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SELECTED PROCEEDINGS

The Private and Public Economics of Sustainable Mobility Patterns

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This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

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Review Results

We thank the reviewers for their very helpful and comments. We have addressed all of them (see below). In particular we have shortened the paper by 6 pages in order to approach the envisaged length of well below 20 pages. In our opinion, further cuts would only be possible with a loss of contents.

Reviewer 1

This is an interesting and original attempt to look at the case for promoting active travel looking at health and environmental benefits. However, it is admitted that the health benefit values are ´pure guesses´.

Response: Indeed, in the level of individual transport users we are presenting examples. And this is discussed at several stages of the paper. On the macro level, however, we have approached overall health benefits via obesity statistics and tip patterns from the ASTRA-D model. Together with the WHO figures on economic gains per person we believe that the results are sufficiently reliable for this exercise. We have thus removed the sentence of "pure guesses" in Section 3.2, 3rd paragraph.

It is found that the measures considered are not worthwile in BCA terms if time losses are included (this is said to lead to a case for reconsidering the role of time savings in such studies, although it is not clear why these results should lead to such a conclusion).

Response: We have focussed the line of argumentation (last paragraph of Section 7) more on the fact, that the ASTRA-D model does not support the more flexible use of bikes, congestion impacts, etc. in cities and thus travel time calculations are highly questionable. However, we feel that the debate on valuing time should be re-opened and thus we have decided to leave the respective recommendation in the discussion part of the paper.

For some reason, it is chosen to include only external costs of accidents, even though there seems no reason to do this an a CBA (as opposed to when looking at pricing) especially as all time costs are included.

Response: This is indeed a critical point. But in the light of the argumentation above and as the paper is not looking into setting optimal prices we prefer to maintain the omission of time *costs in the CBA. They are contained in the full study with the result that all benefit-cost ratios get negative.*

Other issues of completeness are whether impacts on congestion are fully allowed for, and whether the policies imply any changes in public transport subsidies (only capital costs are included).

Response: Congestion impacts are not covered by the ASTRA-D model in sufficient detail; an addition was made to the final paragraph of Section 6. Concerning transport subsidies we took a very generic approach by addressing the overall capital and operating costs of roads and public transport undertakings. A clarifying sentence has been added to Table 3 and the text below.

A further query is whether the impacts on employment and GDP allow for consequent measures resulting from changes in govenrment spending and tax revenue to maintain equilibrium (changes in other taxes or government spending).

Response: We did not in detail look into public funding and budget processes. We generally argued that the considerable costs of implementing these measures may to a large extent be funded by the instruments themselves, i.e. through road charges, parking fees or PT revenues. We can add this point to the discussion part.

It may not be possible fully to resolve all these issues in the time available but at least discussion of them should be improved.

Reviewer 2

Although this is a very interesting paper it has subjectivity in the determination of the indicators. It is not clear how and by whom the macroeconomic as well as environmental indicators are selected. Who are the decision makers. How the time value of individual and business trip are specified etc.

Response: We added a short description on the selection process in the heading of Section 4.3. Addressed are individuals and state level decision makers.

The reason of selecting a system dynamic model in general and ASTRA-D in particular are not clearly justified.

Response: The issue is that we are dealing with long term processes, for which we believe SD is suited better than CGE models. We have added a short justification to Section 4.2, 2nd paragraph.

Additionally, the paper is very long and should be reduced to 15 pages.

Response: we have cut the introductory parts of the paper (Sections 1 to 3) and the conclusions (former section 7.1) largely. Further we have deleted the final section 7.2 on critical as the respective issues have been discussed throughout the paper. Including cover page and references (3 pages) we have cut the paper down to 6700 words or 17 pages.

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Abstract

This paper emerged from a study on the economic consequences of non-technical measures to reduce transport emissions for the German Federal Environment Agency (UBA), finalized in October 2012. It looked at the costs and benefits from more active mobility from two perspectives: the individual transport user and the society. Out of the five measures for emission reduction investigated by the study, this paper focuses on increasing the modal share of walking and cycling and of public transport use in urban areas. Looking at individuals, typical travel situations show that health benefits can easily compensate for safety problems, and that the costs of motorized travel often exceed the time gained by using the car instead of bikes or public transport. But statistics reveal that the safety of cyclists clearly increases with their modal share. In total, we find that environmental benefits only account for a marginal fraction of the overall travel costs, but that private savings often go hand-in-hand with reduced emissions. Under selected transport investment scenarios, the macro-economic analysis reveals that more active mobility can reach considerable benefit-over-cost ratios and even foster economic growth and employment by 2030.

Keywords: Walking, cycling. public transport, health benefits, external costs, CBA

1 Introduction

The recent Transport White Paper of the European Commission (EC 2011) envisages cutting transport CO_2 emissions by 60 % and approaching zero fatality rates by 2050, while stating that curbing mobility is not an option. Similar goals put forward by rail and automotive associations in Europe and worldwide focus mainly on technical solutions. While technical progress has brought major advances in the past two decades, in particular with respect to air emissions and accident rates, other areas such as greenhouse gas emissions and noise pollution have not been tackled satisfactorily.

Better technology has to be accompanied by measures influencing the mobility behavior of people and freight forwarders. Changing daily travel patterns, however, will not only affect the sustainability of the transport sector, but will impact individual variables, such as time availability, costs and health. Further activities by the public sector, e.g. investments in infrastructures and information provision will be necessary.

This trade-off between the personal and public implications of more sustainable mobility patterns and appropriate instruments to achieve the objectives of reduced car use are investigated in the study “Economic Aspects of Non-Technical Measures for Emission Reduction in Transport”, commissioned by the German Federal Environment Agency (UBA) and finalized in October 2012 (Doll et al., 2012).

This paper presents the passenger transport-related findings of the study. Section 2 delves into the study design, Section 3 discusses methodological approaches by key benefit and cost category and Section 4 introduces the assessment tools.

Results for the specific cases of more walking and cycling and increased use of public transport are presented in Section 5 on the individual level and Section 6 on the macro-economic level. Section 7 eventually discusses the results and draws conclusions for further research. Particular attention is paid to health effects, their social benefits and their safety implications.

2 The Study design

The study was designed to give advice on how to present sustainability goals to affected travelers (individual level) as well as to transport policymakers and planners (public level). Its main hypothesis is that sustainable transport policy goals can be achieved much more efficiently if policy instruments coincide with peoples’ daily needs and preferences. It is also expected that a mix of information on the pros and cons influencing individual preferences together with push and pull measures will be required to achieve major changes in travel patterns within a reasonable time span.

The study terminology distinguishes between measures, i.e. changes to be implemented in the transport sector in order to achieve given emission reduction goals, and the instruments required to implement the measures. Both the individual (micro) level and the national (macro) level explore five measures, of which four concern passenger transport and one freight transport. To keep our message clear, in this paper, we focus on two of the passenger transport measures:

- M1: Increase the modal share of cycling and walking in urban areas by 10 percentage points by 2030. Given the current share of 37 % of these slow modes in German cities, the measure implies increasing walking and cycling by 27 % until 2030.
- M2: Increase the modal share of public transport in cities by 10 percentage points by 2030. Compared with today's share of 8 % of trips made by bus, tram or subway in German cities, this means the public transport market share has to be more than doubled by 2030.

The time span of the macro-economic analysis is 20 years from 2010 to 2030. Along this time line, economic, environmental and social output variables are computed by the ASTRA-D model. The instruments are applied within the 10 year period 2015 to 2025 such that the modal split targets of the underlying measures M1 and M2 are met in 2030. On the individual level, only the base year 2010 is considered.

To achieve these measures, we assume the joint application of several types of instruments in a policy mix. These contain push, pull and information measures:

- Autonomous change of peoples' norms and values via cost-neutral information campaigns of public authorities. The result is a shift in transport behavior.
- Pricing measures such as congestion charging, parking charges or motorway tolls. These create costs for the users in the form of toll fees which are a source of revenue for the public sector as well as costs for the state in the form of toll system installation and operation costs.
- Investments in better infrastructure and services, here, cycling, walking and public transport, and accompanying organizational changes to support the performance of the desired transport mode. We assume that the costs are shared between the users and the public sector.
- Regulation, e.g. urban access control, congestion management, etc. Direct costs for running and enforcing the regulation are borne by the state, while transport users bear the impacts of these regulations (vehicle investments, etc.).

The feasibility and effectiveness of these instruments will heavily depend on local circumstances such as city size and structure, available transport modes and infrastructures, congestion levels and system quality, etc. As we are looking at the problem from an aggregated national perspective, detailed urban assessments are hardly possible. Thus, it was decided to pre-select certain elements of policy packages and select an upper limit of implementation for each of them, i.e. maximum charges, largest possible network extension, etc. The intensity of each instrument in the final policy package was then determined by its potential contribution to meet the 2030 modal shift targets.

This approach has a critical implication for this study: the macro-economic cost-benefit considerations apply only to the specific package of implementation instruments selected here. The mandate and budget of the study did not allow numerous sensitivity tests with different packages, nor was an optimization procedure for optimal policy packaging part of the study design.

3 Valuation principles

This paper seeks to derive cost-benefit ratios for the selected policy packages on the macro-economic level and for changed mobility behavior on the individual level. The components of the CBA include infrastructure and vehicle fleet investments, time costs, health impacts, safety effects and environmental impacts. The quantification approaches and data sources are briefly summarized in the following.

3.1 Infrastructure and system operation costs

The provision, maintenance and operation of transport infrastructures and vehicle fleets generally denote costs for public authorities and transport companies if the aim is to reduce the car modal share. However, for the individual transport user, reduced car use – or getting rid of a private car completely –means relief from a considerable financial burden. Vehicle-related investment and operating costs are considered on the individual level only. The life cycle operating costs of passenger cars, including depreciation, maintenance, fuelling, insurance and taxes are taken from the Database of the German Automobile Club (ADAC, 2012). Ticket prices rather than system operating costs are referred to for public transport because this is the cost information visible to the consumer. Fare levels were averaged across single and seasonal tickets in major German cities.

In the macro-economic analysis, infrastructure and vehicle investment costs are considered on two levels: direct investments are defined as external inputs to the ASTRA-D model, while second round investments in transport and other economic sectors are computed by the input-output tables and related productivity functions of the model. Direct or first round investments are estimated as follows for the two measures considered here:

- M1: Doubling the current expenditure of the German federal government for investments in bike lanes and pedestrian areas and the installation of congestion charging zones in major cities between 2015 and 2025 to around €1.3 billion annually.
- M2: Investments in transit infrastructures and services (tracks, stations and vehicles) plus urban congestion charging between 2015 and 2025 of €2.4 billion per year.

3.2 Travel time

User time costs denote the most critical element of transportation cost analysis. In the German Transport Infrastructure Investment Plan (latest issue 2003: BMVBS 2005), 75°% of total project benefits are due to time gains. And this is despite rather moderate values of travel time (VOT) of €3.83 per person-hour for private travel and around €24.00 per person-hour for business trips. European value of time studies (see reviews in Bickel et al, 2006, Maibach et al, 2008, van Essen et al, 2011) arrive at much higher values for private and commuter trips of around €9.00 per person-hour.

Although the studies listed here find higher values of travel time for car use compared to alternative modes, we selected a unique value of travel time in this study for two reasons (compare also Börjesson and Eliasson, 2012). First, our focus is on the benefits and costs of modal choice behavior. In this case the time perception of a single person will remain unchanged when shifting modes. Second, we have isolated some of the key determinants, namely safety and health concerns by separate benefit and cost categories. Thus, the VOT should contain only the users' fundamental time preference, which is only influenced by the current travel purpose and travel time of the journey.

For the individual analysis, we applied stated preference values of €8.48/h for private trips and €23.82/h for business trips. For the macro-economic analysis, we refer to the resource consumption approach and use the values from the German federal investment plan of €3.83/h for private travel and €24.00 for business travel with a 20 % share of business travel.

3.3 Health impacts

More attention has been paid recently to the health impacts of more active mobility behavior. For instance, the Health Economic Assessment Tool (HEAT) for cycling and walking (Kahlmeier et al., 2011) of the World Health Organization (WHO) makes use of the results of recent European studies (Cavill et al., 2008, Samitz et al., 2011). Assigning the value of €1.6 million to a human life and considering average German mortality rates, health benefits of up to €2000 per year are found for formerly untrained people cycling or walking regularly 75 minutes per week. The definition of "untrained" is not clearly specified in the sources, but denotes people who do not regularly take part in sports, active mobility (cycling or fast walking) or other physical activities (climbing stairs, housework and gardening etc.).

In the macro-economic assessment, we assume that this maximum benefit of regular physical activity applies fully to overweight adults between 25 and 65 years. Overweight is defined as a body-mass-index (BMI) above 25, which applies to 60 % of adults in the regarded age class. The BMI is defined as weight (in kg) divided by the square of height (in m). Studies suggest that, for trained people, the respective benefits of additional regular physical activity may be valued up to €500 annually. This maximum benefit applies to the remaining 40% of German population. However, as this group already takes part in more physical activities, we assume that these theoretical health benefits are only actually realized in 25 % of cases.

We also acknowledge that even less well-trained people, and in particular those who are prepared to accept a steady shift of their behavior towards more active forms of mobility, do have some level of physical activity and may actually reduce this as a consequence of more cycling and walking. In light of these considerations we make a cautious guess that only 50 % of the additional physical activity due to more active forms of mobility of untrained or overweight people is truly additional and thus leads to extra health benefits. For trained people, this share is assumed to be only 25 %.

For greater accuracy, however, data about personal mobility and other activity patterns would be needed, which is not featured in the ASTRA-D model, nor is it supported by available statistics. Other effects which may also be of considerable magnitude include direct medical treatment costs, indirect medical costs and the costs of absenteeism (time off work due to illness) and presenteeism (working despite illness) at the workplace. The costs of presenteeism and absenteeism for in Germany are estimated at €3600 per employee and year on average. A considerable share of these can be traced back to a lack of fitness and physical activity (Maar and Fricker, 2011).

3.4 Traffic safety

The safety implications are quite significant for cycling and walking. According to the fatality figures published by the German Federal Statistical Office (DeStatis 2011) in combination with estimates of passenger-kilometers in slow modes (Infas and DLR, 2010), the fatality rates for cyclists are more than 10 times higher than the fatality rates for drivers and car passengers in urban areas. This is not surprising as fatal car accidents tend to occur more on rural roads or on motorways with much higher permissible speeds.

The safety of cyclists very much depends on the type and quality of cycle infrastructures and the share of cyclists on the roads. In many European cities, it is now common to have clearly marked cycle lanes on the road to ensure cyclists are highly visible for car drivers. Cycle paths separated from roads by trees or other objects have proved to generate accident hotspots when cyclists have to crossing junctions and surprise car drivers. Finally, according to a European review of accident statistics in Jacobsen (2003), the safety of cycling and walking increases considerably with increasing market shares of these modes.

When quantifying safety costs we need to decide whether to evaluate the private risk or the external risk. The private risk denotes the risk a transport participant is taking for himself / herself and his / her passengers when performing a trip. The perception of private risks is difficult, will differ widely from actual risks and depends on infrastructure, traffic conditions, weather, and other external factors, and, to a large extent, on individual capabilities and self-assessment. In contrast, the external risk assesses the impacts a travel decision has on other traffic participants.

This study adopts the external risk approach in order to avoid the mentioned assessment problems. To quantify the external costs of safety, we use the same value of a statistical life of €1.6 million as for health costs in the case of a fatality, and 15% and 1% of this figure for a severe and slight injury, respectively. On top of that, we calculate some 10% for production losses, medical costs and the administration costs of public bodies and insurances.

3.5 Environmental impacts

The valuation of environmental effects, including greenhouse gas emissions, air pollutants and noise, has been studied in-depth by a parallel study commissioned by the German Federal Environment Agency (Maibach et al., 2012). GHG emissions account for the highest share of costs (or benefits) in this group; here we use the current value of €80 per t CO_2 and €146/t CO_2 in 2030. All environmental values vary with vehicle size, emission standard and settlement density. Emission values are taken from (HBEFA, 2011).

4 Assessment instruments

4.1 The PExMo mobility cost analyzer

The PExMo (Private and External costs of Mobility) tool was designed and implemented in the course of the study to visualize the effects of alternative forms of mobility on the traveler, expressed in monetary units. For a selected set of travel alternatives, PExMo allows the private costs of travel to be compared with the impacts on health, safety and the environment. The cost functions implemented in the tool reflect the technological and economic conditions in Germany around 2010. In its current version, PExMo does not feature future scenarios.

The tool uses the evaluation principles and data sources introduced in Section 3. It allows users to select travel purpose, vehicle type, load factors, the availability of monthly and seasonal passes for public transport and long-distance rail. Each journey may consist of up to three segments, for which mode, costs and regional conditions can be set individually. The tool works at the following level of detail:

- Vehicle type: 3 car size classes plus vans, mopeds and motorcycles by EURO exhaust emission standard.
- Public transport and car sharing by type of ticket.
- Travel purpose: business, private and leisure.
- Route by area type (metropolitan, urban, suburban and rural) and infrastructure (motorway, minor road).

The graphical representation of health benefits turned out to be challenging as all other CBA categories denote costs. Thus, the concept of “health opportunity or shadow costs” was introduced. This describes the potential omission of health benefits if the healthiest form of travel, which is walking when looking at potential benefits per distance, is not chosen.

Another challenge turned out to be the treatment of fixed cost blocks, such as motor vehicle depreciation or annual PT ticket expenses. As PExMo only considers a specific trip and not the overall mobility behavior of people, a cost allocation mechanism had to be added to the tool. To this end, the user is asked to enter the total annual mileage per mode.

The Microsoft Excel tool and is available at www.ntm.isi-projekte.de.. Currently, the tool is only available in German..

4.2 The ASTRA-D system dynamics model

Impacts on the macro-economic level are quantified using the ASTRA-D model. ASTRA-D is a newly developed national version of the ASTRA model (Assessment of Transport Strategies), a system dynamics model of the transport sector and the European economy, which was first introduced in 1998 and has been developed since then during the course of several EC-funded research projects (Schade, 2005). A dynamic input-output table forms the economic core of the ASTRA model family, which is linked to detailed sub-modules of population, foreign trade, regional economics, transport, vehicle fleets and the environment. The German version ASTRA-D is consistent with national databases and offers a NUTS-2 detailed evaluation.

The unique thing about ASTRA is that it has detailed, dynamically interdependent modules to simulate the development of macro-economic variables like GDP, employment, productivity, investments as well as government policies and passenger and freight traffic. This feature is considered decisive for carrying out the macro-economic assessment in this study as only the integrated computation of transport supply and demand changes and related industrial processes, such as vehicle production, in the national economic context can derive indicators of state budget implications. And it is out of question that these are decisive for the feasibility of the envisaged paradigm shifts in transport system design and usage.

In the modules for passenger traffic, traffic volume and distribution are calculated following the first three steps of the classical four step method: trip generation, trip distribution and modal split. As ASTRA-D does not contain transport networks the final assignment step is omitted. The policy instruments are implemented into this framework through changes in generalized times and costs, and, in the case of autonomous behavioral changes, by manipulating the parameters of modal split or trip distribution parameters.

4.3 Application of the assessment tools

Table 1 summarizes the cost elements and their treatment with respect to the two perspectives. The indicators used in the CBA were selected jointly by the project team and UBA. They should address the personal interests of transport users on the individual level and some key indicators for public bodies on the macro level. The level of communal decision makers or transport companies could unfortunately not be covered directly by the selected indicators.

Table 1: Perspectives and cost elements

Cost & benefit category	Individual level impacts (2010)	Macro-economic level assessment (2010–2030)
INTERNAL (PRIVATE) COSTS & BENEFITS		
Private expenditures	Depreciation, maintenance, fuel, tickets, fees	*no consideration*
Travel time	Assessment according to travel purpose and mode	Supplementary information; (only project level relevant)
Health effects	Value of additional healthy life time; benefits from HEAT tool	Cautious consideration of fitness and activity levels
EXTERNAL COSTS		
Accidents (causality principle)	Supplementary information; costs by region and mode	Assessment by region type and mode
Environment (climate, air pollution and noise)	Supplementary information; Costs by area and vehicle type	Costs by area type and vehicle technology
MACRO-ECONOMIC ASSESSMENT INDICATORS		
Public expenditures	*no consideration*	Additional information: investments, operation etc.
Macro-economic indicators (GDP, employment)	*no consideration*	Additional information: ASTRA-D model outputs

Pattern codes: white = full consideration; hatched = supplementary information; grey = no consideration

Source: Fraunhofer ISI

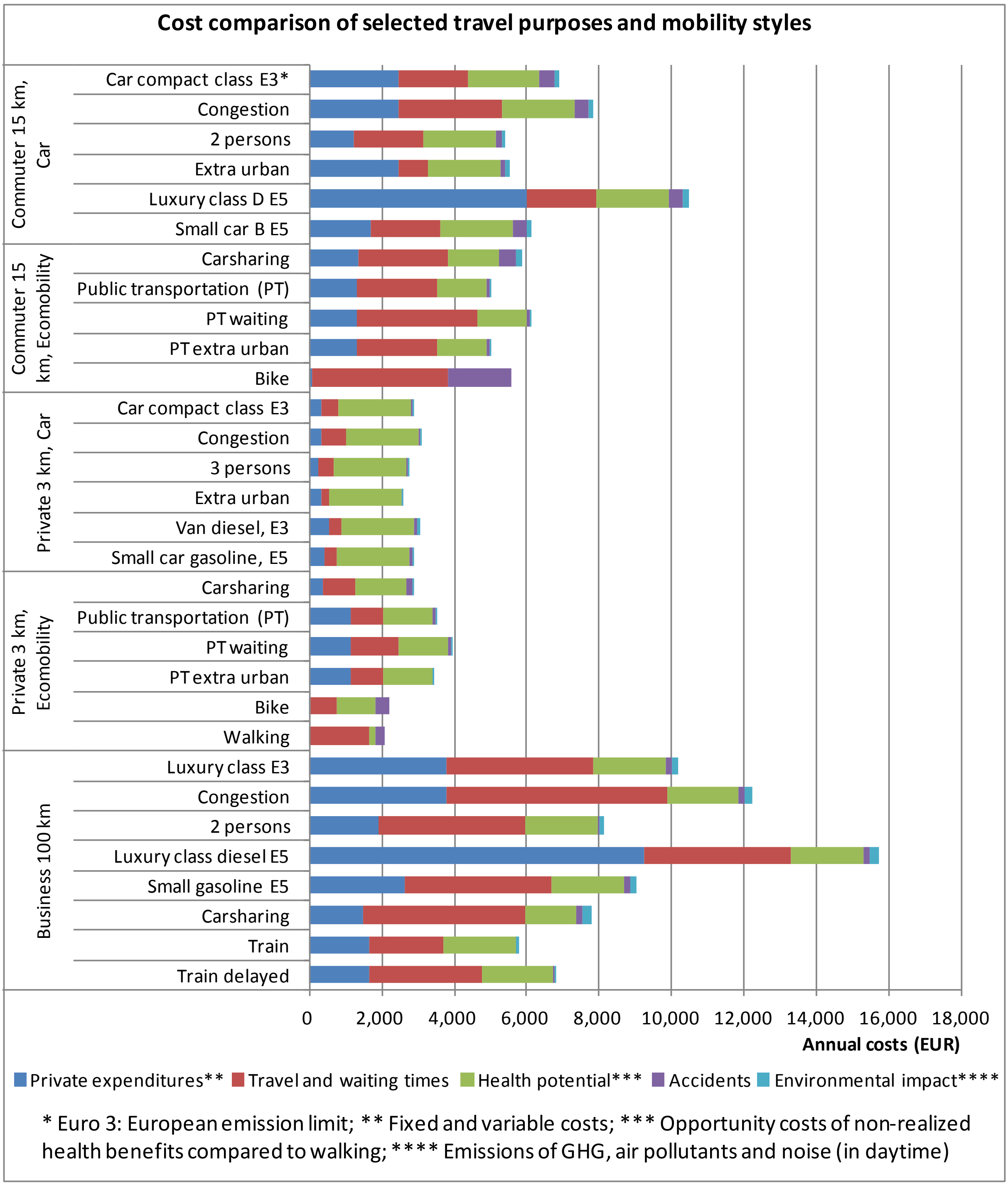
5 Benefits and costs on the individual level

The annual private costs of mobility, and thus the benefits or dis-benefits from changing travel routines, depends on a large variety of factors. Firstly, on the trip characteristics in terms of travel purpose, length, frequency, time of day and route. Secondly, on the modal choice (car, public transport, cycling, walking) and – in particular for car travel – the efficiency of these vehicles (size, emission standard, occupancy) determining the private and environmental cost balance. Figure 1 gives indicative examples for varying these parameters. Presented are the annual costs of a 15 km commuting trip, a 5 km private trip and a 100 km business trip computed by the PExMo tool using the following parameters:

- Car compact class E3: standard mid-size car, gasoline with Euro-3 emission standard and occupied by 2 persons
- Congestion: 50% increased travel time on urban roads due to peak traffic
- 3 persons: one additional passenger in the car
- Extra urban: trip on rural instead of urban roads
- Luxury class D E5: passenger car > 2 liter diesel engine, Euro-5 emission standard
- Small car B E5: car < 1.4 liter gasoline engine with Euro-5 standard
- Car sharing: Monthly fixed costs of €50 plus €0.50 per km

- PT: public transport (German mix of bus, tram, metro and light rail)
- PT waiting: double wait time at PT stations
- PT extra urban: trip with public transport outside urban areas.

Figure 1: Annual private costs by cost category for selected travel alternatives



Source: Fraunhofer ISI

Figure 1 presents results for all four passenger transport related measures investigated in the study (Doll et al., 2012). On shifting car based mobility to cycling, walking and public transport in urban areas we can conclude the following:

- **General observations on cost ratios**: Private costs play a dominant role in using cars or public transport. However, the longer the distance, the more significant the impact of time costs. When looking at the bigger picture, the huge impact of health costs is rather interesting. Finally, but no less interesting, the estimates of external environmental and accident costs are marginal compared to user-related costs.
- In general, public transport is quite competitive compared with car travel over medium to long distances, where car occupancy rates are usually low. For short trips, and when considering all the cost categories, cycling and walking are usually the cheapest alternatives.
- The generalized costs of motorized travel (car, public transport and railways) are decisively influenced by the **quality of service**. 50% longer travel times for commuting is equivalent to around €1000 additional costs per person and year, increasing the costs of motorized individual travel by 14% in the given example. The respective cost increase in public transport was found to be 22%, indicating that public transport is more sensitive to disruptions than car travel.
- The **settlement type** has a decisive impact on travel times as well as on the environmental impact of the trip. Traveling is usually faster on inter-urban roads than on urban roads and the typically less dense settlement structure in such areas reduces the negative impacts of emissions and noise.
- **Safety and travel times** play the central role when evaluating cycling. With the given cycling infrastructures in most German cities, riding fast as well as safely, however, compromise each other. The examples plotted in Figure 1 indicate that cycling is only partly competitive with car travel for the chosen commuting path. The attractiveness of cycling in urban areas could be increased by establishing safe, comfortable and high capacity cycling networks. Under such conditions, this mode could be competitive with car travel even on medium distance trips.

Other factors such as the residential area, topography, health conditions and fitness of the traveler, income and household size all influence the results as well. The study did not look at these determinants of mobility, but it is clear that they impact costs, the availability of alternatives and the freedom to change to other modes of transport. In many cases, car sharing, which represents a gradual rather than a fundamental change in mobility patterns, can reduce private costs and encourage an increased use of public transport to active forms of mobility.

6 Costs and benefits of implementing mobility measures on the national level

6.1 Impacts on GDP, investments and employment

The measures investigated and their specific investment strategies have direct and indirect impacts on the economy. A huge impact on growth and employment is found for direct demand effects and their related investments in infrastructures, rolling stock and services. Table 2 presents the results of the ASTRA-D model for Germany in 2020 and 2030 relative to the base case scenario without M1 and M2.

Table 2: Comparison of the macro-economic indicators of measures M1 and M2

Indicator	Year	M1 10% more cycling and walking trips in cities	M2 10% more public transport trips in cities
GDP	2020	+0.19%	+0.24%
	2030	+1.11%	+1.56%
Employment	2020	+0.14%	+0.21%
	2030	+1.37%	+1.76%
Employment in transport	2020	+3.34%	+4.10%
	2030	+4.14%	+5.29%
Investments	2020	+1.67%	+2.31%
	2030	+5.45%	+7.03%
Investments in transport	2020	+3.38%	+5.17%
	2030	+2.65%	+5.27%
Investment in transport infrastructure	2020	+3.38%	+5.60%
	2030	+3.67%	+7.48%

Source: Fraunhofer ISI, ASTRA-D model outputs

Both measures have a slightly positive effect on economic growth and employment. This holds even though more cycling, walking and PT means less demand for new cars. Considerable investments in urban infrastructures and public transport were assumed, which could balance out the cost-reducing effect of the measures on car purchase and use.

The gross domestic product (GDP) develops moderately in both measures and has the same sign as the investments. Measure M1 (more cycling and walking) mainly considers investments in the construction sector, which does not usually generate large spillover effects to other sectors. Spillover effects do occur in M2 (increase of PT share) with its large investments in transit infrastructure and vehicles. However, the net effect here remains minor because the public transport vehicle sector is a rather small one and, on the other hand, a considerable decline in automotive construction has to be compensated.

Changing consumption patterns acts as a stimulating factor for the whole German economy. Consumption in the transport sector shifts from private cars, which have a high tax rate due to the high fuel duties in Germany, to public transport or even non-motorized transport. As a result, consumer expenditures previously needed for taxes and cars are available for other economic sectors.

There is a positive development in employment in line with the development of GDP. Across all sectors of the economy this leads to 1.3 % and 1.8 % more jobs in M1 and M2, respectively. Given the German workforce of currently around 40 million people and presumably around 30 million people in 2030, this is equivalent to 300 thousand to 450 thousand more jobs in 2030. This number is significant and deserves a closer look. In measure M1, we assume investments in cycling and walking infrastructure and urban congestion charging of around €1.3 billion annually. At the €100,000 assumed for a qualified job including overheads in the construction industry, 130,000 jobs can be financed by the direct investments of M1. However, total jobs in 2030 are 41,000 (1.37 % of 30 million). Accordingly, the rest of the economy – including the declining automotive sector – is supposed to generate twice the number of jobs generated through direct investments. Looking at the strong increase (+4.1%) of employment estimated for the transport sector by the ASTRA-D model, we can assume that the structural changes in the labor market are mainly within the transport sector.

6.2 Cost-benefit analysis

In Figure 1 we have compiled national estimates of net present values of all benefit and cost categories for deriving benefit cost ratios of the two measures. Out of all categories, the largest benefit is gained in the health impacts of a more active mobility behavior. Most interestingly, the highest benefits from health effects are not obtained for measure M1 (more cycling and walking), but from measure M2 (more public transport). This means that fostering public transport actually generates more walking and cycling than the direct promotion of these modes themselves. This effect can be explained by two facts: Firstly, the core instruments of M1 and M2 are identical, namely congestion charges in urban areas. Secondly, establishing high-quality public transport provides a real alternative to private car-based travel, which makes owning a private car less necessary.

As discussed above, the safety of cycling and walking in cities constitutes a considerable problem for more active mobility patterns. Despite the high safety improvements assumed in measure M1, expanding public transport (M2) achieves almost as many safety benefits as M1. The general effect can be explained by the overall reduction of trips through the instruments chosen.

Table 3: Benefits of the measures M1 and M2 on national level

Benefit category Billion euros (2010)	**M1** **10% more walking and cycling trips in German cities**	**M2** **10% more public transport trips in German cities**
Travel time benefits	-63.26	-51.35
Health benefits	11.53	18.67
Safety benefits	0.64	0.40
Environment and noise benefits	0.76	0.51
Total benefits incl. travel time	-50.34	-31.78
Total benefits excl. travel time	12.92	19.57
Infrastructure and operations	1.29	2.41
Benefit cost ratio incl. travel time	-38.95	-13.21
Benefit cost ratio excl. travel time	10,00	8,14

Source: Fraunhofer ISI, ASTRA-D model outputs

These benefits are offset by two cost elements: First, direct investments of communities and the state in walking and cycling facilities and in public transportation systems range between

€1.3 billion and €1.8 billion per year. These costs, which include life cycle capital costs as well as operating expenditures, are clearly lower than the benefits presented in Table 3.

Second, active mobility is generally more time-consuming than going by car. But in particular in urban areas congestion and searching for a parking space makes these benefits of the car questionable. Moreover, less cars on the road will make traffic flows more reliable and possibly even faster. Eventually, cycling and walking can be more enjoyable experiences than driving a car and time spent on public transport may be used for reading, checking emails, etc. As the ASTRA-D model does not support these behavior-specific analyses we have decided not to report overall time costs in the CBA.

7 Conclusions and discussion

From the analyses of the individual and macro-economic assessments, the following key conclusions emerge about the environmental effectiveness and efficiency of the two measures:

Emission reduction: More active travel in urban areas generates significant environmental benefits, in particular through greenhouse gas reductions. Only, these remain small compared to other benefit and cost categories. Thus, environmental sustainability is an important selling argument for less car use, but needs to be accompanied by more powerful arguments. However, the picture looks different when including long distance travel into the policy portfolio. More efficient car use and shorter car trips have the power to reduce CO_2 and air pollutant emissions by up to 30 percent as found by the study underlying this paper (Doll et al., 2012). These deep cuts in emissions can only be achieved if rail and public transport invest in renewable electricity and clean vehicle fleets. This should, however, be feasible regarding the huge investments in rolling stock assumed here.

Private costs: The most powerful argument for users to go for less car dependent mobility is savings in private costs. On the individual level, we can reckon with €5000 annual costs for owning and using a mid-size car. Getting rid of the car would leave sufficient funds for collective transport and car sharing. Of course, the feasibility of such a personal paradigm shift depends on the residential area and current family situation.

Health: Another very important driver of active mobility is health benefits. While these can be up to €2000 in the individual level, cautious estimates reveal benefits from more active mobility of between €14 billion and €19 billion annually for Germany.

The safety of cyclists and pedestrians in urban areas deserves careful attention. But international experiences reveal that a well developed infrastructure and higher volumes of cyclists and pedestrians possibly yield a considerably reduced accident risk.

Travel time: The speed of active mobility modes and public transport is a critical issue. To improve the competitiveness of slow modes with cars, the establishment of safe and high capacity cycling infrastructures and the acceleration of public transport are regarded as top priorities for sustainable urban planning. Nevertheless, the contrast between the dominant role of time (disbenefits in CBA) on one hand, and rising public health concerns due to stress and burn-out in a permanently accelerating world on the other, raises the question of whether the common approach of including travel time savings in transportation planning should be reconsidered.

Wider economic impacts: As is the case for investments and GDP, the employment balance is positive in nearly all scenarios. The changes are enormous, which mean the German labor market will face considerable challenges in 2030. The country already has to deal with a shortage of well-educated workers due to its aging and declining population. The economic benefit of replacing the auto industry with a high labor productivity by more labor intensive sectors is thus open for debate.

Investments to foster active mobility create broader societal benefits. These include, for instance, the attractiveness of urban living spaces for leisure activities, what was not quantified here, but could further improve the benefit-cost ratio of more active mobility forms.

Policy packaging: The specific benefits of each measure on the macro-economic level cannot be regarded in isolation. Promoting sustainable transport with certain instruments always fosters a broad palette of reaction patterns. It is thus recommended to consider a portfolio of measures and instruments and to base local sustainability policy on the environmental goals to be achieved rather than on specific measures. However, users' reactions are complex and do not always result in the anticipated direction. For instance, less car use reduces congestion and thus makes car travel more attractive and may increase fatality rates. These rebound effects must be monitored and – if necessary – addressed by local policies.

Funding: The main funding sources for the measures assumed here are public households plus revenues from the instruments applied, e.g. urban congestion charging, parking charges, the deduction of mortgage taxes etc. Another part of the bill could be funded by additional tax revenues and less public duties by the projected increase in GDP and employment figures. The construction sector profits the most from investments in alternative transport modes. For most measures the investment balance is positive even when including the downturn in automotive production.

The assessment of the various measures and instrument packages leads to the conclusion that a good mix of instruments and measures can lead to a cost-effective achievement of social goals, inducing a cleaner environment and healthier and more contented citizens. Transport should be embedded in a broader vision of an improved urban and regional environment and the associated side benefits of active travel should already be taken into account in early planning stages. Therefore the budgetary aspects of healthier people for companies and the public sector deserve a more in-depth investigation

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