Economic aspects of non-technical measures to reduce traffic emissions

Summary

by

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UMWELTBUNDESAMT

Content

1   What are the study's objectives?

Over the last two decades, the pollutant emissions from motorized transport have decreased significantly thanks to technical advances in motor vehicles. However, this does not solve the problem of traffic-related pollution. Air pollution causes cardiovascular and respiratory diseases, damages crop quality, reduces the biodiversity of plants, despite growth-enhancing properties and contributes to global warming (UNECE, 2012). The decisive factor for the quality of life and health, however, is not primarily the total emissions of air pollutants but their concentration in urban areas. Another unresolved problem concerning road traffic is its noise emissions. Against this background, the European Union, nation states, cities and communities are promoting measures to further reduce the emission of greenhouse gases, air pollutants and noise from all modes of transport.

This study "Economic aspects of non-technical measures to reduce traffic emissions" looks at non-technical options to reduce the emissions of motorized road traffic. The focus of the study is on the effect of measures to reduce emissions and the associated consequences for the private sector and the economy as a whole.

This study aims to provide an objective basis for the debate about the commercial and social consequences of more sustainable traffic behavior on the part of both individuals and companies. Selected measures and instruments to achieve given environmental targets are used to illustrate:

- the significance of measures and their implementation for affected users and
- the impacts which can be expected on a social and economic level.

The target groups of this study are individuals and companies who are interested in the environment as well as transport providers and decision-makers in government and administrations.

2   Which measures are examined?

The current study examines the economic consequences of alternative mobility concepts from two different perspectives:

- the **user-based or private sector perspective**, taking into consideration the environmental costs and
- the macro-economic perspective, which analyses the macro-economic impacts of the analyzed measures.

Five measures to reduce traffic emissions are examined from the viewpoint of both perspectives. The term "measure" describes transport policy objectives which are to be implemented to reduce traffic-related emissions. The measures cover key mobility indicators such as modal split, distances traveled or fuel consumption. They represent ways of reducing the traffic-related emissions of greenhouse gases, air pollutants and noise. In the economic context, every measure is allocated a specific target value, for example, the distances traveled or the share of different modes of transport in all journeys, passenger- or tonne-kilometers (modal split). Depending on the type of measure, these refer to different regional contexts and address different target variables. The impacts on user costs and time budgets, macro-economic indicators and the external effects of traffic are examined for all measures.

- Measure M1 describes the effects of **increasing the right of way for bicycles and pedestrians** in city centers at the expense of car users by 10 percentage points. This means an increase in the modal split share of non-motorized transport by 27 %.

- Measure M2 examines the economic and ecological effects of **increasing the share of local public transport** in urban passenger services by 10 percentage points. Compared to the present share of 8%, this means the share is more than doubled compared to a reference scenario assuming constant transport mode shares until 2030.

- Measure M3 examines the effects of **shortening the average distances traveled by car**. This assumes that transport participants change destinations by substituting those farther away by closer alternatives.

- Measure M4 investigates the macro-economic consequences and sustainability effects of **more efficient car use**.

- Finally, measure M5 investigates the economic and ecological impacts of **increasing the railway share in national freight transport** by 10 percentage points. From the railways' perspective, this would correspond to an increase of almost 80 % compared to a reference scenario until 2030.

To realize the measures to reduce traffic emissions, pricing and regulatory instruments, incentives, information and communication strategies are examined. The correct dose of these instruments, i.e. the price or investment level needed to achieve the objectives and the necessary investments for their implementation are determined by the ASTRA-D model (see Chapter 4). Finally, sets of instruments are combined to form policy packages. Table 1 gives an overview of the instruments used.

Table 1:   Measures and instruments in passenger transport

Measure	Type of instruments	Possible instruments
Measure M1: "Modal Split" Pedestrians and bicycles	Pricing incentives	Parking fees, city toll (congestion charge), subsidized car sharing
	Infrastructure	Expansion of pedestrian zones and cycle path networks, shifting capacities from motorized individual transport (cars) to bicycles
	Regulation, enforcement	Speed limits, restricted access
	Soft measures, spatial planning	Mobility management; information systems; city planning ("city of short distances")
Measure M2: modal split local public transport	Price incentives	Public transport subsidies; parking space management; city toll (congestion charge)
	Infrastructure	Investments in public transport; making railway stations more attractive; Park&Ride–offers
	Regulations, enforcement	Speed limits Restricted access (environmental zones, pedestrian zones)
	Soft measures and spatial planning	Mobility management; information systems/labeling; guide systems; alignment of city planning and public transport
Measure M3: Shorter distances traveled by car	Price incentives	Differentiation of real estate prices using incentives for raising urban density; elements of mobility pricing or "ecological tax reform"
	Infrastructure	Redesigning urban areas ("city of short distances"); making regional destinations more attractive (far beyond purely transport infrastructures)
	Regulations, enforcement	Land use, reporting/displaying commercial areas
	Soft measures and spatial planning	Urban planning ("city of short distances"); information on regional travel offers and leisure activities
Measure M4: Increased efficiency of private car use	Price incentives	Differentiated private car tax and fee systems; increased environmental tax; state subsidies for alternative drive technologies
	Infrastructure	-
	Regulations, enforcement	Restricted access (environmental zones); vehicle regulations/banning vehicles with lower Euro classes
	Soft measures and spatial planning	"Awareness Raising" and guidelines for efficient driving behavior; information systems/labeling
Measures M5: Modal shift to rail freight trransport	Price incentives	Subsidies rail infrastructrure, rolling stock and operations, HGV toll incl. external costs
	Infrastructure	Bottleneck removal port hinterland transport, etc.
	Regulations, enforcement	Longer trains, shorter rail block distances, stricter supervision of HGV social regulation
	Soft measures, spatial planning	Labeling sustainable logistics, revision national transport investment plan (BVWP)

Source: Fraunhofer/Infras

3   Which effects are assessed?

The objective of this study is the economic assessment of alternative mobility chains on the individual level and of transport policy measures to reduce emissions on the macro-economic level. The analysis is roughly structured in three cost categories:

- Internal costs: expenditures and outlays by transport participants directly related to them being mobile and which do not or only marginally affect third parties.

- External costs describe the monetary value of the effects on third parties caused by transport participants.

- Economic indicators include the level of required investments and operating costs for implementing the measures and describe their impact on the macro-economic development, which is described here using the variables Gross Domestic Product (GDP) and employment.

Table 2 gives an overview of the inclusion or exclusion of cost categories in the two perspectives and the decisive reasons behind this. The aspects of the cost categories are assessed according to the following principles.

The measure-related **investments in vehicles** and their operation are integrated in the individual user's perspective as life cycle costs. **Investments in infrastructure** are only examined from the macro-economic perspective. Two mechanisms are applied here to estimate investment costs:

- Direct assessment of investment costs. Depending on the measure and mix of instruments, specific investment programs and their development over time are estimated. While investments by the transport industry result in increased prices for consumers, public investments result in increased taxes.

- Endogenous estimation of investment costs. If the traffic volume of one mode of transport changes significantly, transport routes have to be modified, constructed, replaced and operated for the quality to remain unchanged. This induced investment effect is simulated by the ASTRA-D model. Deconstruction costs of routes are not taken into account, however, in the case of a significant drop in demand for individual parts of the system.

The **use of vehicles** causes fixed costs for depreciation (loss in value), taxes and insurance as well as variable costs for fuel, supplies (oil) and calculated repair costs. The data used to determine the operating costs of a passenger car are taken from the German Automobile Association (ADAC 2012). Operating costs for road freight transport are available from the statistics and compendium of the "Costs-Information-System

(CIS)" of the Federal German Freight Haulage Logistics and Disposal Association (BGL e.V.2012) for different HGV classes. For local public transport and freight rail transport, the costs for consumers are assessed according to ticket prices or railroad and traction charges. Operating costs enter the macro-economic analysis only indirectly via their productivity effect because the operating costs of one market player mean income benefits for other market players.

Table 2: Cost elements according to perspectives

Cost category	Individual user assessment (2010)	Macro-economic assessment (2010–2030)
INTERNAL (PRIVATE) COSTS		
Private spending	Depreciation, maintenance, fuel, tickets, fees	*Balance between market players*
Travel time	Assessment according to purpose of journey and mode of transport	Additional information; assessment only useful at project level
Effects on health	Value of the years of life gained above and beyond the level of normal activity	Careful consideration of fitness and exercise frequency of population
EXTERNAL COSTS		
Consequences of an accident (polluter pays principle)	Additional information according to type of region and mode of transport*	Assessment according to type of region and mode of transport
Environmental, greenhouse gas and noise emissions	Additional information, calculation according to type of region and vehicle technology*	Assessment according to vehicle technology and type of region
MACRO-ECONOMIC INDICATORS		
Expenditure for public transport	*not considered*	Additional information: investments, general expenditure for network maintenance
Macro-economic indicators (GDP, employment)	*not considered*	Additional information: modeling via ASTRA-D

* Subject to macro-economic assessment in the strict sense: white = considered; gray = not considered; shaded = additional information.
Source: Fraunhofer/Infras

The **costs of travel time** are calculated at € 3.83 per person and hour for private road and rail travel in line with the German Federal Transport Infrastructure Plan (BMVBS 2005); this has already taken a deduction of 30 % into account for time changes under 5 minutes. For commercial traffic, a cost rate of € 19.74 per person and hour is applied. For freight transport, the figures from the EU IMPACT study (Maibach et al. 2008) are used. For cycling and walking, the value attributed by the user to the travel time is

usually closely linked to the perceived health benefits. For this reason, a uniform time value is applied to all modes of transport to avoid double counts (Börjesson and Eliasson 2012, Wardman et al., 2007).

Current studies indicate that the social benefits of regularly riding a bicycle for 30 minutes per week can amount to €4,000 annually (BMVBS, 2012, BMG 2011, Titze et al. 2010, Samitz et al. 2011, Martin, 2002). In order to quantify the **health effects of more active types of mobility on the individual**, the World Health Organization (WHO) has published the "Health Economic Assessment Tool" (HEAT) (WHO Europe 2012, Kahlmeier et al., 2011). According to this tool, the reduced probabilities of the premature death of adults or their increased life expectancy due to cycling and walking are assessed using the "Value of Statistical Life" of approx. €1.6 million. This approach is adopted in this study. For the private user perspective, the results show a potential of possible health benefits which have to be adjusted according to personal circumstances. In the macro-economic assessment, an average fitness level of the population and average weekly journey times for pedestrians and cyclists are estimated to arrive at a figure for the overall health benefits.

The **social consequences of traffic accidents** include medical care, administration of the health insurance companies, legal departments, police and the immaterial value attributed by society to the preservation of life and health (statistical value of human life VSL). The problem in the case of road safety is that the risks of accidents is perceived very differently by different individuals and is determined to a large extent by individual abilities, readiness to take risks and mobility behavior. Accordingly, road safety is regarded from the perspective of the accident perpetrator as part of the external costs. The VSL is the central component of the consequential costs of accidents. European studies have determined a consensus value for Germany of approx. €1.62 million for each fatality and €0.21 million for each severely injured person in 2010 prices (cf. Essen et al. 2011).

Accident statistics show that the risk of cyclists in towns and cities provoking a fatal accident is at least three times higher than car drivers - even when making optimistic assumptions about the transport performance of non-motorized traffic (Federal Office of Statistics 2011). According to the German Government's National Bicycle Plan 2020 (BMVBS 2012), the safety of cycling has not improved in line with the overall decline in road accident victims. The subjective perception of cyclists' safety has also become noticeably worse over the past few years (SINUS/ADFC 2012). One reason for the high rates of accidents caused by cyclists and pedestrians is the expansion of the respective infrastructures as well as not adhering to safe distances on roads (König 2006, Veisten et al., 2007). However: international comparisons indicate that a rising share of

cyclists and pedestrians in traffic increases their safety as they become more visible to car drivers whose awareness of them is then heightened (Jacobsen 2003, UBA 2010).

The basis for calculating the **external costs of transport** for Germany are summarized in the methodological convention of the Federal Environment Agency (INFRAS/IER/ISI 2012). In addition, several standard works are available at European level for quantifying the external costs of air pollution, climate change and noise per vehicle, passenger- or tonne-kilometer according to the transport situation. The environmental costs of motorized transport are dominated by the carbon dioxide emissions, which are valued at 80 euros for 2010 and at 145 euros for 2030 per tonne CO_2.

4 How are the effects assessed?

Assessing the impacts of designing daily mobility in an alternative way is a complex process. Medium-term capital commitment, variable expenses and immaterial effects on the individual's time as well as on health and the freedom of scope in organizing daily routines have to be balanced. In addition, there are image issues and the impacts of private individuals' decisions on society and the environment.

The assessment tool **PExMo (private and external costs of mobility)** was developed in this study as a decision-making aid for transport participants. PExMo offers the user the possibility to analyze the different cost aspects of specific trips and compare them with each other. Interested users can download PExMo as an Excel application at www.ntm.isi-projekt.de.

PExMo takes the costs of mobility from the individual's point of view as a starting point. Accordingly, attention is focused on the monetary and immaterial costs of mobility which affect the transport participants themselves. In addition, the most important categories of external costs are incorporated in order to provide ecologically motivated users with the relevant basis for decision-making. In total, the PExMo-Tool distinguishes eight categories of costs, which are grouped in three areas:

- direct private costs: fixed and variable expenses for vehicles and tickets,

- indirect private costs: time costs and health benefits,

- external costs: air, climate, noise, safety.

These are used to calculate the annual costs of alternative variants of specific trips. Whilst the trip is determined by purpose and distance, the transport alternatives differ by mode and the infrastructure used, and the type of area traveled through. The level of fixed costs to be allocated to the specific trip, e.g. for purchasing a car or season

tickets for public transport, is estimated by asking travelers about their annual amount of travel.

The **ASTRA-D model** is used to assess the macro-economic effects of the selected measures. This model is a further development for Germany of the European ASTRA model ("Assessment of Transport Strategies"), which was constructed within the framework of several research projects assessing transport strategies (Schade 2005). The degree of analysis has been substantially refined for the German version; the individual sectors have been separated based on the German Federal Statistics Office's 2003 classification of economic activities. The period of calibration covers the years 1995 to 2008.

The use of input-output tables enables the integration of "bottom-up" impulses to assess policy measures by sector including any possible second-round effects. ASTRA-D does not limit itself to one branch of macro-economic theory, but connects elements such as the neo-classical production function for modeling economic growth with Keynesian demand impulses. An important characteristic is the possibility to allow imbalances to occur between demand and supply. Therefore ASTRA-D is not an optimization model.

On a very simplified level, Figure 1 illustrates how the main macro-economic contexts have been modeled. ASTRA-D enables a gradual scaling of policy measures over time by calculating steps each year. This makes it possible to design policy instruments flexibly with regard to their intensity and to pinpoint any differences attributable to different investment paths for example.

Figure 1: Macro-economic modeling logic in ASTRA-D
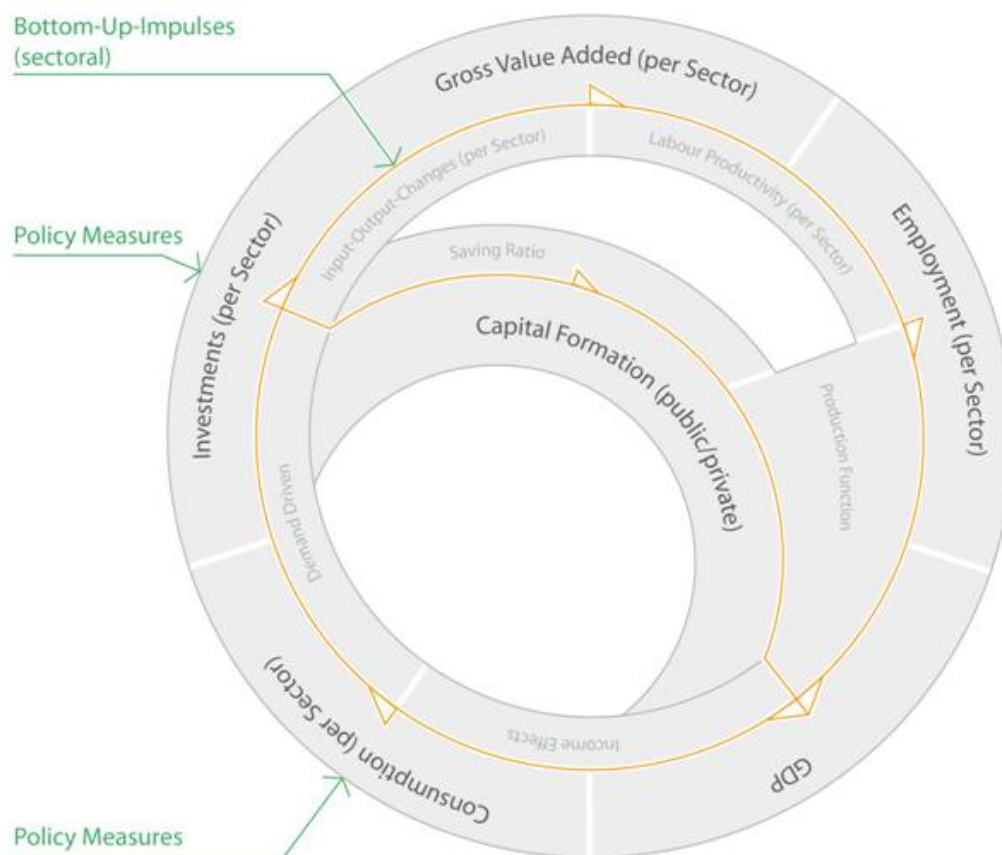
Source/Fraunhofer/Infras

5 What does more active mobility mean for transport participants?

How high are the total costs of single types of mobility from the individual's point of view? The answer depends on three factors: the route itself (purpose of journey, distance), the choice of transport mode (public transport, car, cycling or walking) and the efficient use of the respective mode of transport (particularly for cars: size, type of drive and occupancy). The following diagram shows the variations of costs for selected mobility alternatives. Different types of cars, occupancy rates, locations and modes of transport are compared. These and other influencing factors can be illustrated in principle by adjusting the input values and parameters of the PExMo-Tool. The results are shown in Figure 2:

- Generally **private costs** play an important role when using a car or public transport. The greater the distance, the bigger the influence of time costs. The large health potential for cycling and walking is interesting. The calculations show this as lost

benefits if the entire distance was not covered on foot. The shares of calculable accident costs and environmental costs are rather low. The latter in particular play a more significant role in the macro-economic analysis.

- The **purpose of the trip** is decisive for distances, frequency and how the user rates the time involved. In principle, local public transport is able to compete with motorized private transport (MPT) over medium to longer distances if the car occupancy rate is relatively low. For shorter distances, travelling by bicycle and on foot is the most favorable alternative when considering all the cost categories.

- Variations in the annual costs for users are determined by the **size-class** of the used car to a large extent. This is particularly visible when moving from the compact class to the premium segment for commuting and business trips. Here, private spending increases by more than 100%, while it is possible to halve this if switching to a small car.

- The private costs for local public transport are significantly lower than travelling alone in a private car. The two alternatives only differ slightly in the selected examples at higher car **occupancy rates**. However, this does not consider the fact that similar reductions are also possible for groups traveling together in local public transport and trains.

- The **quality of the connection offered** is decisive for the costs of motorized transport, private cars and local public transport. 50 % longer travel times for commuters mean additional private costs of almost €1,000 annually, which, in the selected example, increases the total costs of private car use by 14 %. For local public transport, 50 % longer travel times means higher annual costs of 22 %, whereby local public transport is more sensitive to disruptions than private car use.

- The **location** of the route examined has a decisive influence on both the travel time costs and the environmental balance. It is usually possible to drive faster on roads outside built-up areas than on city roads, and less developed areas diminish the harm caused by pollution and noise. Overall, there are similar impacts on the annual costs per person to increasing the car occupancy rate.

- The transition of vehicles from **emission class** Euro 3 to Euro 5 causes only a minimal reduction in the external costs of environmental pollution. This is because, on the one hand, Euro-3 vehicles are already relatively clean and therefore the predominant share of external costs is accounted for by greenhouse gas and noise emissions. Their effect, however, does not necessarily diminish with higher emission classes. This leads to the conclusion that using smaller vehicles and strict CO_2 limits contributes significantly more to the sustainability of traffic than merely modernizing the fleet.

- **Safety and speed** play a central role when assessing cycling. In existing cycling infrastructures, however, these two objectives are in conflict. The example calculations show that, for commuting, bicycles can only compete with cars to a limited ex-

tent due to longer travel times and higher external accident costs. The private-sector benefit-cost-ratio of cycling could be increased by a convenient, safer and faster network of cycle lanes to such an extent that cycling becomes better than private car use for longer distances as well.

Figure2: Total private and external costs for selected mobility alternatives
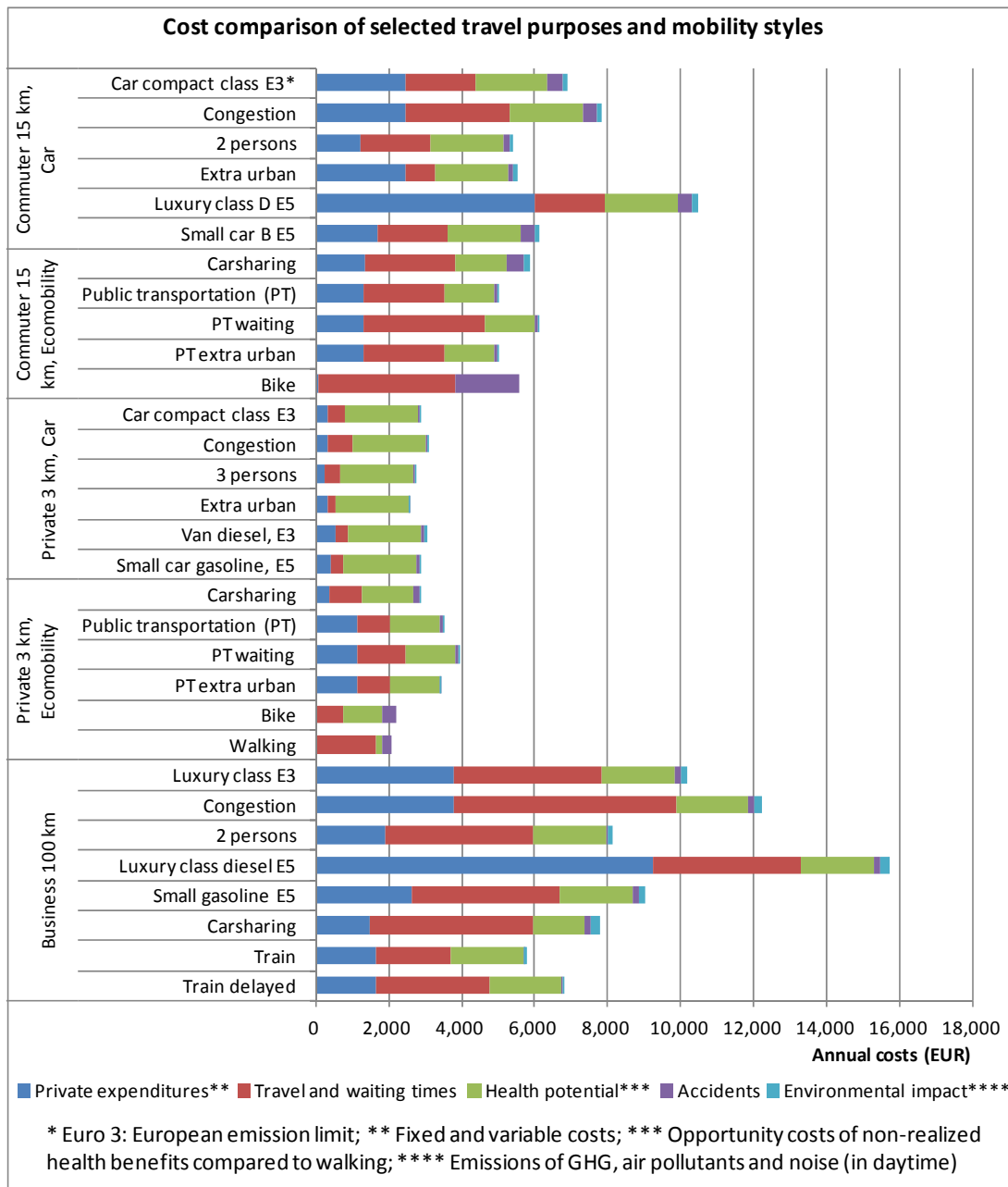
Source: Fraunhofer/Infras

Additional factors also have an effect on costs. Where a person lives plays a crucial role. The more urban the environment, the better the offer of local public transport ser-

vices and the greater the importance of short distances. The topography of the terrain and the individual's general fitness also influence the potentials for cycling. In addition, the evaluation of travel time compared to monetary costs increases with increasing income. The type of household is another important factor. Based on private costs, families are more oriented towards cars than a single person household and also tend to use bigger cars. Here, car sharing offers could satisfy the different demands.

A number of conclusions can be drawn from these calculations for the private and external costs of the four passenger transport measures examined here:

- M1: Increasing the share of cycling and walking mainly reduces private expenditure and environmental costs and improves health. This makes it possible to lower the costs of illness for the health care system and the economy. The years of good health gained are an added benefit, although these effects can only be evaluated from an individual's point of view. In Germany, the benefit of a prolonged healthy life for an unfit individual is valued at up to 2,000 euros per year. This has to be set against longer traveling and waiting times depending on the route and – if there are no separate cycle lanes available - a higher accident risk for cycling. Two typical example routes illustrate that, including the avoided environmental pollution from cars, the annual total costs for commuters (15 km) and shoppers (3 km) can be reduced by 1/3 or by up to 1,000 euros annually if traveling by bike.

- M2: Increasing the share of public transport lower private expenditure and external costs, particularly for urban commuters and long-distance traffic. This is offset against – depending on the quality of the transport chain – higher travel time costs. The costs for a compact car can amount to €5,000 per year, of which €1,800 per year or 12 cent per kilometer are attributed directly to the use of the vehicle. In comparison to this, public transport offers good value for money. Annual tickets are around €700 on average. Local public transport can be slower. At 30 to 40 km/h, the speed of cars and local public transport in cities is fairly similar. Both modes of transport involve the time needed to access it, but public transport often involves time-consuming transfers. On the other hand, the risk of getting stuck in a traffic jam is higher when traveling by car.

- M3: Shortening the routes for private cars decreases the variable mobility costs for road users and the external costs for the environment and road safety they cause. A corresponding change in behavior, however, requires a change in lifestyle in most cases and the routines which are part of it. This new orientation can even extend to someone relocating their home or workplace.

- M4: Smaller cars and their more efficient use can substantially reduce private vehicle maintenance and running costs as well as the external costs of motorized traffic per trip. There are significant differences for different size classes of cars. Depending on the type of vehicle, smaller cars can save between €3,000 and €9,000 in private costs each year. While a small car has CO_2 emissions of 103 g/km (diesel) or

124 g/km (gasoline), premium-range cars emit 180 g/km (diesel) up to 270 g/km (gasoline).

In an ideal case, operating costs, environmental and safety costs can be reduced by shifting freight transport to rail (Measure 5); the effect, however, depends heavily on the quality of the service offered and the capacity utilization of the trains in rail freight transport. Possible savings are usually offset by higher time costs. Correspondingly, instruments to shift freight transport from road to rail apply the variables of transport costs, capacity and journey time. Based on the example of a distance of 400 km, these are as follows:

- Operating costs: Operating a freight train costs on average 12 euro/km in track access charges and three euro/km for traction and energy. For the 400 km shipment, these figures result in specific costs of 20 euro/t for a 300t train. With toll charges of 15 Ct/km, operating costs of one euro/km and a load rate of 11.5t/HGV, the operating costs for road freight transport amount to 40 euro/t for the same distance.

- Train capacity utilization: Doubling the load factor of freight trains to 600t cuts the transport costs by 50% to 10 euro/t. This reduction is mainly due to a more efficient use of the rail infrastructure and more efficient train composition processes; rising costs for traction energy and track wear and tear can be ignored in a first approximation.

- Travel time: Due to transit and shunting operations, rail transport is considerably slower than road transport. However, road transport is less reliable than rail transport due to congestion and road works. Rail transport could be accelerated by introducing more direct connections and, on top of this, fewer shunting operations could help to balance the time disadvantage of rail transport to some extent.

The longer the distances covered by rail, the greater the shift potential. The following diagram compares the private and external costs of freight transport by rail and road for the chosen example.

6   What does more active mobility mean for society?

Table 3 depicts the measures' macro-economic effects. The results were calculated using the system dynamic ASTRA-D model of transport and the economy by considering exemplary implementation paths for the five selected emission reduction measures.

Figure 3: Private and external costs for rail and road transport
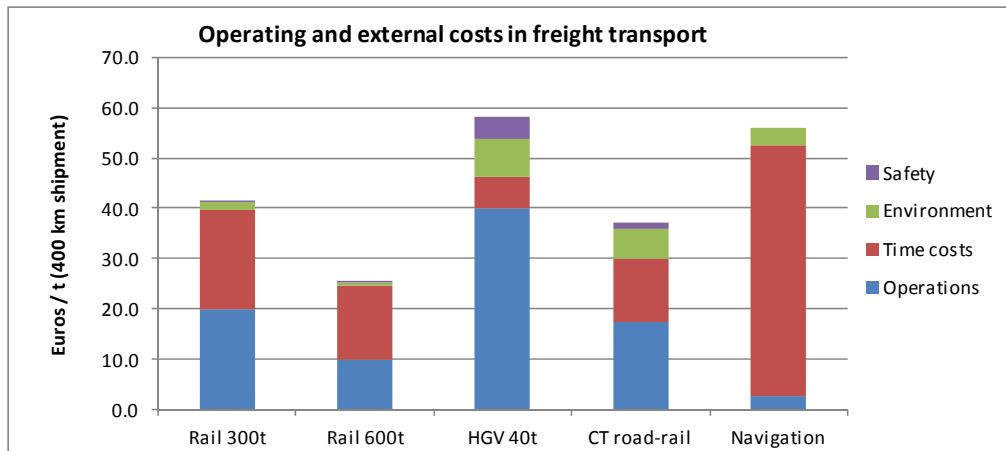
Source: Fraunhofer/Infras

Impacts on GDP, employment and investments: The different measures to adapt mobility have direct and indirect effects on the economy as a whole. The direct demand effects and the necessary investments in infrastructure and vehicles have a strong influence on growth and employment. Table 3 shows the effects calculated using the ASTRA-D model. The negative signs of the investment costs in some scenarios are based on declining investments in road construction and the automobile industry due to a shift of demand to other modes of transport.

Table 3: Comparison of the macro-economic effects of all measures

Variable	Year	M1	M2	M3	M4	M5
GDP	2020	+0.19%	+0.24%	+0.35%	-0.02%	+0.02%
	2030	+1.11%	+1.56%	+2.23%	-0.18%	+0.02%
Employment	2020	+0.14%	+0.21%	+0.35%	-0.02%	+0.04%
	2030	+1.37%	+1.76%	+2.49%	-0.16%	-0.08%
Employment transport	2020	+3.34%	+4.10%	+3.88%	-0.34%	+0.25%
	2030	+4.14%	+5.29%	+11.74%	-0.38%	+0.60%
Investments	2020	+1.67%	+2.31%	+3.33%	-0.24%	+0.16%
	2030	+5.45%	+7.03%	+9.09%	-0.99%	-0.13%
Investments transport	2020	+3.38%	+5.17%	+16.32%	-0.13%	+0.45%
	2030	+2.65%	+5.27%	+25.09%	-0.18%	-3.96%
Investments transport infrastructure	2020	+3.38%	+5.60%	+22.55%	-0.06%	+0.64%
	2030	+3.67%	+7.48%	+37.27%	-0.19%	-9.55%

Source: Own illustration based on ASTRA-D model

Most measures have a positive effect on the national economy, with the exception of M4 (increased efficiency of car use). The shift from cars to alternative forms of mobility could have a considerable dampening effect on the automobile industry. The macro-economic magnitude of the changed value added, however, depends upon the extent to which investments to promote alternative forms of mobility are possible and necessary.

The gross domestic product develops moderately in all measures until 2020 and with the same sign as the investment impulse. The measures examined in this study mostly look at investments in the building sector due to the expansion of alternative means of transport such as cycle paths, local public transport, railways, urban redevelopment or the expansion and operation of toll systems; the latter, however, do not create any significant growth impulses for the other economic sectors. M2 is an exception with investments in the public transport vehicle industry. However, these do not generate any noteworthy impact on productivity either, as they only affect a relatively small branch of industry and are partially compensated by a reduction in the demand for passenger cars in the same sector. One stimulating macro-economic effect comes from the change in consumption structure. Transport consumption shifts from private cars, with its higher tax component due to the taxation of fuel, to transport services or even non-motorized transport. The assumption is made that, as a result, there is a shift of consumption to other sectors.

The estimates of additional investments in transport infrastructure range between one billion euros per year for cycle lanes and pedestrian zones, two billion euros for the expansion of public transport networks and 10 billion euros to create incentives for the regionalization of destinations in passenger transport. The latter measure goes far beyond the transport sector as this implies urban and regional planning redevelopments on a larger scale. The height of this investment impulse varies depending on the measure.

Employment develops positively in almost all measures. Induced by the positive investment balance of the measures examined and the growth of the GDP, employment also increases compared to the reference scenario. Spread across all sectors, this implies 1.4 % to 2.5 % more jobs for the year 2030 in M1, M2 and M3. Growth in the transport sector, which provides additionally demanded transport services, is four to five times higher.

Cost-benefit analysis: The changes which benefit Germany in the period 2010-2030 can be determined based on the macro-economic analysis. The benefits for health, safety (reduced costs resulting from accidents) and environmental costs (particularly

climate, air pollutants, noise) can be calculated. The following table shows the results of the five measures examined.

The additional benefits are the most obvious in the area of health. Interestingly enough, the biggest health benefit from physical exercise (active mobility measures) occurs for M2, not M1. Promoting local public transport generates far more non-motorized transport than concentrating exclusively on measures promoting walking and cycling. Two aspects can help to explain this: First, the selected support instruments, particularly the implementation of city tolls (congestion charges), are identical in both measures. Second, expanding local public transport creates a real alternative to private car use, which then makes it possible to manage completely without owning a car.

As already mentioned, the traffic safety of pedestrians and cyclists is a serious problem affecting more active mobility modes in towns and cities. In spite of the enormous safety improvements assumed for cyclists up to 2030 in M1, the highest social benefit does not result from the shift to active forms of mobility, but from shortening the distances covered by car (M3). The explanation is that M3 is the only measure which reduces the absolute volume of traffic without this having an effect on other transport modes. This is also the reason why M3 has the best results for reducing the environmental effects. Reducing the distances traveled by car by 10 % means an overproportional reduction in the volume of traffic (in pkm) of 38 %. These secondary effects reduce air pollutants and CO_2 emissions by 29 % to 36 %.

Table 4: Benefits of the measures' avoided social costs

Benefit category	M1	M2	M3	M4	M5
Billion euro 2010	Walking and cycling	Local public transport	Shorter routes	More efficient cars	Modal split rail freight
Benefit health	11.53	18.67	12.60	17.40	0.00
Benefit safety	0.64	0.40	6.93	-0.01	0.11
Benefit environment & noise	0.76	0.51	9.10	-2.28	4.33
Total	12.92	19.57	28.63	15.11	4.44

Source: Fraunhofer ISI

These benefits are contrasted with two cost elements:

- The direct public investments in transport systems and built-up areas are between 1 and 3 billion euros per year for the modal split measures (M1 and M2). These costs are significantly below the identified benefits. Only in the case of M3 (re-designing urban areas for shorter car trips) are the investment costs considerably higher than those in other measures (11 billion euros). It is assumed here that enormous plan-

ning and construction activities are required to make cities and regions sufficiently attractive to impact peoples' destination choice to a considerable degree. Virtually no investments are needed for M4. It should be noted that these investments can in turn trigger impulses for growth and employment – as shown in the analysis above.

- In the macro-economic assessment, changing the forms of mobility due to implementing the examined measures leads to time losses in many cases. These are estimated in the range of 50 to 60 billion euros for M1 to M3 and are therefore higher than the generated benefits which were monetarized. The time losses are much lower for using a more efficient car (M4) at 29 billion euros and virtually irrelevant for M5 (shifting freight transport). However, macro-economic evaluations of travel time changes over a long period of time are disputed because travelers will adapt to the changed circumstances. Furthermore, in the period up to 2030 investigated here, the aspect of transport quality, e.g. in local public transport, cannot be ignored, as this could increase the options for spending travel time in different ways (reading, working, conversing). Despite its importance for understanding the net effect of time spent under different traveling conditions, it was not possible to assess the overall time budget for all activities of transport users within the scope of this study. Thus, in order to avoid double counts, the time evaluation is not included in Table 4.

- The direct operating costs of the transport modes are taken into account, but in the macro-economic context are offset against the corresponding revenues of other market participants.

- The quality of time spent in public spaces and the design of transport areas are major arguments in favor of the redevelopment of inner cities. However, the benefits resulting from this were not assessed in this study.

7   Which avenues can be taken when implementing the measures?

When transport policies are put into practice, combinations of different measures and instruments are usually postulated. This can create additional synergies (increasing effectiveness and efficiency, heightened capacity, securing financing) and above all, increase acceptance. As non-technical environmental measures, the focus is on the following combinations of instruments:

- "Push-&-Pull" and "Modal Split": A shifting strategy focuses on two points: To improve the framework conditions for public transport or non-motorized pedestrian and bicycle transport and give incentives to make fewer car trips. This approach is suitable for both passenger and freight transport by rail and road.

- Financing and steering: Pricing instruments can set incentives for a steering effect and at the same time can finance appropriate investments. Usually this is closely related to the "push-&-pull" and/or "modal-split" strategy.

- Coordination of transport and housing developments: This tends to be a long-term strategy and combines spatial planning instruments with transport planning and infrastructure policies. The key issue here is to avoid urban sprawl and foster compact settlement structures and shorter distances between destinations.

Three main conclusions can be drawn from the practical experiences made:

- "Push-&-Pull" approaches combined with financing and steering and the redistribution of capacities between different modes of transport in the context of a "Modal-Split" strategy are the most dominant.

- Effectiveness and efficiency are mainly achieved by pricing instruments ("push"). In comparison, however, the modal split instruments (improving the capacities of local public transport and walking and cycling) enjoy a considerably higher level of acceptance and are necessary prerequisites for autonomous behavioral changes (strengthing of individuals' own incentives) and for the intended change of the modal share.

- Consequently, therefore, there could be trade-offs regarding cost effectiveness, the guarantee of mobility targets and acceptance. Simply taxing motorized private car use without any visible alternative (such as the expansion of local public transport or foot paths and cycle routes) is (at least theoretically) considerably more cost effective than expanding infrastructure. However, at the same time, mobility potentials are reduced, which can result in economic losses (reduction of the value added from transport) and the loss of benefits in private households.

The following insights can be derived for the implementation of individual instruments:

- M1: This measure is based on the combination of a market-based instrument (short-term parking fees, longer term city tolls) as a financing instrument for traffic calming and expanding the infrastructure for pedestrians and cyclists linked to a reduction of private car capacities in favor of cyclists (parking management and redistribution of capacities for attractive cycle route networks) which is integrated in urban planning development. Other autonomous changes in behavior (for example managing without a car, increased use of car sharing and public transport, more people cycling to work and cycling as a leisure activity) can be supported by further measures such as information campaigns, promoting car-free housing developments, individual mobility services (including public transport) and specific new resident packages for persons who have recently moved to a city or region.

- M2: This measure is based on a pricing instrument (parking fees, longer term city tolls/congestion charges) used as a financing instrument to expand local public transport combined with a redistribution of capacities (reduction of private car use in favor of public transport) and giving priority to public transport at intersections and traffic lights. Efforts to make public transport more attractive also include improving

access at stops, how stops are equiped and the system of fares. With regard to fares, there are potentials for combining the pricing of roads and public transport; for example, paying city tolls/congestion charges could be used to justify reduced fares on public transport. In the medium term it is decisive which resources are available for mobility tools (car ownership, access to car sharing, tickets for public transport). The focus is on campaigns for ecomobility and promoting car-free housing estates combined with individual mobility advice and management (e.g. free introductory offers for new residents and special offers for families).

- M3: Instruments which can make the local surrounding area more attractive and easier to reach include abolishing tax-deductible commuting costs and introducing cheaper mobility tools (combined "mobility pricing" such as toll charges for passenger cars or ecological tax reform and reduced prices for ecomobility). Higher potentials could result by combining toll charges for passenger cars and autonomous behavioral changes, transport use and capacity use by introducing a differentiated fare structure for different times of the day and spatial units (i.e. higher prices during peak periods or in urban agglomerations).

- M4: A possible instrument package to promote fuel efficient passenger cars consists of fleet limits and financial incentives in the form of car taxes differentiated by fuel consumption. In order to design these effectively, however, it is essential there is a clear progression in the tax rates for larger vehicles. The effect on fuel consumption could be enhanced still further if, in addition to incentives to buy cars with low fuel consumption, incentives were also offered to reduce the day-to-day consumption, for example by raising the tax on fuel or imposing a CO_2 tax. It would also be possible to increase the use of labels for fuel and/or environmental classes which are aligned on emission classes and fleet limits and are also used as targeted discount models (in the form of bonus-penalty models within the framework of vehicle taxes).

- M5: The focus is on linking a HGV toll and investments in railways to accelerate rail freight and increase productivity in terms of the steering-financing approach. However, account has to be taken of the fact that a HGV toll can also result in a reduction of the incentive to switch from roads to rail because rail prices tend to follow the lead of road prices. A prerequisite to increasing the efficiency of rail freight is the competition between haulage companies. This means ensuring non-discriminatory access to attractive tracks and track prices (e.g. bonus for fully loaded and punctual trains) and an efficient infrastructure including the promotion of terminals which do not discriminate against freight transport compared to rail passenger transport.

8　What are the consequences?

The following key conclusions for the effectiveness and economic efficiency of the five chosen measures can be derived from the analyses of the private-sector and macro-economic effects:

1. **The environmental impacts differ considerably when comparing the measures.** In M3 (shorter car trips), greenhouse gas emissions are reduced by 36% which is much more than in the other measures. This can be explained by the fact that, on the one hand, shorter trips immediately reduce mobility volumes. On the other hand, the measure affects local, regional and long distance travel to the same extent, while M1 and M2 only influence local traffic. In contrast, for the shift to walking and cycling (M1) and to local public transport (M2), the reduction of total CO_2 emissions amounts to only 1 % and 4.3 % for the more efficient use of passenger cars. The results are similar for the other pollutants (NO_X, CO and particulates).

2. **Long-distance transport measures make the biggest contribution to emission reductions.** Approximately two thirds of passenger transport services and more than 90% of freight transport are regional and long-distance. In addition, the share of private cars is considerably higher here than in cities. Against this background, measures which cover all distances reduce traffic-related emissions to a much greater extent. This also applies when considering the greater harmful effect of emissions and noise in densely populated areas.

3. **Public passenger transport still holds high efficiency potentials**. In this study, the environmental development of passenger cars was considered by including all the future emission standards and the EU fleet targets for greenhouse gas emissions in detail. However, the analysis of the emission improvements in local public transport was rather conservative. Huge investments in new vehicles will be due because of the market growth of almost 80 % assumed in M2 compared to the reference scenario. On the one hand, these new emission standards will be sufficient; on the other hand, the local public transport network offers the potential for new and more environmentally-efficient forms of propulsion. Furthermore, it is decisive where growth is concentrated – on which market segment, namely trams or buses.

4. **Greenhouse gas emissions make up the biggest part of environmental costs.** However, emission profiles vary strongly between transport modes. While greenhouse gas emissions make up 90 % of the external environmental costs of passenger cars, NO_X and particulate emissions are the biggest problem of the local public transport network. These originate from older diesel buses. Assuming the modernization of the fleet and a greater use of trams improves the environmental balance, but simultaneously makes new demands of environmentally-friendly electricity production. Reducing the environmental effects could be improved from 2 % to 8 % by using modern trams and local trains operated with zero-emission renewable electricity.

5. **The benefits of individual measures at macro-economic level cannot be regarded in isolation.** Implementing market or regulatory instruments and incentives always promotes a wide range of reaction patterns by transport participants and sets longer term incentives for efficiency improvements. Depending on the local

conditions, a mix of transport policy measures and instruments is therefore recommended for an efficient transport and environmental policy in order to achieve the set environmental standards.

6. **User reactions decisively influence the overall results of transport policy measures**. The reactions of transport participants to transport policy measures and instruments are complex and do not always occur in the desired direction. For example, if raising car occupancy rates reduces the costs of car use, this can trigger a transport shift away from rail to road. Measures to promote walking and cycling can make local public transport more attractive or result in competition. These so-called "rebound effects" should be monitored and if necessary limited by relevant regulatory measures.

Besides the benefits of active mobility for the environment, car-independent mobility also triggers other effects on the individual and his/her direct environment. These can be characterized as follows:

7. **Active mobility promotes better health and reduces the risk of chronic illness.** The World Health Organization calculates a 50 % reduction in the risk of premature death for people who regularly cycle or walk approx. 75 minutes per week. Macroeconomic benefits can be estimated from this of between 11 and 15 billion euros per year based on average figures of the general fitness and mobility behavior of the population. This is more or less the same for all the measures regarded here, because the instruments selected for implementation always promote walking and cycling.

8. **Active mobility is financially attractive**. Depending on the type of vehicle, using a car costs up to 5,000 euros per year. Getting rid of a private car means that sufficient funds remain for the use of local public transport, trains and car sharing for long distances. It can therefore be expected that, for economic reasons alone, more people will turn to cheaper forms of mobility. According to current studies, this trend has already started in several industrialized countries.

9. **More attention has to be paid to the safety of cyclists and pedestrians in towns and cities.** The probability of being severely injured or killed as a cyclist in German cities is about 10 to 20 times higher than for a car passenger. Pedestrians also run a higher accident risk. Experiences from other European countries, however, prove that a greater number of cyclists and pedestrians on the streets increases the awareness of car drivers which helps to lower the accident rate. Ideally, cycle lanes should be integrated into roads but designated by highly visible markings and a well developed network of such lanes can shorten journey times and at the same time further increase safety levels.

10. **The speed of more active forms of mobility and of public transport is a critical factor.** For fit persons and where there is a well-developed cycle infrastructure, cycling in towns is often almost as fast as travelling by car. However, these preconditions are not always given, so that more active forms of mobility are often linked

with substantial additional journey times. This also applies to local public transport with access and departure times, waiting times and transfers. On the other hand, the risk of congestion or traffic jams is much higher for cars and their reliability therefore lower. Nevertheless, the calculable time losses for switching to alternative transport modes are considerable. This means that a sustainable transport policy accepted by users should rely more on improving socially desired mobility alternatives (pull measure) rather than on making cars less attractive (push measure). Accelerating freight rail in M5 shows the positive results of such a policy. It also proves that accelerating local public transport via organizational measures does not have to be costly. This is especially true for cycle paths, which are the most cost efficient and the safest in the form of well visible road markings.

11. **In view of the social debate about slowing the pace and improving the quality of life, the strong influence of time costs raises the question of** whether the traditional focus of transport policies on the factor of saving time and the assessment methods of traditional transport economics should be reconsidered. Phenomena like burnout and permanent time-related stress are increasingly being addressed by society as critical issues. A transport system with the highest priority on accelerating transport for the purpose of saving time exacerbates these problems. There is the need for action here when making assessments and conclusions about whether there are limits to reasonable acceleration and time savings, where these have already been reached and how the positive effects of slowing the pace of life can be incorporated into transport policy decisions. Today's assessment methods are still directed towards the existing paradigm of acceleration and might therefore record the positive effects of deceleration with a negative sign in the assessment.

12. **Economic and ecological costs and benefits of mobility point in the same direction.** From the individual's perspective, the environmental benefits of alternative forms of mobility hover around the single digit percentage range of the total costs and benefits from health, transport safety, travel time and vehicle use. So the main benefits of more environmentally-friendly mobility for travelers are not just ecological, but to a large extent financial savings and a healthier lifestyle.

13. **Investments to promote more active mobility create broad social benefits.** Besides the purely transport-specific benefits, the quality of public areas in general can profit from the promotion of cycling and walking or the attractive design of local public transport systems. These benefits were not quantified within the scope of this study, but should be set against the investment costs in a comprehensive calculation. This might positively influence the cost-benefit indicator which was clearly negative for the five measures analyzed when taking time costs into account.

Switching from cars to alternative mobility forms can have dampening effects on the automobile industry. To what extent there are also negative effects on the wider economy or whether these can be balanced by investments in transport infrastructures and their operation are described as follows based on the results of this study:

14. **The level of investments differs fundamentally in the measures examined.** The estimates range from one billion euros annually for cycle paths and pedestrian zones, two billion euros for expanding local public transport schemes and 11 billion euros for creating incentives to increase the attractiveness of regional destinations of passenger transport. The latter measure extends far beyond the transport sector because it presumes town and regional planning transformations on a much larger scale. It is however conceivable that more regionally-oriented mobility patterns could be achieved or supported by more favorable measures. Stopping the grants for first-time home owners from 2004 was a first step by the German government which, for example, can be supported by abolishing the tax deductibility of commuting costs.

15. **Remodeling the transport systems does not necessarily have to be a burden on the state budget.** In the measures analyzed, it is assumed that infrastructure investments are financed by additional revenues from users and from the state budget. The building sector profits from the additional investments more than all the other sectors. As a consequence of the measures, sectoral demand is partially reduced, e.g. in the automobile industry due to a drop in car purchases, which is not compensated for by additional demand for public transport rolling stock. However, the macro-economic investment balance still remains positive in four of the five measures. The drop in demand in the automobile industry due to fewer cars is more than compensated for in the majority of measures due to infrastructure investments by the construction industry. Only for the reduction of fuel consumption (M4), where no direct investments were assumed, does the drop in automobile production cause a macro-economic decline in investments of about one percent in 2030 compared with the reference scenario. If state support programs for transport management of 100 to 200 million euros are assumed, however, this evens out and a balance can still be reached.

16. **Investments and organizational changes in the transport sector are mutually supportive.** In two of the measures examined, improving efficiency in car use and shifting freight transport to rail, there are large impacts of operational changes in rail transport and mobility management in passenger transport. Both measures can be implemented without significant investments. The prerequisite, however, is the willingness of users and companies to abandon habitual routines and adopt new forms of organization using current technology aids.

17. **There is a positive employment development in almost all measures**. Driven by the positive investment balance of the measures examined, employment increases slightly compared to the underlying reference scenario. For 2030, this means 1.4 % to 2.5 % more jobs across all sectors in M1, M2 and M3. The growth is about four to five times higher for the transport sector, which provides additional transport services. M4 is the exception here (more efficient car use), where the decline in car use and thus also car sales is not offset by any positive impulses of the measure. Under the given assumption of annual investments of 100 to 200 million euros in improved transport management, which are attributed to the service sec-

tor, however, this negative balance of overall employment can be evened out. It must be stated that job losses in Germany will probably become less significant in the coming decades against the background of demographic change and the related lack of skilled labor. Admittedly, jobs in the construction sector will continue to offer opportunities for low-skilled workers even in the future.

18. **Macro-economic productivity remains more or less constant.** The measures investigated in this study mainly look at investments in the construction sector, which, however, only generate minor impulses for increasing productivity in comparison to other capital goods sectors. M2 is the exception with investments in local public transport vehicles. Even these only trigger smaller productivity improvements compared with sectors like electronics, mechanical engineering or computer appliances and thus only a negligible increase in macro-economic productivity. Changed travel times, especially in freight transport, can also bring out productivity changes, but these are still limited in the measures.

19. **There is a positive development of the gross domestic product.** The GDP is slightly above that of the reference scenario in four of five measures in 2030. The additional investment impulse and the second-round effects of the measures compensate the negative effects in the automobile industry and the effects of structural changes with their impacts on sectoral demand. Funding the investments from additional revenues of the measures and the state budget is feasible. Against the backdrop of the huge uncertainty regarding the macro-economic development, the consequences of more sustainable mobility for the national economy have to be termed as moderate, with changes in the GDP ranging from − 0.2 % to + 2.2 %.

Finally, the economic feasibility and the acceptance of behavior-changing measures for a more ecological transport system can be summed up as positive.

20. **Sensible packages of measures can significantly increase the effectiveness and efficiency of transport policy.** Both the individual assessment and the macro-economic assessment can be improved if the different measures and instruments dovetail. This also raises the level of acceptance. The focus here is on "Push & Pull" methods in the sense of a shifting and financing strategy by using market instruments (e.g. mobility pricing) simultaneously for financing and control. The strategy of shorter distances and the switch to more active mobility go hand in hand with and, at the same time, necessitate the coordination of transport and town development and raising urban density. In such an approach, environmentally-friendly forms of mobility (modern local public transport, cycling and walking) have higher potentials a priori.

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