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VIVER

A sustainable transport vision for Germany

Fraunhofer ISI

Vision without action is a daydream,

action without vision is a nightmare. Japanese proverb

Abstract

VIVER (Live) – *Vision für nachhaltigen Verkehr in Deutschland* (A sustainable transport vision for Germany) is an internal research project of Fraunhofer ISI, initiated by the Business Unit Transportation Systems. The objective of the project was to come up with a clear vision of sustainable transport in Germany for the year 2050. In doing so, a conscious decision was made to only draw on the interdisciplinary expertise available within the Fraunhofer ISI.

The result clearly shows that sustainable transport in Germany will only be achievable via a compatible combination of technological change and behavioural changes. In a sustainable transport system, passenger and freight transportation will not continue to grow up to 2050, but will stabilise over the next decades – passenger transport earlier than freight – and passenger transport will even decrease significantly in the final decades. This trend break from constantly growing transport demand to stagnation and decline can mainly be traced back to behavioural and structural changes in production and globalisation processes (i.e. ultimately to behavioural changes in companies). These changes can be explained by changing values in society on the one hand (e.g. in the direction of a greater importance of climate protection and quality of life) and, on the other hand, by changing framework conditions (e.g. due to an increased shortage of fossil energy sources) and political strategies (e.g. transport taxes, user charges and town planning based on environmental aspects).

Technology change ensures that the remaining transport will be sustainable. Important aspects here include the broad diffusion of efficient drive technologies and lightweight construction and the associated introduction of new vehicle concepts both in passenger and freight transportation. The optimisation and intelligent design of multimodal mobility concepts via information and communication technologies also play an important role. For example, in passenger transport, these technologies will enable access to the respective optimal mode of transport with standardised real-time booking and invoicing interfaces; in

freight transport they will allow the efficient combination of different means of transport and a much improved rate of utilisation and better route management. The combination of passenger and goods transport in one vehicle may also become more important in the future.

The vision presented describes the result of moving towards a sustainable transport system. It can help to communicate sustainable development targets to the relevant target groups in society and is attractive and appealing instead of sparking fear of changes.

Keywords: Sustainability, mobility, transport, vision, Germany, 2030, 2050

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1 Preliminary remarks

This working paper was compiled in an internal project at the Fraunhofer ISI. The objective of the project was to *create a graphic vision of sustainable transport in Germany for the year 2050*. Such visions are usually created with the close involvement of interest groups in chaired workshops. Naturally, these interest groups represent their own individual interests when participating in such a process. This can result in unwanted limitations which mean that the vision is not able to freely develop. In order to avoid such limitations, a different concept was chosen for the VIVER project (VIVER stands for V*ision für nachhaltigen Verkehr in Deutschland – A sustainable transport vision for Germany*).

VIVER is based on Fraunhofer ISI's combined and interdisciplinary expertise accumulated over many decades of research, especially that of the Business Unit Transportation Systems. A conscious decision was made not to involve external actors and interest groups. Instead, a team came together at the Fraunhofer ISI consisting of researchers from different disciplines – industrial engineers, economists, land-use and transport planners, naval architects and psychologists. This team laid the foundations for the vision in numerous rounds of discussion and a chaired internal workshop, which have been summarised and documented in this working paper. The core members of the team assumed responsibility for writing this working paper.

The starting-point of this work was the observation that we no longer have a sustainable transport system in Germany today, but that, e.g. the noise, pollution, accidents and fragmentation of our cities due to today's transport infrastructures are not sustainable and that our system of transport will have to change in order to become a sustainable one. The time horizon of 40 years is long enough to allow the assumption of trend breaks, whether these concern framework conditions, technology or behaviour. Such a vision can only become reality, however, if it fits the frame and is appealing to society and its different interest groups. An important prerequisite for the vision's ability to attract people is that it can be clearly visualised and imagined by them.

The vision is described through its framework conditions, key fields and a synthesis of the resulting evolving system of passenger and freight transport. When discussing the framework conditions and key fields, different, even diverging developments were often conceivable. Where discrepancies arose, a general agreement was usually able to be reached and we believe that a feasible vision has emerged, which unites the various aspects considered to be relevant. By

insisting on the requirement of sustainability, a deliberate decision was made not to consider other possibly negative and thus non-sustainable alternatives such as the collapse of social systems due to demographic change and unequal income distribution, even though these are within the realms of probability if the necessary political and societal changes do not take place.

As well as the written description of the vision in this working paper, a graphic visualisation was also developed, which illustrates the framework conditions and key fields for sustainable mobility in a pictogram on the one hand and also depicts our vision of an urban environment in 2050. Excerpts from this picture are used to illustrate the working paper.

The report starts by looking back at mobility visions from the past and giving an overview of selected current visions, goes on to provide a definition of sustainable transport and then describes the method used to develop our vision of sustainable transport. The description of the vision starts with the general frame conditions which help to shape it and which can be expected in 2050 given consistent policymaking and then discusses the changes in the key fields important for mobility. The consequences for passenger and freight transport are described on this basis. Finally, the finished picture is presented, excerpts of which will already have been used to illustrate the preceding description of the vision. The working paper finishes with conclusions and an outlook.

2 Other visions of transport and mobility

This chapter takes a brief look at existing visions of mobility and transport and describes (1) historical versions from the last century, (2) selected current visions and scenarios.

2.1 Historical visions of transport and mobility

If you look at how the topic of this project is formulated, the focus is on the desire for a sustainable development of mobility and transport in Germany. The awareness of the dangers of a growing volume of transport for society, the environment and the economy has been amplified over many years and influences how the vision of sustainable mobility is shaped. Radical changes in the transport sector are necessary in order to transform the existing system into a sustainable one. From today's standpoint, at least some parts of this vision of a sustainable transport system in 2050 may seem unrealistic. Looking at past visions of transport in the year 2000 from the 1940s to 1960s (see also [1]), however, illustrates that even radical visions can become reality over a long period of time. When people came up with these visions in the past century, climate change, the finite nature of fossil fuels and air pollution were not issues which were being widely discussed. This is why most of the visions of future transport in 2000 at that time were concerned with other topics: increasing speed, improving accessibility and travelling comfort. This is also shown by the illustrations of the visions of that time, of which Figure 1 gives an impression.

From today's standpoint, several visions certainly seem to clash with how we envision a pleasant way of life. Transport at many different levels in cities does not seem a desirable concept with regard to the urban quality of life. Nevertheless, these constructs have been shaping urban landscapes for many years in numerous mega cities around the world (e.g. in Tokyo). In several visions, multiple units or magnetically-levitated (maglev) railways travelling at speeds of up to 400 km/h connect urban centres in Germany. Technically, many high-speed trains were actually capable of reaching these speeds in 2010; however, the huge amounts of energy consumed, the dense settlement structure in Germany and expensive infrastructures as well as track safety force them to run at lower speeds. Up to 2010, maglev trains had not yet become generally accepted as a consequence of their enormous infrastructure costs. Besides passenger trains, ultrasonic airplanes are also a topic. However, after the Concorde and Tupolev fleets were discontinued, mainly for economic reasons, ultrasonic civilian airplanes were no longer being operated in 2010.

Figure 1: Compilation of visions from the 1940s to 1960s (Sources of the individual illustrations: [1]).

These examples make it clear that the visions were or are able to be realised technically. However, rising energy prices and the public's lack of acceptance were usually not considered when developing the visions. And yet, people were already trying to come up with ideas for a new source of energy for transport. Nuclear power was regarded by many visionaries as a universal, clean, inexhaustible source of energy for almost all modes of transport (ships, trains, planes and buses). Some could even imagine "vehicles without petrol", powered by liquid gas or wood gas [1]. Other energy sources, in contrast, were rarely included in the visions.

As early as the 1960s there were visions of what a fifth mode of transport could look like apart from wheels, rail, water and air. Transporting passengers and goods in systems of pipes was the most common vision, powered for example by compressed air or propellers. This vision is currently experiencing a renaissance in concepts like "CargoCap". Several visionaries formulated concrete ideas of how to master the third dimension for private passenger transport. In the year 2000 they thought people would be travelling in micro planes or com-

bined car-plane hybrids to quickly reach their destinations. In view of the high prices for fossil fuels, low energy densities of alternative fuels and the presumably irresolvable safety problems associated with coordinating a fast transport mode for the masses with three-dimensional freedom, these concepts never caught on despite their technical feasibility. However, they continue to form one component of research programmes designed for the long term like the European 7th Framework Programme.

Some other technical ideas of the visionaries at that time with regard to mobility in the year 2000 have already made their way into today's transport systems and some of them have even become standard features. Drivers in every means of transport are being supported more and more by computers. Navigation systems have already been used for some years in private cars. Some undergrounds and metros operate without drivers and are controlled by computers.

2.2 Current visions and scenarios of transport and mobility

Visions and scenarios of the future development of mobility and transport have been developed by different parties. The distinction between vision and scenario is a difficult one to make and not clear-cut. By using the term "vision", we want to emphasise three main aspects:

(1) The vision should be graphic.

(2) The vision should be holistic, i.e. not cover only one or a few selected aspects of transport systems.

(3) The vision can stand alone and should portray our idea of a sustainable transport system. Variants are not to be developed which assume differing optimistic developments or stress different measures; instead the result should be a comprehensively positive but definitely realistic vision.

In contrast to this, scenarios often emerge from combining quantitative trends, only regard the development in a selected sector or can only be understood in the context of several scenarios, which are compared with one another.

The next section briefly presents a few selected examples of current visions or scenarios. Well-known scenarios include, e.g. the Shell Passenger Car Scenarios up to 2030 [2] and the scenarios of "The Future of Mobility – Scenarios for the Year 2030" of the Institute for Mobility Research (ifmo) [3]. Apart from these,

the Complete Mobility concept of Siemens [4]; [5]; [6] is also referred to, which is shaped by a multitude of scenarios and technical developments for individual aspects, but which ultimately also attempts to paint a complete picture of mobility in the future. However, to some extent, the aspect of the quality of life is missing from this picture, or at least this aspect seems to have been neglected in favour of technical solutions, so that this vision can probably be classified as having only limited power to attract a following. On the other hand, we think that the projections of the VIBAT project (visioning and Backcasting for UK Transport Policy) by Hickman and Banister [7], which will also be briefly outlined, are a positive example of a realistic vision of a sustainable transport system.

The study by Shell [2] describes the possible consequences of demographic change for future auto-mobility in Germany and analyses possible developments and sustainability potentials of vehicle propulsion technologies up to the year 2030. The study restricts itself to a small domain of sustainable transport systems when describing the degree of motorisation, the mileage and the technology of cars in Germany. Future developments are mainly derived based on the continuation of previous trends. Trend breaks are hardly considered; for the alternative or sustainability scenario, no further structural changes or behavioural changes are described alongside a technology change due to strict environmental and sustainability targets and the corresponding environmental policy actions. The design of transport systems is only dealt with in passing by Shell [2], again based on the assumption of a continuation of today's settlement and regional development trends.

In contrast to the passenger car scenarios of Shell [2], the ifmo's scenarios [3] take a comprehensive view of the transport system as a whole as well as of the many different factors which are decisive for future mobility and whose influences were analysed in scenario workshops with experts. The objective of the ifmo scenarios is to describe possible and conceivable alternative visions of the future which cannot automatically be derived from a linear extrapolation of the trends today and those up to now. The descriptions of future technologies and innovations, which are sometimes rather abstract, are illustrated and made more specific, where possible, by examples of first approaches, some of which already exist in practice.

With regard to the relevant factors of influence, developments are regarded at societal, economic, political, technological, ecological and transport mode-related levels. To some extent, the scenarios vary considerably in their assumptions about several very relevant frame conditions of mobility. In particular, the

different assumptions concerning economic performance as an important framework condition for mobility have obvious impacts on transport in the scenarios. The influence of sociocultural factors and therefore possible changes in social attitudes and values are incorporated in the scenarios via different attributes.

According to ifmo [3], the most coherent scenario (“Global take-off”) is characterised by positive economic growth, the close involvement of Germany in global trade, an active, creative policymaking and strong growth in mobility. An obvious change in mobility behaviour is assumed to have taken place with a much more pragmatic view being taken of mobility and much greater flexibility being displayed when choosing a means of transport. The scenario “Matured progress” is largely characterised by the same assumptions concerning political factors of influence, but overall has much lower growth dynamics, especially due to a much steeper decline in population. The scenario “Frantic standstill” is similar with regard to demographic conditions, but is characterised by several crisis-laden developments which result in marked business cycle fluctuations, policy actions geared to the short term and a stagnating or declining demand for freight and passenger transport. Similar scenarios result in the study by SCMI [8], which developed seven scenarios for built-up urban areas in Germany.

The ifmo [3] scenarios of the future of mobility comprehensively describe possible forms and framework conditions of future systems of transport. However, by varying the framework conditions within the scenarios, the design of the individual scenarios is dependent on these assumptions to a substantial degree. When developing the ifmo scenarios, the objective was to describe possible and conceivable developments, and not, as in this project, to describe an explicitly sustainable future transport system, which is ecologically and economically feasible and at the same time guarantees a certain quality of life for today’s and future generations (see Section 3). In this project, therefore, which intends to develop precisely this vision of a sustainable transport system, plausible framework conditions are laid out in advance and the vision is then developed on this basis.

Siemens has also developed numerous scenarios or scenario building blocks of future mobility over the last few years [4]; [5]; [6]. The motivation to develop scenario building blocks is in many cases to improve the environmental effects of mobility which can easily be linked to improvements in the quality of life. The most prominent characteristic of these scenarios, however, is their obsession with technology; at the same time, but not always, they often do not sufficiently

consider the quality of life. The results are urban visions with lots of technological improvements but without clear improvements to their general attractiveness and quality of life (see Figure 2).

Figure 2: Vision of technology-focused urban mobility in 2030 from the year 2010 [6].

In the VIBAT project of Hickman and Banister [7], a set of images of the future was also developed that represent different alternative images for the year 2030. Based on the developed images, the objective, among other things, was to determine the effective action plans necessary to achieve them. The images of the future, unlike the ifmo scenarios [3], were developed based on the target of reducing CO_2 emissions by 60% by 2030 compared to 1990. This approach also allows for trend breaks. Two alternative images were developed, each of which contain a specific focus on different policy measures: a “New Market Economy” compared to “Smart Social Policy”. In the *New Market Economy,* the target is to achieve the CO_2 emission target with the minimum of behavioural changes by focusing on technology. In *Smart Social Policy,* on the other hand, behavioural changes play the major role. The future images are used to describe the key fields influencing society’s mobility comprehensively and clearly. Changes in demographic and socio-economic trends are taken into account as the framework context for both images in the same way; different assumptions are only made in a few exceptional cases.

Hickman and Banister [7] develop graphic and comprehensive visions of transport systems with these images of the future which meet the fixed CO_2 emission targets – either through technological change or through behavioural changes. In particular, the Smart Social Policy vision explicitly targets an improved quality

of life and is therefore suited to having a motivational effect on society. The New Market Economy, in contrast, performs better with regard to economic factors. Both visions achieve high scores for the main, but different components of a sustainable system of transport, which has to consider the ecological as well as the economic and the social dimension. These visions do not, however, explicitly include a sustainable system of transport.

To develop a vision of an explicitly sustainable transport system which has the power to motivate people to change, it seems necessary therefore to combine the potential of technology change and behavioural changes and to ensure ecology, economic viability and a good quality of life and to describe these changes in graphic and holistic terms.

3 Vision of sustainable transport – definition and objective

The concept of sustainability entered the political and social debate at the United Nations Rio Conference in 1992. In principle, the needs of today's generations should be satisfied without limiting the possibilities of future generations to be able to satisfy their needs. Ecological as well as economic and social dimensions are all relevant for sustainable development.

If this abstract definition is transferred to transport, this would roughly translate as: the mobility needs of present and future generations should be satisfied in an environmentally-compatible way; transport should be available and affordable for everyone and organised in an economically efficient way. These goals can be made more concrete at least to some extent, e.g. as targets, to achieve a reduction of the greenhouse gases from transport by 80% until 2050 or zero road fatalities by the year 2030.

In our vision of sustainable transport in the year 2050, we have not defined quantitative targets for achieving sustainability, nor have we gone into details in this project about the development necessary to reach this, i.e. the necessary measures. The aim was to develop a vision of sustainable transport in Germany, which we believe to be feasible. It is normative because we are working towards the abstract goal of sustainability as described above and has a pictorial presentation because the vision should make the necessary and possible changes imaginable and should have the power to motivate and attract. However, the quantitative targets, framework conditions and sustainable development options which are frequently discussed in society and the scientific literature do point us in a certain direction and we take on board generally recognised and comprehensive concepts.

A well-known and widely recognised concept with a pictorial presentation is e.g. the 2000 Watt Society, an energy policy model which was developed within the Novatlantis programme at the ETH Zürich [9]. According to this vision, the average global energy demand per person should correspond to 2000 Watt by 2100 in order to be sustainable. We estimate the average share which is available for sustainable mobility to be around one quarter to one third of this.

If such targets and concepts are refined for passenger and freight transport, the image of an integrated transport system emerges which meets human mobility needs in a way which is low-polluting, energy-efficient and simultaneously comfortable and, by offering a multitude of options, as cost-effective as possible. It

manages this without having negative impacts on where people live. This includes preventing the further increase in land use for transport; reduction in the energy used by passenger transport by a factor of 4 for energy and greenhouse gas emissions and for freight transport by at least a factor of 2. Freight transport is reliable and flexible, able to adjust to new production and trade concepts. Overall, transport will become quieter and also less visible in urban areas; pollutant emissions are no longer significant.

In this context, studies show that this level of sustainable transport can only be achieved by the parallel development and application of new technologies and behavioural changes [10]; [11] (see also section 2.2). A vision which inspires people to use new technologies and change their behaviour to become more sustainable has to have a strong motivating force and be able to convey an improved quality of life.

Sustainable transport can certainly not be achieved with a trend scenario, i.e. with a simple continuation of previous and current trends. In addition, past experience shows that trend breaks have always occurred and can and should be reckoned with in the future, whether these are due to changed framework conditions, specifically applied measures or the complexity of social developments, all of which shed doubt on the practice of simply updating observed trends in a linear fashion. The expectation of important trend breaks in the next decades has also been confirmed by experts in scenario and foresight projects [12]. Trend breaks will therefore also be part of the vision of sustainable transport in Germany. These can take effect in the framework conditions such as the increasing shortage of fossil energy resources, or as breakthroughs in new technologies such as lithium-ion batteries. But trend breaks are also conceivable in social values and behaviour patterns, such as, e.g. a shift from owning a private car to more utilisation-oriented concepts, or a shift of what a car represents from a status symbol to a mere commodity.

4 Methodology

To develop the vision of sustainable transport, a team of scientific researchers from the Fraunhofer ISI was brought together, mostly from the Business Unit Transportation Systems, who have broad expertise in the field of transport and combine different scientific perspectives or disciplines (industrial engineers, economists, land-use and transport planners, naval architects and psychologists). External actors and interest groups were deliberately not included in order to allow the vision to develop freely without being restricted by individual interests. It is planned to discuss the vision developed in this project in further stages with external experts, actors and representatives of relevant interest groups.

The approach taken was to split the work into the following stages with an internal workshop as the main element. To start with, the project's core team constructed the framework assumed to be in place for the developed vision. The relevant social, economic and ecological frame conditions were identified and a consensus was reached about their realistic development (see section 5). In parallel, the relevant literature was compiled and screened; especially important visions and scenario projects concerning the topic of future mobility (see sections 2.2 and [11]). This guarantees that the vision takes into account existing relevant findings and visions or scenarios and either integrates these or explicitly differs from them and justifies this divergence. Our own ongoing and completed preliminary work (among others [10]; [12]; [13]; [14]) also helped to construct the foundation for the vision to be developed.

In a next step, the core team members developed five individual visions which served as the input to the workshop. These visions shared a common general framework set by the agreed frame conditions. The definition formulated in Section 3 and the vision's targets served as further guidelines. The description of the measures necessary to implement the vision were deliberately excluded from this process in order to allow a realistic but also ambitious vision to develop which was not restricted due to implicit assumptions about the feasibility of measures. Plotting the concrete development paths, especially of bundles of measures to achieve the sustainable vision is planned for a follow-up project. The individual visions of the core team were presented at a two-day workshop and discussed with a dozen scientists from Fraunhofer ISI and then further developed in a joint consensus process into the final vision. The post-evaluation, further elaboration and groundwork for the developed vision were again conducted by the core team members.

The main element of VIVER was ultimately the goal to create a graphic and inspiring vision of sustainable transport. Alongside a vivid description employing examples, an additional pictorial or graphic visualisation was intended to clarify the vision and help ensure its power to motivate and inspire people. This was done in two stages by developing a concept (Phase 1) together with the designer Judith Kozinski and then implementing this (Phase 2).

The result of the entire process is documented in this working paper.

5 Framework of the VIVER vision – basic assumptions

The framework of the vision consists of two elements: (1) the definition and (2) the basic assumptions about the most important framework conditions (in the following called “mega-trends”). These elements are described in the following sections.

5.1 Definition

The vision of sustainable transport is developed for Germany in the year 2050. However, it should be transferrable within Europe and feasible in other regions of the world, at least in some aspects – and in developing and emerging countries more directly than in industrialised nations, i.e. for example without having to go down the route of privatised mass mobility first. Alongside the time horizon of 2050, 2025 +/- 5 years is regarded as a base period as far as is possible and reasonable. Passenger and freight transport are both included in the vision. When illustrating the vision, the top priority was its visual impact while the level of detail is low. Selected concrete examples of implementation are included as to illustrate the vision.

5.2 Mega-trend 1: Demography – declining population

Two trends play a decisive role for our assumptions about demographic changes: on the one hand, there is a slight increase in the birth rate due to a policy of actively supporting families, but this is still not able to prevent the overall decline in the population; on the other hand, there is increasing ageing of the population due to further rises in life expectancy. However, we assume a smaller increase in life expectancy than many other studies because we expect unhealthy lifestyles to persist in some parts of the population and that the health system will not continue to improve its services in line with this. By 2050, therefore, we anticipate a clear drop in the population in Germany to 70 to 74 million persons from around the 82 million living here today. This drop occurs in spite of the assumed annual positive migration balance (net immigration) of around 100,000 persons. This presupposes that Germany pursues an active immigration policy.

5.3 Mega-trend 2: Only moderate growth of GDP and income

It is assumed that Germany recovers from the financial and economic crisis of 2008/2009 and that in subsequent years the economy starts to grow again. However, the average growth rates of 1 to 1.5% will be lower than in the past. Even if we talk about average growth rates here, we still expect economic cycles to occur in the future so that much higher growth is possible in specific years while in other years zero growth or even an economic decline with negative figures can be expected. The highest growth rates are expected in the years immediately following the crisis, roughly up to 2015, driven by state trade cycle policy and the recovering global economy. After this, in the medium and long term, the dominant effects are those which curb economic growth.

These effects can be traced back to several factors. On the one hand, the shrinking population curbs growth, especially because the population of employable age declines faster than the total population. On the other hand, the debts incurred to combat the economic and financial crisis have an adverse effect on growth. They raise interest rates, restrict state spending and may make it necessary to increase taxes in order to reduce debt. In addition, a further rise in the prices of raw materials has to be reckoned with, caused by increasing demand from emerging economies (especially China and India) and from the producing countries themselves. It can be assumed that such shortages together with climate protection requirements may indeed trigger greater innovation and the growth spurts associated with this (key term “Green New Deal”); but this will not affect all raw materials in short supply or the (increased) shortage of some materials will proceed so quickly that alternatives will not be able to be developed quickly enough and implemented in innovations.

Accordingly, Germany continues to rely on the further development of its competitive industry sector, which also produces the required innovations and on its service sector, which has moderate growth, especially in higher value added services. Agriculture, the building and trade sector, on the other hand, are expected to stagnate or shrink.

The distribution of income also plays an important role for future mobility. The available income for transport services varies strongly between the different income groups. For example, the amount spent on mobility in absolute terms differs by a factor of 7 between households in the lowest income group (<900 euros available income) and those in the highest (>3600 euros available in-

come) [15]. The associated transport services show a similar range. In recent years the distribution of income in Germany has become more and more unequal, i.e. the number of persons in low income groups has increased and thus also the number of persons with low transport demand. If the gap in income continues to widen, this will contribute to passenger transport stagnating or even declining. However, we assume that measures will be taken to prevent a continued widening of the cleft between the income groups. Ultimately, this means that the lower income groups are supported at the expense of the higher groups.

In this context, however, the expected increase in transport costs should be pointed out, e.g. due to rising energy costs but also due to more expensive infrastructure and utilisation costs. The relative increase in transport costs will be highest for low-income groups and its effect of curbing the demand for transport will be strongest here.

5.4 Mega-trend 3: Stable social security and pensions

It is assumed that the social security system in Germany will remain intact, especially the health, unemployment and pension insurance schemes, i.e. these will continue to contribute significantly to the population's social security. This presumes a continuous process of reform which adapts the related systems to changing conditions (e.g. ageing population, enhanced accumulation of economic potential in a small population group). Especially if an increase in employment can be realised, we assume that, at constant saving patterns, two thirds of the households in 2050 will have an inflation-adjusted pension which is around 20% higher in 2050, but one third of households will not be able to compensate the pension shortfall fully or indeed at all. Correspondingly, these households will only have very limited budgets available for transport purposes.

5.5 Mega-trend 4: Foreign trade and logistics decelerate

It is assumed that the process of globalisation continues into the future as well, although at a slower rate. As a result, the increase in trade flows is also slower than in the past. For Germany and Europe we assume that the East-West trade corridor will continue to gain in importance compared to the North-South axis

Production is partly shifted back to Germany or Europe because the saving potentials in other countries which acted as the motivation for relocation in the first place could not be realised, e.g. due to the lack of qualifications or shrinking low wage cost advantages.

5.6 Mega-trend 5: Perceptible influence of climate change

It is highly probable that the influence of climate change is increasingly being felt by 2050. Extreme weather events like storms, droughts, floods or heat-waves will become more frequent and impact transport. This results in restrictions in the availability of transport, for example, in inland water transport due to low water levels, or in aviation due to storm events. Increasingly, parts of the infrastructure could be temporarily unusable e.g. due to flooding. However, we expect transport to be only moderately affected until 2050 due to the adaptation measures employed.

It is assumed that there will be a massive shift in tourism flows because of the impacts of climate change. Holidays in the Mediterranean will become increasingly unattractive, while the more northern coastlines will become more popular including the German North and Baltic Sea resorts. In the Alps, summer tourism will be more important than winter tourism.

We expect Germany and the EU to pursue an ambitious climate policy after 2010, which is also supported on a global scale. All the external costs of transport including climate impacts will be completely internalised by 2050 by integrating all the transport operators in the European emissions trading scheme. As a result of the much stricter policy of allocating certificates per sector, their price will climb to more than 200 euros/t by 2050. Despite this, at least up until 2035, climate policy will not be able to influence the progress of climate change. The global climate system is so sluggish to react that up to then the increase in global temperature will proceed unaffected by the actions taken.

5.7 Mega-trend 6: Shortage of fossil energy sources

Physical, individual mobility is expected to become dramatically more expensive up to 2025 with the increasing scarcity of fossil fuels and rising global energy demand. Especially the energy costs for imported fuels rise sharply until 2025. Strongly fluctuating prices for crude oil with price spikes of more than 250 US dollar per barrel in today's prices will be the norm in our estimation. Newly discovered reserves can only be accessed with difficulty (in the deep sea or Arctic), which has the effect of making energy and mobility even more expensive on the supply side. The rise in energy prices and an active climate policy act as drivers forcing renewable energy sources to permeate energy generation up to 2050. The power sector in particular has been converted almost completely to renewable energies by 2050.

5.8 Mega-trend 7: Economic order and political background

We expect that private initiatives and market liberalisation will continue to characterise the economic order. However the economic crisis of 2008/2009 probably marked the end of the phase of *liberalisation at any cost* which was aimed at lean government reduced to the tasks of defence and social security. In the future, a strong government sets clear rules for markets whose implementation and compliance are monitored by the relevant national or supranational regulating authorities. In view of the possibilities of new communication technologies and forms we expect that civil society initiatives are able to improve their activities through better networking, coordination and communication and in this way gain greater influence on the markets and are better able to introduce the wishes and demands of responsible consumers.

5.9 Visualising the mega-trends

The vision of sustainable transport in Germany in VIVER is supported by illustrating this on two levels. At the level of the *mega-trends* (also basic assumptions) and *key fields*, pictograms were chosen as the means of representation as these should enable a quick grasp of the relevant framework conditions and key fields and at the same time indicate the assumed trends and developments. For instance, the flat curve of GDP development symbolises the slowdown of growth, the polar bear on the drifting ice floe climate change and the racing car on snail wheels deceleration (see Figure 3).

Figure 3: Pictograms representing the mega-trends and key fields of VIVER [16].

6 Key fields

To move in the direction of sustainable mobility, developments in different key areas and especially their interaction will play a decisive role. The following sections describe the identified key fields as components of a sustainable mobility vision for the year 2050. The *perspective taken to do so is from the year 2050* in order to make the vision as realistic as possible.

6.1 Values

Climate protection and sustainability, urban lifestyle, multimodality, deceleration and regionality are described below as values which make a substantial contribution to developing sustainable transport services.

Climate protection and sustainability

Since 2010 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 to a greater awareness among Germany's population about their own contribution to climate change, an increasing readiness to make relevant changes to their own behaviour and a high level of acceptance of climate protection measures. In 2050, there is a generally raised level of environmental awareness. This has been aided by the fact that environmental protection and sustainability are firmly embedded in schools as part of the curriculum and are taught in an imaginative and application-oriented manner so that generations have grown up with a much greater awareness of the environment and have adapted their behaviour accordingly. Driving schools consistently teach efficient driving methods whose practical realisation is supported by driver assistance systems and traffic management in cities (user fees, traffic light controls etc.).

Urban lifestyle

The drawbacks of suburban life have become more and more apparent since 2010, especially with regard to the increased costs of transport and the time consumed. In 2050, it is viewed as an integral part of a good quality of life to be able to meet everyday needs and be mobile without having to use a motorised form of transport. Walking and cycling have become part of the way of life of a population more interested in better health and a sustainable quality of life. When deciding on where to live, high priority is given to good access to work, shops and leisure activities and different possibilities for social contacts.

Multimodality

When selecting the means of transport, since 2010, use and cost considerations as well as health aspects have become more important alongside emotional factors. The generational shift has also contributed to this: Among those born since 1980, the car has lost its standing as a status symbol compared to other transport means; people have a different relationship to cars and, in contrast to previous generations, do not view them as a symbol of freedom and economic success, but merely as one possible transport option among others. A growing number of drivers in 2050 use cars more pragmatically and rationally, a trend also caused by the significantly risen costs of mobility. Heavy, inefficient cars are not popular. In urban regions, the improvements to local public transport and the network of foot and cycle paths – combined with priority right-of-way at many intersections - have further reduced both the attractiveness of cars and the necessity to use them for shorter distances. Most people choose a means of transport best suited to their travelling purpose, e.g. considering size and efficiency aspects.

A trend towards using instead of owning has taken place especially in urban regions, because the advantages (cost/benefit optimisation, being able to do without maintenance and repairs, sustainability aspects, flexibility through continuous choices) have been increasingly recognised and attractive, customised services have been created. Utilisation-oriented concepts like car sharing, Car2Go and bike sharing schemes, of which promising approaches already existed at the beginning of the 21st century [17]; [18]; [19], have been an unprecedented success within German cities. Figure 4 shows different variants of transport-sharing schemes by means of the corresponding stations for sharing bikes, Segways and electric cars. The compass symbolises a tool which enables barrier-free and fully informed switching between the different means of transport. In 2050 such sharing schemes are linked with public transport in a barrier-free way. Integrated, standardised booking and invoicing systems with a pre-paid function or monthly bills make it possible to access every service using a one-stop-shop.

Figure 4: Detail from the illustration of the VIVER vision symbolising barrier-free and comfortable switching between various shared urban transport modes [16].

These developments have opened up greater scope for more multimodal services. The ideal of multimodality which can be designed individually has also gained emotional appeal and is a good match especially for the life style of urban residents. Bicycles and highly efficient, lightweight electric cars are the new status symbols of city dwellers. They symbolise independence, a fit and active way of life and concern for scarce resources.

Deceleration

Supported by improved and optimised transport systems as well as risen mobility costs and interim bottlenecks, a trend towards deceleration has taken place. In general, many Germans are aware that their quality of life improves with having to travel only shorter distances and appreciate the resulting extra free time and flexibility they gain and so try to avoid longer motorised trips in 2050. The population over 60 in particular value a slower pace of life after their generally “active life”. For trips of every length, the quality of the journey itself and stress reduction have become more important than just getting there as quickly as possible.

Because there are better connections between the different types of transport, day-to-day short trips can easily be made multi-modally and without forfeiting

large amounts of time. The local public transport system is suitable for the elderly and designed in an increasingly barrier-free way due to increased comfort and simple handling. A deceleration of the pace of daily life and how this is experienced has also taken place due to ever better networking due to modern communication technologies which also help to reduce journeys. These values are also promoted by a strong health consciousness; walking and cycling have a positive image and are used by almost everyone to get about.

In the meantime, the speed of transport has been optimised from the viewpoint of energy consumption. For instance, high-speed railway lines have been expanded, but the maximum velocities do not exceed the top mark of 300 km/h. A large share of flights over short and medium distances has been replaced by train journeys for cost reasons and because of increased climate awareness. The permitted speed limits have been standardised across Europe to 120 km/h on motorways, 80 km/h on main roads, 70 km/h on secondary roads and 30 km/h in towns. There is a high level of acceptance for these measures among the population because they experience the gains in safety and the quality of life first-hand and because this is how reliable mobility can remain affordable.

Regionality

Regionality has once again become an important, emotive value, and a trademark for tourism and consumption, supported by an increasing quality and environmental awareness, active marketing and actions to improve regional attractiveness and not least due to the increased cost pressure in transport. The rediscovery of a slower pace of life, e.g. in the form of a relaxed arrival or car-free holiday locations, lend additional support to this trend. Being integrated in a local community and helping neighbours have become more important values again. Figure 5 shows illustrations from marketing campaigns which were conducted around 2010 for regional products and services and the promotion of car-free tourism in Germany and Switzerland.

Figure 5: Marketing for regional products or services. On the left: Campaign “Kurz nah weg: Urlaub in Deutschland” (Getting away from it all nearby: Holiday in Germany) (2008) [21]. In the middle: Label for 100% regionally produced products [22]. On the right: Logo of the Gemeinschaft autofreier Schweizer Tourismusorte (Association of Swiss car-free tourist resorts) [23].

6.2 Urban and regional planning

In order to substantially reduce additional land consumption, the legislation governing building regulations was tightened considerably post 2010: Converting additional land for housing and transport developments is only permitted as a rule if desealing measures are applied to other developed areas (deconstruction measures of vacant buildings, replacing asphalt and concrete with grass pavers etc.). The role of regions was strengthened here at the expense of the right of local communities to self-government because land-use compensation is easier to implement at the level of regions than at local community level. But informal cooperation among municipalities also plays an ever greater role: In 2050 coordinated spatial development of towns and communities is the rule, often via contracts to balance the pros and cons of the negotiated solutions. The ideal urban development visions of the past decades, characterised by sustainability concepts, shorter distances and the desire to organise life along more compact urban lines, have finally been implemented to a large degree by 2050: The majority of people really are able to get to work or other everyday destinations by foot or muscle-powered vehicles (bicycles, push scooters). At regional level, the regional planning corridor concept (locating development cores along transport corridors) has undergone a renaissance due to the increasing relevance of rail lines and the boom of housing developments along the line (transit oriented development).

Figure 6: On the left: Illustration of Sonoma Mountain Village near San Francisco, a residential area of approx. 80 ha, which is being developed to be 100% sustainable (Source: [24]). On the right: Market-place, consistent roof landscaping and urban multimodality in VIVER [16].

Re-urbanisation and green suburbia

The quality of life has been substantially improved in many cities due to sustainable town and transport planning and a greater greening of the cityscape (see Figure 6). Very promising practical examples of sustainable town planning already existed in 2010 [25]; [26]; [27]; [28] (see also Figure 7). Since 2010, this has led to a gradual re-urbanisation; upgraded and improved cities have become increasingly attractive to singles, young families and the elderly. They offer a variety of services such as theatres, cinemas, nightlife, medical care and good care facilities for children and the elderly, which have suffered large cutbacks, or are even missing completely in rural regions. Inner-city alternatives to single-family homes are very popular because of their smaller land-use and energy footprints, the shorter distances in daily travel and the associated flexibility and independence and the generally higher quality of life.

The successful cities in 2050 match the ideal of a compact city with easily accessible shopping, cultural and social organisations and new mixed forms of higher density housing. A larger number of people are able to live and work in the same area in city centres due to attractive and compact building structures (e.g. four-storey buildings, communal gardens, attractive building developments for vacant lots and former industrial sites).

Cities are green, desirable places to live which are pedestrian and cyclist-friendly and promote and enable diverse and varied multimodal mobility options. Attractive networks of footpaths and cycle paths have been constructed and pedestrian crossing systems that stop all motor vehicles in every direction have been introduced in every city. The public transport stops and passenger information systems have been attractively designed, and there are car-sharing parking spaces and cycle stations at every larger transport hub. This means that less space is required for parking cars and road traffic so that attractive quiet zones and meeting places have been able to be created at many places instead. The remaining motorised urban traffic is concentrated on key, often subterranean axes and flows better due to a reduction and better coordination of the traffic lights, by switching off less frequented crossing lights during off-peak periods and by the use of roundabouts.

Figure 7: Grassed-over tram lines connect the car-free district of Vauban in Freiburg 2.5 km away from the city centre [29].

Shrinking regions

In shrinking regions and on city outskirts, a conversion or deconstruction of vacant buildings, roads and other infrastructure facilities has taken place since 2010 depending on the local situation. Zones with utopian potential, i.e. places for social and creative experiments have been created here and have been promoted as incentives by being given additional freedoms as already outlined by Kil in 2007 [30]. Generally, however, there is an increasing gap to the wide range of services offered in the successful urban regions.

Thanks to the increasing diffusion of information and communication technologies (ICT), a whole series of public and private services of general interest are offered and received in rural communities as well in 2050. Public and private initiatives in the form of local neighbourhood shops and buying groups to secure local supplies were already being successfully operated in a lot of rural communities in 2010 (on 01.09.2010 the village shop network in Germany listed 17 shops across Germany being managed in private or public initiatives). By 2050 these are widespread in rural areas and go hand-in-hand with the new internet services of general interest.

A general trend towards a more urban lifestyle has taken place in better mixed housing developments which have good public transport links so that daily needs can be met using less transport. For people, who want to remain living in shrinking regions or who deliberately move to such areas, a reasonable quality of life and the fulfilment of everyday needs are still guaranteed.

6.3 Work and leisure

Work

In 2050 many measures to avoid transport (such as, e.g. commuter rooms, telecommuting, mobile workplaces, telephone and video conferences, carpooling) or to shift transport mode (e.g. company bikes, providing bike tool kits, job tickets, showering and changing facilities at work, travel information for public transport services and mobility management) have been fully implemented in the workplace, some of which were already firmly established in forward-looking institutions and companies in 2010 (see also [30]).

Fixed working hours and workplaces have become rarer. The core working hours common at the beginning of the 21st century have been increasingly replaced by individual schedules which are based on people's different life plans. This has had the effect of reducing some of the peak traffic periods. Another trend is the increasing decentralisation of work. The necessity to commute to work from one agglomeration to another is also lessened due to the technical possibilities for home office and modern video conferences.

The authorisation of long-distance business trips by plane is much more strictly managed by companies, not least on account of the increased cost pressure. The use of modern communication technologies has been strongly promoted as an alternative so that behavioural changes have been brought about. Technically, all medium-sized and larger companies are well equipped with modern

communication technology. New technologies make improved collaboration possible even over long distances. It is possible to discuss things with business partners using 3D holographic projection technologies as though everyone were in the same room, without ever having to leave your office or desk at home. A considerable share of business trips has been able to be replaced in this way. Not least the time able to be saved by using these technologies led to their increased acceptance. Despite this development, “real” social contacts still remain very important for business, and new traffic over longer distances has even been created in many cases due to ever closer intercultural exchanges and more complex business relations. As a rule, modern communication technologies are then only used to maintain these contacts, a core of “real” social contacts remains (50% compared to 2010).

Nevertheless, the general mobility requirements made of employees have increased with continued globalisation and a further increase in job specialisation. While daily routes to work have become shorter, the journeys made to stay in touch with family and friends have become longer. These cannot be compensated by virtual contacts so that there has been a slight increase in the average individual mobility for private social contacts since 2010.

Consumption structures

Consumption structures have become much more locally based by 2050. The labelling of consumer products with their CO_2 intensity, supported by a growing awareness of climate change in combination with risen transport costs have brought about a change of attitude among consumers and, as a consequence of this, among producers. Regional structures have undergone a renaissance for many products as a result and transport routes up to product completion have been minimised. Regionality is a trademark in 2050 and the advantages of only having to travel shorter distances in daily life are appreciated by many.

Another trend which has taken place since 2010 is the greater use of internet shopping, and of online grocery shopping among others. A wide range of supermarket offers, increasing acceptance on the part of consumers and the realisation of saving potentials due to optimal distribution routes and bundling routes mean that more and more consumers are choosing this type of grocery shopping.

Holidays

Mobility behaviour on holiday is similarly characterised by the outlined developments up to 2050. The advantages of regional tourism have been rediscovered (compare section 6.1). Distant destinations are the exception in 2050 due to the dramatically increased costs of air travel. Short weekend breaks by plane are a thing of the past and have been replaced by train travel due to the improved services of high-speed rail connections within Europe. A certain hard core of long-distance travel remains, but this is reserved for the higher income groups in particular. An additional fact is that even holiday destinations which were still fairly affordable in 2010 have become more expensive when compared to holidaying within Germany.

6.4 Production and markets

Transportation and logistics costs have risen considerably by 2050; this rise has been caused by the internalisation of external costs and the increased prices for crude oil as well as increasing bottlenecks in the transport system and, connected with this, higher supply risks in long transport chains. Together with fully developed recycling technologies, a greater awareness among the population of the consequences of globalisation and a new quality awareness, this has led to a reinforcement of regional and local production and services and thus to a trend running counter to globalisation.

A transition to regional economic cycles and local services helps to reduce the outlay for transport in numerous markets. This is especially valid for agriculture, trades, specific finished products and tourism. This makes it possible to live and do business in a transport-saving way. A trend in the direction of the dematerialisation of economic processes has additionally contributed to the decoupling of economic growth and transport. However, this effect is limited to only a few consumer good markets and their primary products. Further advances made in material and process efficiency have had a much more significant effect on the volume of traffic.

Heavy industry has mainly been relocated to Asia; overall, there has been a sector-specific, global concentration of industrial locations so that, in these sectors, globalisation has continued to progress. Europe has retained or managed to regain a strong market position for high-value products, which also applies in the field of electronics and efficiency technologies. Especially in automobile

manufacturing, Europe has succeeded in remaining a global leader by consistently backing clean and energy-efficient technologies.

Since 2010, stronger and more globally-based competition with the then emerging economies has pushed the development of sophisticated logistics on the freight markets. Environmental aspects play a major role here at both European and global levels because of public awareness and the political frame conditions.

6.5 Cross-cutting technologies

Four cross-cutting technologies or technology areas have been playing an increasing role for the changes in mobility and the transport systems since 2010:

- Nanotechnology
- Image communication in 3D quality (holography)
- Biorefinery and biomass use
- Recycling.

Nanotechnology has become ever more important in the market introduction of new drive technologies or new vehicle concepts, due to its use in both energy storage technologies (e.g. in high performance batteries, fuel cells, hydrogen tanks) and lightweight construction (e.g. in high-strength compound materials).

Improved image communication has helped to make video conferences with three-dimensional holographic images of discussion partners possible and has thus led to being able to cancel some business trips or even the attendance at smaller conferences. Furthermore, such media also facilitate multimodality, e.g. finding a means of transport or demonstrating operating instructions.

Biorefineries and biomass use have become much more important, in order to replace fossil energy sources which have become ever scarcer and more expensive ─ this concerns their use both as materials (i.e. replacing petrochemical plastics) and fuels (i.e. use of biofuels). In addition, the amount of traffic itself has been influenced by the large volumes of traffic travelling to and from biorefineries.

Since 2010 the development and spread of recycling concepts became increasingly necessary because of growing shortages in the supply of some, mostly metallic raw materials. The associated new transport flows no longer span the globe, starting from the mines in Africa or Australia, but often occur regionally

within the countries from collection points via companies of the recycling industry to the production plants which use the reclaimed raw materials.

6.6 Transport policy: Market regulation and liberalisation

With regard to future transport policy, the EU finally managed to push through the liberalisation of the railways from 2020/25. After a certain transitional period of different state models, the European rail network has been operated by three supranational organisations under EU control from 2035, which are completely independent of the operating companies. The railway networks are operated under conditions of completely free competition. Former state railways have been privatised. Similar to the air traffic sector, large European concerns and alliances were formed as a result, whose market dominance however was limited by the EU Commission for competition. As a result of the intensive competition with new private players, the efficiency, services offered and quality of rail transport were able to be greatly improved.

In road traffic, the user fees already created by the EU in its 2001 White Paper on transport have slowly caught on and the standardisation of energy taxes – also in transport – has been advanced. By 2050 either a standardised system of collecting fees has become widely accepted or the systems existing in different EU countries have become interoperable.

There is a similar picture for multimodal systems. Europe-wide regulations ensure that no isolated solutions for individual regions or countries emerged, but rather standardised, comprehensive solutions both with regard to booking and invoicing transport services.

The external costs of all modes of transport have been fully accounted for and internalised by 2050 via European regulations. Furthermore, speed limits have been introduced for road traffic, which are valid throughout Europe (see section 6.1).

6.7 Mobility concepts

Multimodal mobility in passenger transport, i.e. a flexible and barrier-free combination and use of different transport means, is a standard feature in 2050, especially in urban regions. Extensive mobility packages are available everywhere and greatly reduce the generally higher mobility costs. Public transport forms the backbone of these mixed interconnected transport services and this can be combined with many other modes and components like bike- and car-sharing,

rental cars, car-pooling including mobility guarantees, delivery services, taxis as well as air travel. Car use has become more similar to public transport. Rental cars and bikes which are available at parking places throughout cities can be used spontaneously with no pre-booking and no fixed time of return and simply left at designated areas anywhere in town (see Figure 8). In 2010, there were already approx. 6000 “Call-a-Bikes” owned by the Deutsche Bahn and others in the cities of Berlin, Frankfurt am Main, Munich, Cologne, Stuttgart and Karlsruhe and available at many ICE-railway stations in Germany [19]. Bike-sharing concepts with fixed stations, which already existed in 2010 in Lyon, Seville, Milan or Paris, have been successfully established in German cities. Car rental schemes like Car2Go, which already supplied 200 cars in Ulm in 2010 [31], are also widespread. In 2050, different types of transport can be activated and paid for with a travel card or a mobile phone with simple billing in line with the “best price principle”.

Travelling by bike – either your own or a hired one – is a much more attractive option in 2050 due to speed limits of 30 km/h in cities, good public transport links including reasonably priced cycle carriage and secure cycle storage possibilities at railway stations and bus/tram stops. Affordable electrically-assisted bicycles make cycling more popular even in hilly or mountainous regions. Similarly, short distances are once again being covered on foot more frequently because attractive pedestrian routes and, in many cases, green, traffic-calmed areas have been created to rest and relax in.

Figure 8: Hiring a rental bike at a tram station (left) or a micro-electric vehicle in an urban area (right) as visualised in VIVER [16].

Situation- and location-specific, mobile information services are widespread and accessible using individual ICT. Intelligent, intermodal route planners in the latest generation of mobile phones find the fastest, cheapest and most ecological alternatives in a matter of seconds and guide residents to the various transport service. The next car-sharing vehicle, the next rental bike and the next tram, metro or overground suburban rail system are displayed and can be booked and paid for immediately.

The population is characterised by a generation of car-sharers and multimodal travellers. As a result, car ownership has dropped to 250 cars per 1000 residents. In city centres, the use of car hire systems like Car2Go together with other means of transport outweighs the use of privately owned cars. If people do still own a car, this is often a much smaller category of vehicle because most people have recognised the advantages of smaller, more fuel-efficient cars for the predominantly short trips taken and have reacted accordingly. People fall back on car-sharing services for the small number of trips for which large cars with greater storage capacity are still needed. For an extra charge, it is possible to have computer-controlled, driverless delivery of the car-sharing vehicle right to the front door, which allows, e.g. mobility-impaired users comfortable direct access to the vehicles without having to walk any distance to access them.

In general, public transport has become more demand-oriented in its design. Local public transport has become more flexible due to real-time information and control so that waiting times are generally short and destinations are reached on time.

In rural regions, i.e. regions with low demand, local public transport services have been increasingly thinned out by 2050 due to a lack of demand. The share of households owning a car is much higher here than in urban areas. However, alternative mobility concepts have been created for those without a car or to avoid car journeys. These offer improved and simultaneously more cost-efficient local public transport services due to more flexible systems which are used in a multitude of ways. Many of these on-demand transport services were first proposed as early as the 1980s for local public transport, but have been increasingly developed and implemented since the 1990s. Böhler et al. [32] were able to identify 89 real-life examples of flexible forms of transport services across Germany in 2009. A mix of different basic elements is employed depending on the specific regional needs and conditions: (1) Fixed scheduled services, (2)

flexible scheduled services, (3) collective on-call services and (4) collective car/bike use. In this way, a certain basic supply of local public transport has been able to be financed and kept going even in rural regions. Goods transportation services are also mixed with passenger transport. Car-pooling services have also been greatly simplified technically. Advance and on-the-spot booking are both used frequently.

The basic mobility of all population groups is guaranteed. Mobility vouchers for public transport and car hire schemes are issued to lower income groups. For the elderly or otherwise mobility-restricted persons, public transport has been designed to be completely barrier-free; flexible pick-up and delivery services have been created for those no longer able to use public transport. Driving licence and health checks from 70 have been introduced and guarantee a higher level of safety for all road users.

6.8 Logistics concepts

Electric delivery vehicles are the main type used for goods transport in cities in 2050. This circumvents noise problems in residential areas as well as environmental and climate impacts, and means that the window of acceptable delivery times has been able to be expanded. Regional production facilities have established themselves in the area surrounding urban centres or freight transport centres which are supplied by long-distance transport in the form of trucks, railways or ships.

In long-distance transport, the truck has come under heavy pressure due to its dependence on combustion fuels and a significant lack of qualified personnel due to the demographic development. Accordingly, there has been no further increase in its market share since 2010.

Figure 9: Automated rail transport. On the left: subterranean container transport in cities with cargo cap [16]. On the right: loading containers [35].

In contrast to trucks and despite the internalisation of the actual track and noise costs, railways have profited from the increased automation, mainly in long-distance transport (Figure 9), more flexible track use and efficiency improvements due to market liberalisation. The loss of heavy industry and the increasing shortage of fossil energy sources did indeed prove very problematic; but these were partially compensated for by the imports of bulk products and biomass-based energy sources in port hinterland transport. Regional transport, on the other hand, is still dominated by trucks. However, potentials for rail transport were also able to be realised here due to the automation processes taking place on the railways.

Inland shipping was not able to profit particularly from progress made in automation and IT solutions. In addition there were negative effects here on the demand side emanating from the collapse of heavy industry and on the supply side from more erratic water levels as a consequence of climate change. Accordingly, inland shipping has been in an extremely difficult economic situation since 2010.

7 What does this mean for passenger transport?

The changes described in the different key fields have the overall effect of substantially reducing passenger transport on German roads by the year 2050. This is caused by shorter travelling distances on the one hand, an overall lower number of motorised trips because of the decline in population on the other and a changed population mix as a result of demographic change. The over 65 year olds in 2050 are on average more mobile than the same age group in 2010; but are still much less frequent travellers than the substantially reduced number of employed persons. In addition, the much higher level of multimodality has resulted in a marked growth in non-motorised trips. The desire for shorter trips and alternative means of mobility is linked with a higher level of social and environmental awareness and with a good quality of life being increasingly associated with having more time and a generally slower pace of life. At the same time, private individuals and firms are active over a larger area and their frequency of contact has increased in total so that new transport is created over longer distances. Some of these contacts are managed using video communication, however, and the rest is more than compensated for by the drop in the number of other trips made, especially as the still existing need for transport for leisure purposes and everyday life is met more sustainably.

The trend towards reurbanisation, optimised infrastructures, new technologies and changed values in society has led to mobility behaviour which is much more efficient and multimodal. Due to multimodal services and more attractive infrastructures as well as a greater number of local offers, more and more people have switched to public transport, car-sharing, bikes and other micro-vehicles (e. g. Segway, i-Real) as well as to walking; this started mainly among younger generations, but gradually spread to more and more older people, who experienced multimodal lifestyles when younger. Everyday life has become more locally-oriented. Trains or a suitable car-sharing vehicle are used for longer distance travel. There has been a resulting sharp rise in the number of car-free households in urban areas. This means the number of parking spaces and parked cars in cities have been able to be drastically reduced. Multimodality, i.e. the flexible combination of different modes of transport depending on the route to be travelled and the purpose of the journey, has become part of transport users' daily routine (see Figure 10).

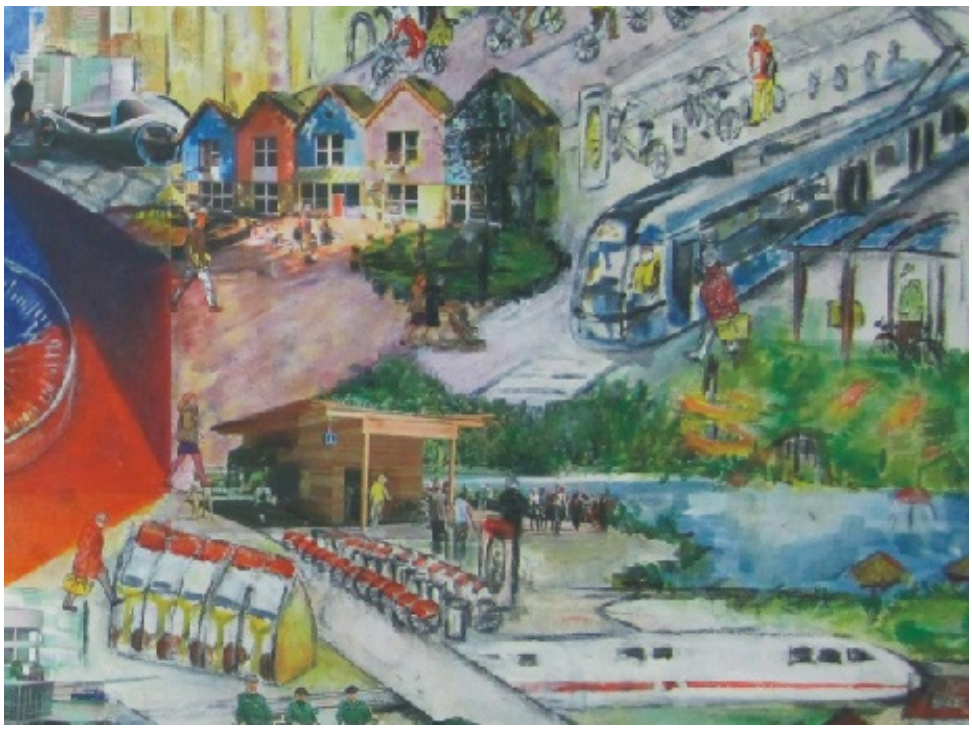

Figure 10: Multimodality ─ from trains to electric cars, bikes or Segways [16].

In rural areas, flexible public mobility services have a growing share in the modal split, even if private passenger cars still play a very large role here. There is a clear motivation for those with low income to move into the towns due to the increased costs of mobility and energy, but basically every social group is guaranteed access to transport services to meet their daily needs due to diverse and differently priced services or subsidies (like mobility vouchers).

The social change caused by climate change and the shortage of fossil fuels represented a never before experienced push factor for innovations in the field of transport. The large potentials and advantages to society as a whole of energy-efficient and climate-friendly technologies at the beginning of the 21st century sparked a global innovation race. There is extensive use of efficient technology in passenger transport in 2050, whether in private cars, micro-vehicles or public transport. The shift in values towards a slower pace of life and comprehensive sustainability awareness is also reflected in the technology, i.e. in a much more moderate and therefore more efficient motorisation of vehicles.

The average CO_2 emissions of the total car fleet dropped to 90 g/km by 2030. The fleet is characterised by a wide range of technologies. Alongside purely electric vehicles, which dominate cityscapes in 2050, there are also plug-in hy-

brids with petrol, (bio)gas and bioethanol engines as well as modern hydrogen fuel cell passenger vehicles and only the odd few conventional cars still running on fossil fuels. All the vehicles are routinely equipped with intelligent motor controls which fine-tune the engine's performance to the respective driving situation. High-lubricity oils, tyres with low rolling friction, and air pressure monitoring as well as improved ball bearings are only some of the many technical improvements which are standard features for passenger cars in 2050. Air turbulence was already able to be reduced to a minimum by 2030. Since 2030, the potential aerodynamic improvements to passenger cars have been fully exploited (external mirrors have been, e. g. replaced by cameras).

The first passenger vehicles powered by hydrogen fuel cells have been available in large numbers on the market since 2025. The purchasing costs of such vehicles are still higher than all the other technologies, but this technology allows the vehicles to be driven for long distances at moderate operating costs. Following the start-up of hydrogen technology in passenger vehicles from 2020, hydrogen storage technologies like graphite nanofibres (GNF) are now ready for series production. Compared to conventional storage methods, these technologies make very large driving ranges of up to 6000 km possible. The long refuelling processes involved (min. 4 hours), however, made it necessary to introduce new systems like the cartridge-exchange system which was launched in 2040.

Cars with highly efficient HCCI combustion engines (Homogeneous Charge Compression Ignition) in combination with electric motors for driving in the city also make longer trips possible, but are mainly owned by higher-income groups because of their high operating costs due to the use of expensive fossil energy sources. Those with average incomes use passenger vehicles with this technology for longer trips only via car-sharing schemes. The share of natural gas-powered passenger cars, which showed marked growth at one time, has fallen again by 2050 because of increased operating costs and their limited efficiency potential.

Significant technological breakthroughs have been achieved in battery technology since 2010, which have resulted in a considerable scaling down of the storage cells per unit of energy, reduced weight and thereby larger driving ranges, faster charging processes and greatly reduced prices because batteries are produced in large quantities. As a result, in 2050, the electric car outperforms other passenger vehicle technologies in terms of its total costs (purchasing plus operating costs).

Different vehicle concepts are implemented with purely electric cars. These are integrated into society's mobility services in many different ways. In urban and densely-populated regions, electric cars are designed to be small, lightweight and therefore very cost-efficient. A more limited driving range is not a problem in such areas especially because the cars have been embedded in comprehensive multimodal mobility concepts. For instance, public electric cars are available in specially designated parking spaces at every major public transport hub. Modern car-sharing technology allows simple access without pre-booking and cars can simply be returned to any other free parking space. New micro-vehicle designs (see Figure 11) have become part and parcel of the urban mobility landscape. These first entered the market in the form of the Segway as a one-person scooter or as a two-seater in cooperation with GM in 2010 as well as the Toyota i-Real and the Honda-3RC in 2015.

Figure 11: New micro-electric vehicles for urban areas ─ on the left: Segway-Puma [36]. In the middle: using Segways in urban areas [16]. On the right: Honda-3RC [37].

The fuelling station infrastructure supports the coexistence of the different technologies, because there is a nationwide network of at least 4000 fuelling stations in 2050 for all fuels and electricity. Domestic power outlets are usually sufficient for micro-electric vehicles and these are mostly charged at home. The share of renewable energies in the electricity mix has been able to be increased to more than 90%. Alternative, non-fossil fuels further reduce the CO_2 emissions of the hybrid cars as well as those cars with combustion engines which are still in use.

Cities and regions in which bicycle use was still beset with difficulties at the beginning of the 21st century, no longer exist in 2050. Many modern bicycles have small, lightweight electric motors, which make their use possible even in hillier

areas (e. g. Stuttgart). The bikes use the energy released by braking to recharge the battery. Attractive urban cycle paths and footpaths have been created, also by converting newly vacated areas.

The increased utilisation of nanotechnologies and compound materials enables substantial weight reduction in all types of vehicle. On average, the cars, trucks and planes in 2050 are 50% lighter than in 2010; rail vehicles and wagons are even 80% lighter. A modified surface structure ensures much lower air resistance.

Modern ICT in passenger transport makes it possible to combine all types of transport intelligently and comfortably. This includes having only one total final bill, optimised traffic flow and greater safety. Hazardous situations due to accidents as well as traffic congestion can be identified in good time and correctly assessed. Drivers are given this information in real-time as well as the resulting time loss and the impacts on fuel consumption due to a different driving style. Vehicle displays indicate the maximum possible speed and regulate any potential speeding through automatic throttling. The level of active safety in all road vehicles has been raised by standard systems for distance warning, braking and monitoring the vehicle's position on the road (keeping to lane). Standard features include Car2Car communication elements which enable optimal traffic flow and facilitate energy-efficient driving. The faster renewal of the vehicle stock due to the intensive use of car-sharing also has the effect of accelerating the take-up of these new technologies. In addition, the stronger links between mobility and ICT has resulted in technology companies also providing mobility services in urban areas alongside automobile companies.

The existing transport systems are utilised to a much greater extent than in 2010 through smart networks and vehicles. It was no longer necessary to further expand these transport networks due to these efficiency improvements in conjunction with the slowdown in economic growth and the decline in the population, so that more funds were able to be invested in the upkeep of the systems and their adaptation to climate change. Mobility services became more reliable as a result. At the same time, due to car-sharing and increased multimodality in cities, the number of parking spaces needed was also able to be drastically cut so that space for new green areas as well as attractive, centrally situated residential areas were able to be created alongside facilities for cyclists and pedestrians.

In general, a sustainable mobility system has developed by 2050 for passenger transport, which enjoys a high level of acceptance across all social classes and whose positive impacts on the quality of life are appreciated. Environmental and climate damage, accidents, noise pollution, traffic jams and other passenger transport externalities have almost completely disappeared in ground-based traffic and have been able to be considerably reduced in air traffic.

8 What does this mean for freight transport?

The changes described up until 2050 also lead to the volume of traffic in freight transport stabilising at 2020 levels and, ultimately, to a reduction in volume due to the shift to more regionally-based economic cycles in many sectors and local services. The negative impacts of freight transport (CO_2, pollutant and noise emissions, energy consumption, costs, time involved and risks because of bottlenecks) have been able to be considerably reduced.

For instance, organisational improvements, new vehicle and cargo handling technologies and modern ICT make it possible to improve and optimise – both economically and ecologically – the cooperation, interconnectedness and utilisation of all the transport modes involved in freight transport as well as to improve traffic flows. Since 2010, logistics operations have been increasingly automated, so that in 2050 goods terminals and marshalling yards operate to a large extent without human intervention, which has substantially reduced the costs and turnaround times in rail transport. Driverless freight shuttles operate along selected routes; bottlenecks in rail freight transport have been removed by a targeted expansion of the infrastructure e. g. to bypass cities. The signalling and wagon coupling technology of the 20th century has been completely replaced by interconnected IT systems and automated systems.

There has been an obvious shift in the volume of freight transported from roads and inland shipping to rail. Combined road/rail transport and, to a more limited extent, also road/rail/waterway have captured a high market share. The market share of rail freight transport in tonne-kilometres (Tkm) has climbed from 17% in 2007 to approx. 40% in 2050. In contrast, the market share of inland shipping has dropped from about 10% in 2007 to around 5% and truck transport has decreased from more than 70% in 2007 to 55% [38].

Many efficient passenger car technologies have also been applied to commercial road vehicles, but the domain of urban delivery traffic in 2050 is dominated by hybrid technologies as well as purely electric lightweight trucks (prototypes from 2009 see Figure 12). Fuel cell trucks were not an alternative up to 2050 due to storage problems. With the development of storage methods like graphite nanofibres (GNF), fuel cell drives can be increasingly expected in commercial road vehicles as well from 2050 onwards. The trucks in 2050 also look very different to those in 2010 because the aerodynamic potentials for trucks, which were nowhere near being exhausted at the beginning of the 21st century, have been rigorously implemented. ICT also improves the efficiency of road freight

transport, whether by enabling convoys (truck-to-truck communication), communication with passenger vehicles especially to avoid collisions or by improving the collection of differentiated road use tolls.

Figure 12: Delivery vans and trucks are offered as hybrids and purely electric models (on the left: Volvo [39]; on the right: Daimler [40]).

Old diesel locomotives and railcars have become a rare sight over the years and have been rendered almost superfluous due to major investments in the electrification of the railways. Their only remaining larger application is in shunting operations. Railways, freight trains and trucks have been made much quieter due to technical progress (rail position control, k-type composite brake blocks, cladding, etc.), so that noise only remains a relevant issue at specific locations. Pollution levels have also become negligible, only CO_2 emissions still play a significant role in freight transport in 2050, but have been substantially reduced due to various developments.

For instance, the power generated for rail freight transport has been designed to be largely CO_2 neutral. Combustion fuels still play a major role in truck traffic but are either produced from biomass for the most part (BtL = biomass to liquid) or completely synthetically. Post 2010, the first pilot plants started to produce photo fuels, from algae to start with, then later directly from solar energy, CO_2 and water. The latest generation of airplanes are much more efficient due to consistent optimisation of their weight using composite materials, but are still being operated with kerosene or bio-kerosene.

There was no general widespread demand for an additional transport carrier such as, e.g. subterranean container transport systems. These kinds of pilot plants are only being operated for transport services in port hinterlands and between and within large agglomerations, e.g. in the Ruhr district of Germany in

2050. Multimodal vehicles which can be used in different transport infrastructures are repeatedly tested but do not feature in the overall picture of freight transport in 2050. In contrast, concepts are becoming more important which link passenger and freight transport and thus make better use of the existing network infrastructure capacity, e.g. the fully automated transportation of freight in long-distance passenger trains or on the lower deck of double-decker city buses.

In this way a more sustainable transport system has developed for freight transport as well, which has been able to reduce its negative economic, ecological and social impacts to a considerable extent.

9 Visualising the vision

The vision of sustainable transport developed here was graphically illustrated on two levels in cooperation with the designer Judith Kozinski (see Figure 13):

- Level 1: Pictogram of the mega-trends (basic assumptions) and key fields in VIVER.
- Level 2: Graphic illustration of VIVER.

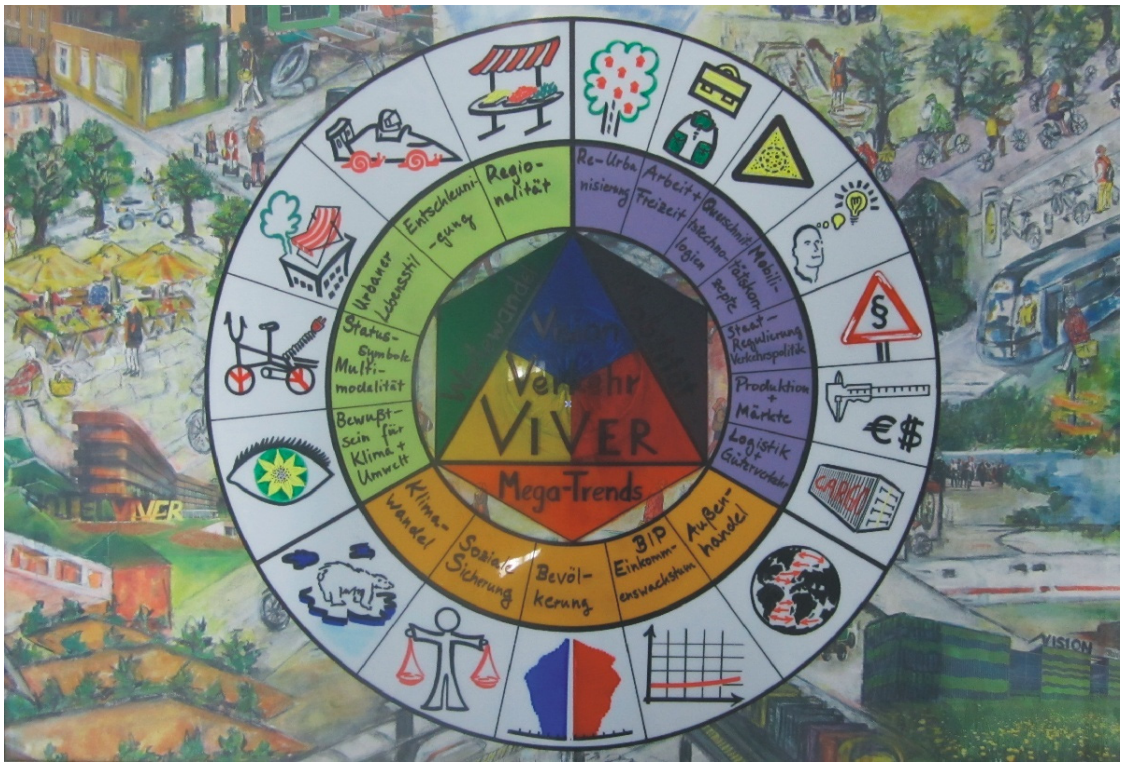

Figure 13: Graphic illustration of the VIVER vision overlaid with the pictogram [16].

The form of a wheel was chosen to group the pictograms on Level 1. Different colours were used to distinguish three areas: the underlying basic assumptions or *mega-trends* (= orange) which set the framework of the vision as well as *changing values* (green) and *mobility* (violet) to illustrate the key fields. A pictogram was created for each value and each key field. The pictograms on the wheel were arranged to match the spatial grouping of the topics in the visualisation.

When looking at the illustration, Level 1 is the first thing that catches your eye and this aims to give an overview of the individual components of the vision and

to make it easier to grasp Level 2 by explicitly illustrating the structure. Level 1 can be folded back or moved to the side in order to reveal Level 2 compare Figure 14 to Figure 13).

Figure 14: Graphic illustration of VIVER (showing Level 2) [16].

On Level 2, our vision of sustainable transport in an urban context is painted in oil on canvas. Different spatial perspectives are mixed in order to illustrate both the urban city scene, the subterranean transport infrastructure and air traffic. Above ground, different areas merge into one another to show urban, green, multi-mobile city centres, as well as the close links of municipal areas to the surrounding countryside and long-distance transport modes.

At the centre of the picture is a compass as a symbol of barrier-free multimodality and as a place marker for the tool which still has to be developed to put this into practice. Seven persons are shown leaving this compass heading towards different forms of transport and they crop up again at several places in the pic-

ture as the users of different transport modes, sometimes driving a Segway, sometime on their way to a car-sharing vehicle, on foot or in a tram (Figure 15).

Figure 15: Person with a red coat and yellow bag using a Segway, tram and bike and in a street café [16].

The illustration of the urban area (Figure 16) shows the transformation to a greener cityscape featuring landscaped squares and street cafés which encourage people to stroll through and linger there; motorised private passenger transport has been partly replaced by micro-electric vehicles and substantially reduced in total and replaced by walking, cycling and using public transport. Roof landscaping and futuristic community gardens in cities offer the chance to be able to relax in green surroundings right in the middle of town. Nearby recreational areas such as lakes and natural swimming pools are easily reached with public transport and (rental) bikes. The intensive utilisation of renewable energies is visible in the solar panels on the roofs and the wind turbines in the surrounding countryside, which is predominantly used for agriculture.

Figure 16: Attractive green cities with nearby recreational areas linked by cycle routes and local public transport and renewable energy supply [16].

10 Conclusions and outlook

We believe the described vision has succeeded in meeting the objectives of the VIVER project. We were able to develop a vision which gives a feasible, comprehensive, graphic and positive picture of the necessary changes and the possible result of redesigning our transport systems in the direction of the currently so frequently demanded *sustainability of transport*. This vision was developed by an interdisciplinary team of experts from Fraunhofer ISI. Having the vision illustrated lends additional support to its visual impact and its power to motivate.

With the described changes and trend breaks in mobility-relevant key fields as well as in passenger and freight transport, a sustainable transport system would be possible by 2050, which makes a significant reduction to the negative effects of transport (environmental and climate damages, traffic accidents, noise pollution, congestion and other externalities), is economically feasible and at the same time guarantees and even generally improves the population's quality of life. It is clear that a sustainable transport system can only be realised by simultaneous and consistent changes in many interrelated areas. Especially in urban areas we expect large changes in mobility which, if managed carefully, will lead to clearly discernible improvements in the quality of life. The assumption of trend breaks here is consistent with most other current studies which construct scenarios with time horizons up to 2030 [3]; [5]; [12].

It seems that several global players from outside the transport sector (e. g. energy, ICT and technology concerns) and several innovative mobility service providers (e.g. car-sharing companies, micro-vehicle tourism) have already started to initiate these changes while the sector itself, and especially vehicle manufacturers, is still hesitating to actively push new vehicle, utilisation and mobility concepts and to offer innovative comprehensive mobility services on the market.

The feasibility and the actual impacts of implementing such a vision are of course not able to be determined with any degree of certainty from today's point of view. Visions and scenarios which extend so far into the future are naturally subject to considerable uncertainty. However, they have an important function when considering systems and their factors of influence holistically and when making decision about goals and actions. In addition, they make it possible to communicate possible or even necessary processes of change to the relevant target groups in a graphic and inspiring way. Of course, the process of change needed to successfully implement such a vision constitutes a major challenge

and requires ambitious and consistent target setting and unswerving and resolute action by implementing intelligent and effective sets of measures.

In spite of the requirement to develop a holistic vision, there are still gaps in the VIVER vision. For example, more attention has been paid to passenger transport than goods transport so that additional considerations are certainly still needed for the latter. However, the limits of what can realistically be changed in such a period are soon reached in freight transport because this is much more dependent on the driving framework conditions (e.g. production and globalisation structures) than on the influencing factors within the transport sector than is the case with passenger transport.

The next step planned is to discuss the developed vision with external experts, in regard to the targets set and the targeted characteristics (sustainability, feasibility, holistic consideration of the relevant factors of influence, visual impact and, motivational power among others). Subsequently, as part of a backcasting process, the necessary and effective strategies and sets of measures will be developed, which are deemed suitable for achieving the sustainable transport system described.

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