to the reference scenario

Transport modes	Dense areas	Non-dense areas
All modes	-35%	-35%
Rail ^(*)	400%	1200%

(*) Passenger and freight rail

Source: Elaboration of ASTRA results

Environment impacts

If half of transport activity occurred by rail there would be also in terms of reducing greenhouse and harmful transport emissions (Table 27). CO₂ emissions would basically follow the energy consumption trend and would be cut by some 35% - 40%. If we assume that in the rail share target scenario the energy sector moves towards sustainability and the electricity is entirely produced by renewable sources, the reduction can reach 45%.

Table 27: Change of GHG and polluting emissions in the year 2050 with respect to the reference scenario

Emission type	All modes		Rail ^(*)	
	Dense areas	Non-dense areas	Dense areas	Non-dense areas
CO ₂ (tank to wheel) – reference electricity mix	-35%	-40%	400%	1000%
CO ₂ (tank to wheel) – All renewables electricity production	-45%	-45%	-100%	-100%
NO _x	-35%	-60%	400%	1000%
CO	-80%	-90%	450%	1000%
VOC	-90%	-90%	400%	1000%
PM	-10%	-35%	400%	1000%

(*) Passenger and freight rail assuming the reference electricity mix

Source: Elaboration of ASTRA results

Polluting emissions would be reduced as well; the size of the reduction would be different for each pollutant (e.g. the reduction of particulate matter would be smaller than the reduction of VOC emissions).

Safety impacts

Another effect of the demand shift on rail would be the reduction of road activity and then a reduction of road accidents, i.e. a positive impact on transport safety. According to ASTRA simulations the gain on terms of reduced accidents is in the size of 25% - 30% in comparison to the reference case (Table 28).

Table 28: Change of road accidents in the year 2050 with respect to the reference scenario

Impact	Dense areas	Non-dense areas
Road accidents	-30%	-25%

Source: Elaboration of ASTRA results

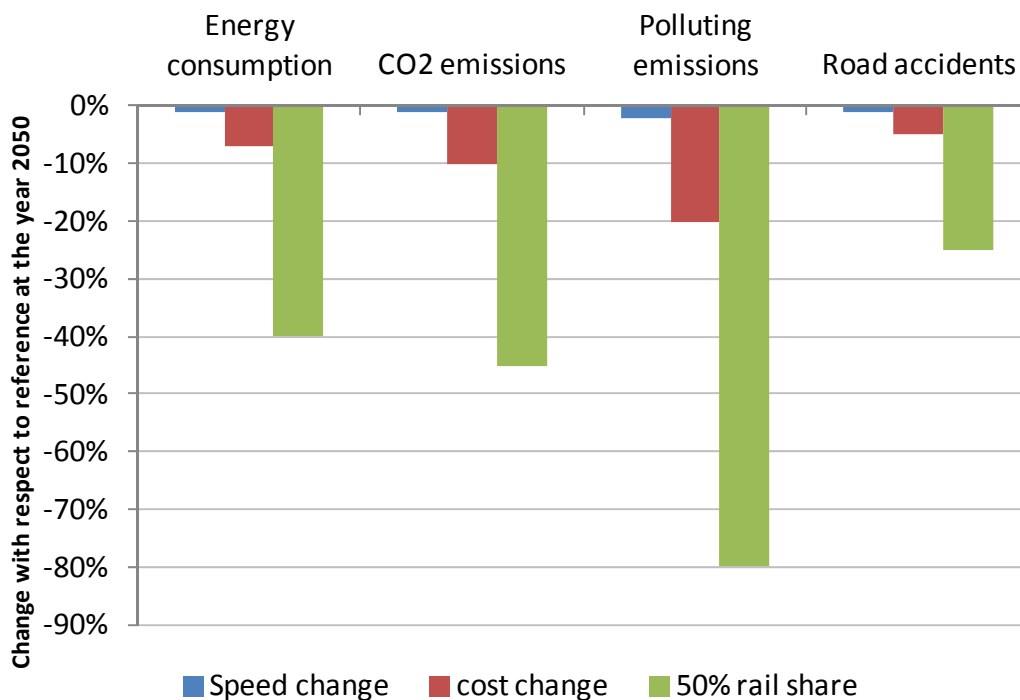
It might be argued that when a massive amount of demand is transferred to rail an increment of accidents involving railways should be expected. This is probably correct, but the occurrence of rail accidents would remain much lower than road accidents also taking into account that in the scenario railmaps a significant improvement of rail facilities (track, stations, etc.) is expected and especially advanced train control systems would be introduced.

6.2.3 Overall impacts

The railmaps developed within LivingRAIL are complex strategies including many measures and technical improvements sometimes tailored to specific local circumstances. Given this complexity, a full quantitative assessment of the railmaps would be a project in itself. Here, the ASTRA model has been used to get some indications of the magnitude of the changes that could be expected on some relevant indicators when the railmaps are implemented. The indicators cover different domains: transport, energy, environment and safety.

The results of the simulations suggest that the changes of transport costs and especially of transport times associated to the implementation of the measures included in the railmaps would not be sufficient to achieve the 50% rail mode share target.

Improving rail travel speed is not the core business of the railmaps, which are more focused on extend services and improve their quality and reliability. Therefore only relatively limited speed gains can be assumed as effect of the application of the railmaps. So their impact on market shares and, in turn, on energy consumption, emissions and safety are expected to be minor or even negligible.



Source: Elaboration on ASTRA results

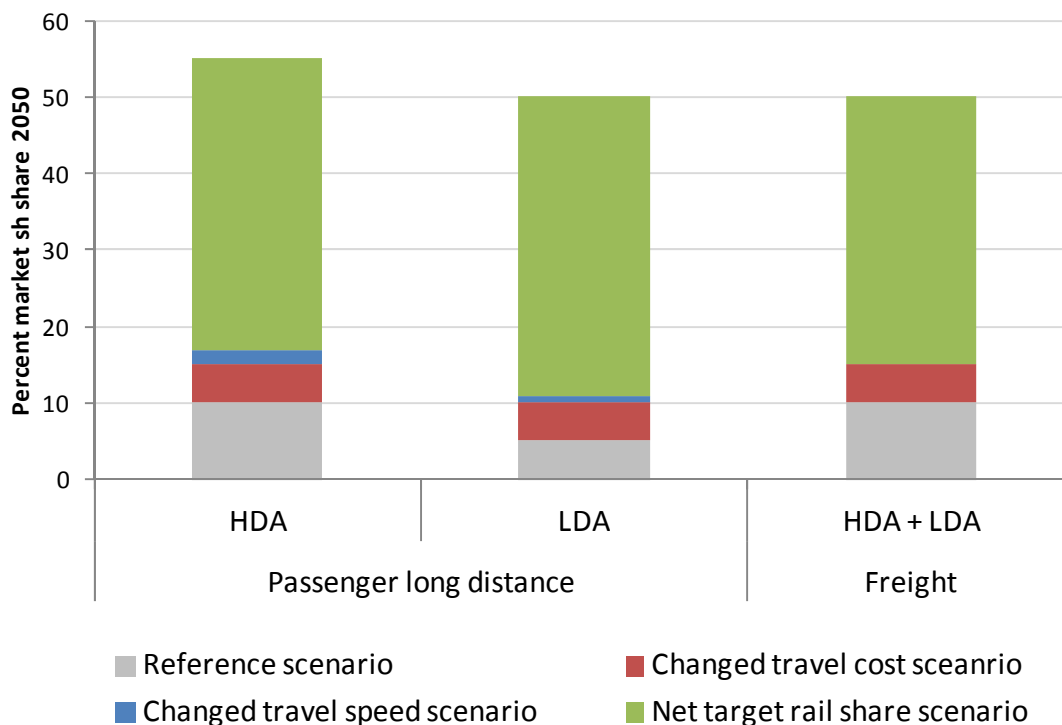
Figure 19: Overview of the impacts of railmaps measures scenarios

Railmaps should be more effective in terms of changing transport costs (reduced costs for rail and increased costs for competing modes as effect of regulation). The rail market share would remain largely below 50% but some positive impacts on energy consumption (5% – 10% reduction), emissions (10% – 30% reduction) and road accidents (5%) could be achieved.

In order to meet the 50% target, costs and speed improvements are not sufficient. Actually the purpose of railmaps is to improve also or even mainly other features of rail transport: quality, frequency of services, reliability, comfort, integration of services and so on. These other features are not explicitly modelled in

ASTRA so a backcasting exercise was carried out by setting the model parameters in order to obtain the required rail share. The results of this backcasting exercise suggest that if rail caters for 50% of mobility demand, energy consumption in the transport sector could be cut by 40% and so also greenhouse transport emissions while polluting transport emissions could be reduced up to 90% and also road accidents could be diminished by 25% – 30%.

So, as shown in Figure 20, the simulations made with ASTRA suggest that matching the rail target of 50% is much more than just a matter of improving travel costs and travel speeds.



Source: Elaboration on ASTRA results

Figure 20: Scenario contribution to 2050 rail market share targets

6.3 Economic and external cost performance

6.3.1 Background and structure

The applications of the ASTRA-EC transport, economic and environment model has unveiled large impacts of the LivingRAIL Railmap on transport mode choice and on social and environmental impacts. Nevertheless, to provide an answer to the question whether the proposed set of interventions generate an overall social surplus, the financial side has to be looked at. In this respect the following considerations seek to approach the questions:

- Which funding is needed to realise the proposed mode shift and who needs to carry this?
- Is the proposed shift to rail financially viable or even self-sustainable?
- Which role do the social impacts play in comparison to funding costs of the Railmap?

We approach these questions by using the following data sources:

- Results of the LivingRAIL deliverables D3.2 and D4.2, including the related data bases on current practices and on 2050 measure reporting forms, (MRFs for actual funding needs.
- Studies on the social and external costs of transport in Europe (CE Delft et al., 2011, RICARDO-AEA 2014, etc.) to quantify current societal costs of transport.
- LivingRAIL D2.3 for developments in energy use, THG emission rates, accident rates and noise pollution in the reference scenario between now and 2050.

According to the research questions the section is divided into two main parts: finding needs and financial performance indicators (Sections 6.3.2 and 6.3.3) and the societal impacts on social costs of transport (Section 6.3.4). For funding and economic performance we consider two alternative cases: the standard case using cost and revenue values derived throughout the project and a sensitivity case. In the latter we consider higher investment and maintenance costs of the policy and rail system measures together with lower revenue figures.

6.3.2 The standard scenario for funding needs and economic performance

Costs

Investment and maintenance costs of the LivingRAIL railmap are taken from Deliverables 3.2 on rail system and Deliverable 4.2 on policy and spatial development interventions. Both are presented as net present values (NPV) related to 2015 and calculated with a social interest rate of 5% p.a.

Costs of the two sources are given by policy (P) or rail system (R) interventions. To both sources some minor adjustments were made:

- D3.2 results are given by area type (LDA and HDA) only in the original source. To be compatible to D4.2 results an additional allocation to transport markets (urban/regional, inter-urban and freight) were made. Where the nature of the measure did not allow for a straight forward allocation plausible factors the market segments were estimated.
- D3.2 packages were re-numbered (R1-1 ... R3-3) in order to look equal to the policy package codes.
- D4.2 results contained the revenues from road pricing measures (P3-3). These were eliminated from the cost figures and moved to the revenue part.

Excluding revenues, total costs of the policy packages was at a NPV of €742 bn. By far the largest cost driver are urban areas as a new mobility culture requires the re-shaping of our living environments to get people out of their self-owned cars.

Although numerous investments in rail networks are required, the rail sector measures are expected to be only slightly more expensive than the policy and spatial development packages. Out of the estimated NPV of €603 bn. €416 bn. are expected to go into infrastructure construction and maintenance. In total we thus receive system re-design costs of €1345 bn. discounted across the period 2015 to 250 for the European Union plus Switzerland and Norway.

Revenues

Two types of revenues are considered:

- Pricing revenues from road and air charging as reported by policy package P3-3.
- Fare box and freight customer revenues of rail and PT companies. These were deliberately ignored by the MRFs.

Revenues from road and air pricing measures are estimated at almost €7000 bn. The highest share of this, nearly €3000 bn., is expected to come from inter-urban car and coach traffic, followed by roughly €2600 bn. from urban mobility pricing. In the case of inter-urban car and truck charging, interestingly low density areas are expected to contribute more than HDA in absolute terms. This is because already now charges in HDA are comparably high.

User revenues were estimated as additional incomes by the railways and PT companies on top of current user payments.

- Demand changes by focus areas in the reference scenario were estimated according to the projections in LivingRAIL Deliverable 2.3.
- Mode shift figures 2015 in the LivingRAIL were assumed to remain unchanged in the 2050 reference case.
- With these figures the additional rail and PT demand in billion passenger and ton kilometres (pkm / tkm) were computed.
- Passenger revenues per pkm in HDA 2015 were computed by statistics of the German Public Transport Association (VDV) and the German Railways (DB AG). Freight revenues 2015 for HDA were computed with figures of the DB Schenker Rail annual report 2013.
- Respective passenger tariffs 2015 for LDA were estimated 50% of HDA fare levels. Freight tariffs in LDA were assumed 75% of HDA due to the presence of international players on the market.
- Passenger and freight tariffs 2050 were derived from the 2015 values by assuming a fare level reduction of 30% across all focus areas. This is in accordance with the provision in the LivingRAIL Vision for low cost rail services. These cost reductions go far beyond the cost changes considered for the impact analysis in Table 3 to Table 5.

Assuming the resulting PT and rail revenues to constantly rise up to 2050 and discounted to 2015 leads to a net present value of €2522 billion. Among the six focus areas inter-urban passenger travel in high den-

sity areas is expected to contribute most (€1084 bn.) to this figure, followed by LDA long distance passenger travel (€466 bn.).

Table 29: Rail and PT user revenues of the LivingRAIL Railmap against the reference case

Policy package	Urban Pass. LDA	Urban Pass. HDA	Int. urb. Pass. LDA	Int. urb. Pass. HDA	Freight LDA	Freight HDA	TOTAL
Rail Demand							
Total demand 2015 (bill. pkm / tkm)	701	2104	1402	2805	1601	2401	
Total demand 2050 (bill. pkm / tkm)	1086	2466	2171	3288	3931	4350	
Mode share rail 2015	10%	30%	4%	15%	14%	25%	
Mode share rail 2050 reference scenario	10%	30%	4%	15%	14%	25%	
Mode share rail 2050 target scenario	50%	50%	50%	50%	50%	50%	
Rail / PT demand 2015 (bill. pkm / tkm)	70	631	62	421	224	600	
Rail / PT reference demand 2050 (bill. pkm / tkm)	109	740	96	493	550	1088	
Rail / PT reference demand 2050 (bill. pkm / tkm)	543	1233	1086	1644	1965	2175	
Additional rail demand 2050 (bn. pkm / tkm)	434	493	990	1151	1415	1088	
Tariffs & revenues							
Customer revenues 2015 (€/pkm,tkm)	0,06	0,12	0,09	0,18	0,035	0,046	
Reduced customer revenues 2050	30%	30%	30%	30%	30%	30%	30%
Average revenue 2015-2050 (€/pkm,tkm)	0,04	0,08	0,06	0,12	0,023	0,030	
TOTAL Railmap revenues NPV (€ bn.)	-134	-305	-466	-1084	-262	-269	-2522

Taking the two components together, the discounted sum of revenues 2015 – 2050 is expected to be nearly 9500 billion euros. In comparison: the gross domestic product (GDP) of the European Union (28 countries) in 2013 was 13,070 billion euros.

Balance of revenues and costs

Table 30 shows the details of the cost and revenue comparison. Out of the comparison we have generated a number of economic performance indicators, which are discussed in turn.

Overall net costs. This indicator subtracts total revenues from total costs and thus expresses the funding needs of the Railmap. The respective number is clearly negative (€-8400 bn.), which means that the entire policy and rail sector package generates a considerable surplus for the public sector.

Looking at the focus areas we find the highest surplus in large agglomerations (HDA). Through the high concentration of travel activities and the anyway high costs of living there, demand reactions can be

achieved in a rather cost efficient way and there is a large basis for pricing.

Cost coverage ratio: This is the simple division of revenues by costs. The overall result – 7.05% - means that revenues exceed costs by six times. I.e. there is enough room higher investment or maintenance costs, or for lowering road, air and rail user charges. Excess revenue rates are highest in high density areas, and here in freight markets.

Return on investment (ROI) is a measure of business accounting, defined as profit by turnover. Here we define profit as negative overall net costs, and turnover as total revenues. We compute the ROI for the rail sector, the policy sector and both together.

The results are close to 100%, which indicates that, due to the rather low investments, all turnover go into profits. This holds a bit more for policy than for the rail sector, but the differences are minor. Although usually high density areas show higher ROI values, we find the highest ROI (93%) for policy measures in inter-urban travel in low density areas.

Table 30: Costs and revenues of the LivingRAIL Railmap – standard case

Policy package	Urban LDA	Urban HDA	Int. urb., LDA	Int. urb. HDA	Freight LDA	Freight HDA	TOTAL
Costs by package (P = Policy, R = Rail sector)							
P1: Urban and regional structures	111	104	44	29	22	15	325
P2: Mobility services	137	88	14	4	3	2	249
P3: Reforms and regulations	44	38	30	17	26	13	168
R1: Rolling Stock	46	63	32	37	3	3	183
R2: Infrastructure	21	60	62	179	40	55	416
R3: Stations, services and customer relations	0	1	1	2	0	0	5
Costs by sector (P = Policy, R = Rail sector)							
P: Policy and spatial planning measures	292	230	88	50	51	30	742
R: Rail sector measures	67	123	95	217	43	58	603
TOTAL COSTS	360	353	183	267	94	88	1345
Revenues							
P3.3: Road and air pricing revenues	-690	-1900	-2102	-922	-900	-450	-6963
Additional rail / PT customer pricing income	-134	-305	-466	-1084	-262	-269	-2522
TOTAL REVENUES	-824	-2205	-2568	-2006	-1162	-719	-9485
Economic Performance Indicators							
Overall net costs (NPV in bn. € 2015)	-465	-1852	-2385	-1739	-1069	-631	-8140
Cost coverage ratio	229%	624%	1402%	751%	1240%	817%	705%
ROI total	56%	84%	93%	87%	92%	88%	86%
ROI for policy	58%	88%	96%	95%	94%	93%	89%
ROI for railways	50%	60%	80%	80%	84%	78%	76%

6.3.3 Sensitivity case of funding needs and economic performance

Estimating costs and potential revenues of such a broad set of measures over a period of 35 years is an extremely vague endeavour. Costs might be largely under-estimated and revenues might be over-estimated completely. On order to test the robustness of the results we thus present a simple sensitivity analysis testing for alternative levels of these two sets of parameters.

On the cost side we can suspect that investments in regional networks have been neglected to a large extent. Moreover, the costs for high speed networks and freight lines could explode due to new mega projects or acceleration activities. Mega-projects could be tunnels through the Pyrenees or the Carpates, re-visiting the Bridge of Messina, etc. The same might

hold for other measures, e.g. reforming railways, campaigning or re-shaping cities and regions. We thus have increased the value of all costs by 50%.

On the revenues side we can have similar concerns. Road and air pricing play an overwhelming role in funding the packages. However, they are subject to equity and efficiency concerns. Concerning rail and PT revenues, the sector might cut fares even more than 50% to achieve the 2050 mode share targets. to address both concerns, we reduce all incomes by 50%.

The result of the sensitivity test is presented by Table 31. Although lower in magnitude, across all focus areas the financial performance indicators still remain clearly positive. We still arrive at €2700 bn. excess revenues, a cost coverage rate of 235% and a return on investment of 57%.

Table 31: Costs and revenues of the LivingRAIL Railmap – standard case

Policy package	Urban LDA	Urban HDA	Int. urb., LDA	Int. urb. HDA	Freight LDA	Freight HDA	TOTAL
Costs by package (P = Policy, R = Rail sector)							
P1: Urban and regional structures	167	156	66	44	33	23	488
P2: Mobility services	206	133	21	6	5	3	373
P3: Reforms and regulations	66	57	45	26	39	20	252
R1: Rolling Stock	69	94	48	55	4	4	274
R2: Infrastructure	31	89	93	268	60	83	624
R3: Stations, services and customer relations	1	1	2	2	0	1	7
Costs by sector (P = Policy, R = Rail sector)							
P: Policy and spatial planning measures	439	346	132	75	77	45	1113
R: Rail sector measures	101	184	143	326	64	87	905
TOTAL COSTS	540	530	275	401	141	132	2018
Revenues							
P3.3: Road and air pricing revenues	-345	-950	-1051	-461	-450	-225	-3482
Additional rail / PT customer pricing income	-67	-153	-233	-542	-131	-134	-1261
TOTAL REVENUES	-412	-1103	-1284	-1003	-581	-359	-4742
Economic Performance Indicators							
Overall net costs (NPV in bn. € 2015)	127	-573	-1009	-602	-441	-227	-2725
Cost coverage ratio	76%	208%	467%	250%	413%	272%	235%
ROI total	-31%	52%	79%	60%	76%	63%	57%
ROI for policy	-27%	64%	87%	84%	83%	80%	68%
ROI for railways	-50%	-21%	39%	40%	51%	35%	28%

Looking at particular regions, however, the picture looks more differentiated. For small and medium sized cities, i.e. urban and regional mobility in low density areas, we receive a cost over revenues level of €127 bn. This can easily be subsidised either between urban areas of different size / density or within low density areas between urban and long distance passenger travel.

We can learn two lessons from these results: first, there are still sufficient funds available for further cost increases or adaptation of sensitive policy instruments without losing the funding case. Second, in case of further cost increases or revenue shortages cross subsidies between transport markets and / or regional entities will be needed.

6.3.4 Social costs and benefits

A comprehensive benefit cost analysis finally needs to take into account the environment and the societal impacts. We do this by computing the external costs of transport, or better their reduction in the LivingRAIL Railmap compared to the reference scenario. For road and rail transport we consider the following components of externalities:

- Accidents
- Air pollution
- Global warming
- Noise and
- Up- and downstream impacts due to the generation and provision of energy sources.

Other components like biodiversity, land use, urban fabric etc. are neglected as they play a minor role in the overall picture and because they are not covered

by the ASTRA-EC model results reported above. Other modes, namely air and shipping, are neglected due to the same rationale.

Data sources and analysis steps are as follows:

- External costs for Europe 2008 are taken from CE Delft et al. (2011). Cost values are differentiated by road passenger, road freight, rail passenger and rail freight.
- Changing traffic volumes to 2050 as well as changes in unit emission and accident rates of

transport are taken from the LivingRAIL Deliverable D2.3 (Fiorello et al., 2013).

- Out of these drivers, external costs for the year 2050 are extrapolated from the 2008 values.
- The reduction levels of total external impacts 2050 by impact category are taken from the ASTRA-EC results, Figure 19. The values for up- and downstream effects were set equal to global warming as CO₂-emissions constitute the main component of up- and downstream effects.

The results are presented by Table 32.

Table 32: Reduction in external costs by the LivingRAIL Railmap scenario

Market segment	Accidents	Air pollution	Global warming	Noise	Up- & downstream	TOTAL
External costs 2008						
Road passenger (bn. euros)	186,5	31,7	90,8	11,2	29,8	350,0
Rail passenger (bn. euros)	0,2	1,1	0,6	0,5	3,4	5,8
Road freight (bn. euros)	38,3	18,9	33,6	5,6	10,6	107,0
Rail freight (bn. euros)	0,1	0,5	0,4	0,5	1,9	3,4
Total ext. costs 2008	225,1	52,2	125,4	17,8	45,7	466,2
Drivers of change 2008 - 2050						
Demand growth passenger						130%
Demand growth freight						207%
Unit costs road 2008-2050	20%	50%	75%	80%	75%	
Unit costs rail 2008-2011	20%	50%	20%	50%	20%	
External costs 2050 - Base scenario						
Road passenger (bn. euros)	48,4	20,6	88,4	11,6	29,0	198,0
Rail passenger (bn. euros)	0,1	0,7	0,2	0,3	0,9	2,1
Road freight (bn. euros)	15,8	19,6	52,1	9,3	16,4	113,3
Rail freight (bn. euros)	0,0	0,5	0,2	0,5	0,8	2,0
Total ext. costs 2008	64,3	41,4	140,8	21,7	47,1	315,4
Reduction levels by LivingRAIL Railmap						
Passenger transport	75%	20%	55%	75%	55%	
Freight transport	75%	20%	55%	50%	55%	
External costs 2050 - Base scenario						
Road passenger (bn. euros)	36,3	4,1	48,6	8,7	16,0	113,7
Rail passenger (bn. euros)	0,0	0,1	0,1	0,2	0,5	1,0
Road freight (bn. euros)	11,9	3,9	28,7	4,6	9,0	58,2
Rail freight (bn. euros)	0,0	0,1	0,1	0,3	0,4	0,9
Total ext. costs 2008	48,2	8,3	77,5	13,9	25,9	173,7
Savings in ext. costs 2050 (bn. €)	16,1	33,1	63,4	7,9	21,2	141,6
NPV savings 2015-2050 (bn. €)	100,1	205,8	394,3	49,0	131,9	881,2

Total savings in external costs amount to €881 bn. in 2015 net present value. This component alone is

around 40% of total investment, maintenance and policy costs.

the most relevant single cost component are saving in the costs for global warming (€394 bn.). Together with the related up- and downstream costs (€132 bn.) these THG-related costs amount to over 50% of total external cost savings. This is largely due to the assumption that the rail sector will be completely THG neutral by 2050.

Accident costs, playing the biggest role in external costs 2008, do not contribute that much to the overall savings because they are assumed to decline already considerably in the reference scenario.

Air pollution - being the second largest contributor to external cost savings - and noise decline due to further technical improvements in all transport modes. In particular addressing the noise problem of freight trains brings about a huge advantage in external costs of rail.

Not included are the positive impact of the LivingRAIL Vision 2050 on the external costs of urban fabric, on biodiversity and on separation effects due to major arterial roads. Also not contained are the costs of public health and of road congestion relieve. It can be suspected that, when taking all of these components together, the external and private impacts alone would outweigh the investment and maintenance costs for the LivingRAIL Railmap.

6.4 Summary of results

Within this chapter we have assessed the impacts of the LivingRAIL Railmap 2050 on mode share, on sustainability and on the financial viability of the sector. Out of the work we can summarize a number of important key statements:

Demand:

- Even if we increase the HSR track length by a factor four across Europe, the share of passenger kilometres profiting from these services is small. The overall mode split effect of more fast lines thus ranges around two percentage points and less.
- Cheap tickets are found to have a visible impact on mode shares. With 30% cheaper railways and 20% more expensive road

transport these range around five percentage points.

- the remaining 30% of mode share to achieve the White Paper targets need to come from quality (punctuality, reliability, service, accessibility, etc.) and from flanking policy measures. So the railways as well as administrations, business and the civil society are asked to co-operate for a successful railway future.

Sustainability:

- Total transport THG emissions would fall by 40% with the Railmap measures and without any other technical measure. Improving car and truck efficiency along side can easily move the transport sector towards the -80% reduction target needed to remain under a 2°C warming limit. Similar reductions are envisaged from noise and – somewhat weaker – for accidents. Even more impacts are envisaged for the reduction of air pollutants.

Economic performance:

- We arrive a total additional costs of €1345 bn. The most expensive single measures are the completion of the European high speed and freight networks with €416 bn. Against these, railway reforms are tagged with a moderate price of €168 bn.
- With a 400% to 500% growth in rail demand, passenger and freight customer revenues are expected to grow by €2522 bn. That is even through we have considered a 50% to 70% reduction in passenger fares and freight rates by 2050.
- If we introduce road user charges across all Europe we would collect roughly €7000 bn. If we would earmark only 25% for railway projects, the Railmap could be fully financed.
- The excess availability of funds provides a great deal of freedom for correcting potentially too low cost estimates. Moreover it provides the freedom to take back some unpopular policy pricing measures. Even if we double costs and half pricing and rail charging incomes the received revenues can easily cover costs.

7 Final conclusions

In some respects the LivingRAIL Vision 2050 differs from the communications of the railway sector and of current research activities funded by the European commission. While re-emphasising the basic and necessary ingredients on railway futures advocated for many years, such as completion of high speed and freight networks, improvement in key performance indicators, use of new technologies, etc., the LivingRAIL vision strongly points on business and cultural frameworks. This broad view leads to a number of core policy recommendations in order to achieve the massive mode shift envisaged by the EC White Paper by 2050.

7.1 The essence of the LivingRAIL Vision and Railmap towards 2050

Be aware of alternative futures. There are a number of threats, such as autonomously driving emission free cars and trucks, austerity and the lack of public funding. Rail needs to address these by incorporating the new technologies as quickly as possible in its own system and by getting more cost efficient without compromising on customer orientation. Otherwise a future of marginal rail market shares is conceivable.

Place users in the core of decision processes. The vision and Railmap towards 2050 takes into consideration that without developing the mindset of customers, company managers, policy-makers and at last of railway staff, no substantial increase in rail mode share will happen. Further we need a change in small scale as well as in large scale urban and regional structures and a flexible mobility sector, for which rail and public transport can function as the reliable and high capacity backbone.

Immediate action is needed. The vision developed in this document foresees changes happening already in the near future. This is the kick-start or push of investment and urban and regional re-structuring programmes, but also the implementation of legislative

initiatives. These actions need to happen quickly and decisively in order to have a sufficiently large effect in the decades ahead.

Interventions need to be consistent. The LivingRAIL Vision 2050 points to a multitude of action fields to be considered by railways, policy, undertakings and customers. This may be confusing and the set of developments considered here may even not be complete. The important message out of this large pool of options, however, is that stakeholders and decision-makers need to co-operate and that steps taken towards more sustainability in transport need to be consistent. Otherwise customers and transport undertakings will pick whatever signal suits best their goals – and these are most likely not closely related to sustainability.

Re-think business and policy cultures. Implementing the radical changes in railway investments, operations and customer care as well as in policy-making, regional and urban planning requires 21st century business and policy-making mentalities. First of all a spirit of self-confidence and an intrinsic will to strengthen the role of rail based modes and to capture new or formerly lost markets by testing new technologies or business concepts needs to enter traditional railway and public decision boards. Continuous training and education, learning from good (and bad) experiences elsewhere and implementing a culture of “fail and learn” instead of expensive and time-consuming planning processes are essential ingredients to this process.

Respect the limits of the railways and strengthen multi-modal transport. Long-distance rail and rail-based public transport in Europe are since long operated to a high share by electric traction. Powered with renewable energy they bear the potential to offer carbon free mobility. Although at the moment catering a smaller fraction of demand in passenger and freight traffic, capacities are there or can be mobilised to shift fossil fuel based road and air traffic to rail. But there

are and will be limits. Rail modes may serve as a high capacity and reliable backbone transport provider over medium to long distances and on high demand routes. But the flexibility of the system and its accessibility in certain urban and sparsely populated areas are limited by relying on rather costly track infrastructures. To meet the high expectations of future passengers and freight customers, rail providers thus need to co-operate with other modes or integrate these into their core business models. This means multi-modal urban transport, airport connections and intermodal freight.

Consider Europe's multiple faces. Some countries in Europe have made good progress in modernising their rail systems and in stopping or even reversing the downward trend of rail market shares of the 1990s. But this happened in high income regions with a good endowment of high quality track infrastructures. Sparsely populated regions with less favourable financial conditions and / or different mobility cultures face way more difficulties in making the change. These different economic and cultural conditions prevailing in Europe need to be taken seriously when setting development goals and when drafting action programmes.

7.2 Specificities by type of region

The LivingRAIL Vision 2050 adds to other publications as it tries to tell separate but related story lines for different regions in Europe. In order not to complicate these stories we restrict to two stereotypical types of regions or *focus areas*: high density well-off regions in the European centre and low density areas with less per capita income at the European periphery. We can summarise the story lines for the two regions as follows:

High density and central areas, large agglomerations

In richer and large agglomeration regions sustainable planning concepts are known, powerful rail-based transit systems are installed and car use is relatively low. High speed rail and powerful freight corridors are in place and rail shares are in average quite high.

We thus assume that changes of green life styles and company habits as well as the installation of multi-modal mobility systems progress rather quickly. Providing sufficient capacity for rail is, however, rather problematic and will entail major efforts by infrastruc-

ture managers. We assume that in high density areas a higher rail share will be possible than in low density areas.

Specific issues for low density areas (LDA)

The private car will play a much bigger role in low density areas than in high density regions still in 2050. Due to more difficult funding conditions changes will take more time, but intelligent recipes for re-shaping city structure and regions will quickly be adopted from central countries.

A particular role in regional planning play medium sized cities. Policies will make them attractive for living and working such that the migration towards large metropolitan areas will be reversed.

Due to their distance to the European economic centres convenient long-distance train connections are most important. Frequent medium speed connections between smaller towns and the large centres and the connection of the larger agglomerations to the European high speed networks will form a competitive and attractive rail sector in low density regions.

The 2050 vision developed in this document forms the basis for the Railmap 2050 indicating a potential pathway how to approach the EC White Paper targets on modal shares for the railway as well as for the policy sectors.

7.3 Effective and affordable solutions

The LivingRAIL Railmap is composed of 62 single measures, which partly describe larger activities and strategies, and partly refer to more detailed interventions. This suite of measures gives an indication which areas needs to be looked in case the EC White Paper targets are taken seriously by rail companies and policy institutions.

The most effective measures: The rank of the measures, reflecting effectiveness and efficiency, clearly points on network extension and upgrading measures to be fostered with most urgency, this is relevant to enable the rail system to cater the three to five fold demand increase expected by 2050. Second, however, come railway and policy reforms, integrated planning and services. Most relevant services are considerably higher train frequencies in all regions, door-to-door offers, guidance and information in passenger and freight, and Europe-wide logistics bro-

kerage platforms. These themes are closely inter-linked as without a clear vision among all parties on where the transport sector shall develop to, and without open, market oriented and self-confident companies and institutions this enormous endeavour is at high risk.

Urban policies (rank 5) and mobility management (rank 7) together are targeted to impact peoples' and companies' perception of mobility. Although the single measures appear rather detailed (mobility management for employers, mobility and accessibility plans, etc.), in total they should provide a stable basis for the railways' service initiatives to be accepted. Between them, funding options play a major role for getting the above (and below) investment measures on track. What is needed are flexible instruments in the short to medium run, while in the long run the railways' income from passengers and freight customers will pay back all investments. The remaining measures stations, rolling stock and regulation fill important gaps in the policy and service landscape, but are not alone capable to alter mode shift decisions in passenger and freight transport considerably.

Most affordable strategies. Within the LivingRAIL Railmap there are two single measures with high importance and comparably low costs: reforming railways and inclusive planning. Reforming railways means to transform the rail sector from technology and process orientation to market and customer orientation. Only open and flexible companies for which their customer is not the state as the funding organisation but the passengers and freight forwarders can compete with road and air transport. But these reform processes need to be conducted by the policy sector too. One step would be inclusive planning. Here the different policy levels, stakeholders and – most important – the railways and other transport providers jointly work at visions and implementation plans for the transport system of the future.

Policy and railways need to act jointly. To each of the measures potential actors from policy, the transport sector or private players are assigned. From the ranking of measures we see that the most important are to be carried out jointly by international policy and the transport sector. Local policy (LP) follows with urban and mobility management measures and thus likewise plays a decisive role.

7.4 Impacts on demand and on the environment.

The LivingRAIL Railmap measures were tested with the ASTRA-EC transport and economics system-dynamics model. The computed results provide an interesting insight in what helps, what doesn't help and which impacts on our social community we can expect.

More high speed helps only little. If we extend the European high speed network we will most likely achieve impressive mode shift effects along these lines. In many countries we have around 50% market share of rail along the fast axes. However, even if we increase the HSR track length by a factor four across Europe, the share of passenger kilometres profiting from these services is small. The overall mode split effect of more fast lines thus ranges around two percentage points and less. What is much more needed are smooth and reliable connections between all regions possibly with speeds between 150 and 200 kph.

Making the railways cheaper helps more. Freeing the market of commercial bus services in Germany and the success of Bla-Bla-Car in France or Ubar in London demonstrates the high price sensitivity of travellers. A look into transport modelling handbooks or national planning guidelines as for the UK or Germany confirms this observation. Cheap tickets are found to have a visible impact on mode shares. With 30% cheaper railways and 20% more expensive road transport these range around five percentage points.

Quality and soft measures are most decisive. By high speed investments and lower prices we can gain up to 7 percentage points mode share for the railways in high density areas – in low density areas this is even less. The remaining 30% of mode share to achieve the White Paper targets need to come from quality (punctuality, reliability, service, accessibility, etc.) and from flanking policy measures. So the railways as well as administrations, business and the civil society are asked to co-operate for a successful railway future.

Sustainability impacts are overwhelming. One might ask why we should undertake this enormous endeavour and re-vitalise such a traditional mobility system. The justification is provided by the impressive sustainability gains we could achieve by a large-scale shift to rail. Total transport THG emissions would fall by 40% without any other technical measure. Improving car and truck efficiency along side can easily

move the transport sector towards the -80% reduction target needed to remain under a 2°C warming limit. Similar reductions are envisaged from noise and – somewhat weaker – for accidents. Even more impacts are envisaged for the reduction of air pollutants.

7.5 The business case

Railway infrastructure is expensive and operations are complex and resource consuming. But for realising the envisaged growth of 400% to 500% in rail demand, massive capacity investments are needed. Estimating potential costs and revenues of the policies introduced here leads to a number of astonishing and encouraging results:

The LivingRAIL Railmap costs 1345 billion euros.

When going through the single measures and packages for policy and spatial development as well as for the railway sector we arrive a total additional costs of €1345 bn. (net present value). Interestingly, rail measures (€603 bn.), which include the expensive network and rolling stock investments, are considered cheaper than the policy and spatial re-design activities (€742 bn.). Nevertheless, the most expensive single measures are the completion of the European high speed and freight networks with €416 bn. Against these the highly decisive reform of the business culture and market presence of the railways tagged with a moderate price of €168 bn.

Rail user revenues can pay twice for the costs.

Besides general taxes which have been disregarded here, there are two options of funding railways: through their own user revenues and / or through cross-funding by other modes. With a 400% to 500% growth in rail demand, passenger and freight customer revenues are expected to grow by €2522 bn. That is even through we have considered a 50% to 70% reduction in passenger fares and freight rates by 2050. So that source alone would suffice to fund all railway programmes twice.

Road and air charging revenues exceed Railmap costs by four times.

And even more: if we introduce road user charges across all Europe we would collect roughly €7000 bn. (in NPV). If we would earmark only 25% for railway projects, the Railmap could be fully financed. Thus: funding of railway projects is more a problem of low market shares and of a clear political

and societal commitment; not of the availability of funds per-se.

The findings are stable against higher cost and lower revenue assumptions.

The excess availability of funds provides a great deal of freedom for correcting potentially too low cost estimates. Moreover it provides the freedom to take back some unpopular policy pricing measures. This is relevant as – besides in urban areas – pricing road and air does not contribute a great deal to mode shift. Moreover, we can further reduce rail tariffs, which certainly helps mode share. Even if we double costs and half pricing and rail charging incomes the received revenues can easily cover costs. In this case only some cross-financing from high density to low density regions needs to be installed. The inclusion of social external costs provides a sound justification of cross funding. from more polluting and risky modes to rail and PT even if we assume a clear improvement of road and air in this respect towards 2050.

7.6 The essence

For a quick overview we can conclude that of course expensive investments into the rail sector are needed. However, flanking measures making railways and policy capable to act, and providing users with the right incentives to decide for rail, are equally important. International policy and the transport sector (rail and PT companies) play the most relevant role and need to push forward capacity and quality enhancing measures on the European passenger and freight rail networks. Low density countries are considered to have more time to act and erect their networks than high density areas.

Funding is not an issue if the available instruments are utilised. Part of funding comes from higher rail volumes. We had the situation of net surpluses of the rail sector already in the past before the steep rise of car ownership. Back in the 1960s rail and public transport have cross-subsidies the newly emerging electricity companies. The second half of funds comes from charging less environmentally friendly and space consuming modes of transport. The Swiss example demonstrates that such a cross subsidisation system works even for financing large mega-projects. It is thus more a question of political will and social acceptance to utilise these fiscal tools.

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