ANALYSING THE MODAL SHIFT TO RAIL POTENTIAL WITHIN THE LONG-DISTANCE PASSENGER TRAVEL MARKET IN GERMANY

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1. INTRODUCTION

The German Federal Government has set ambitious targets to save energy and reduce harmful emissions. The goal is a reduction of greenhouse gas emissions of 80-95% of the 1990 values by 2050. Alongside, a reduction of the final energy consumption is needed. It is widely acknowledged, that the transport sector will have to be considered in this process, as it amounts for about 18% of total CO_2 emissions and its final energy consumption is directly linked to this magnitude of emissions.

In recent years, several measures have been taken to make the use of energy in the transport system more sustainable. These measures focused on new technologies and on encouraging the use of alternative means of transport. Many of these strategies address everyday mobility. Especially in the urban context, numerous measures are being discussed in research projects and by local planning authorities.

In addition to everyday mobility, long-distance mobility has to be considered for reducing greenhouse gas emissions and final energy consumption. This segment of the passenger transport market is of great importance, as it constitutes more than 30% of transport performance in Germany. In this segment, rail transport can offer a fast and environmentally-friendly means of transport, as the predominant share of long-distance passenger rail transport services is operated by electrified trains. Therefore, the railway system is well suited to become an important component of a sustainable transport system.

This paper reports the results of a recently finished study carried out by the authors on behalf of the German Federal Ministry of Transport and Digital Infrastructure (BMVI). The goal of the study was to investigate the impact of selected measures to encourage the use of rail transport for long-distance trips, herein defined as trips within Germany longer than 100 kilometres) on Modal shift, CO_2 emissions and final energy consumption in the transport sector. Their effects are quantified under the application of three alternative scenarios.

The paper gives insights into the study, the chosen approach and main findings. It starts with results from a literature review to identify relevant measures that could increase the attractiveness of the long-distance rail transport system. A brief insight into the German long-distance railway market is given afterwards. On the basis of these findings, three different scenarios are developed to identify and evaluate possible measures to support a modal shift to rail in the long-distance travel market.

The quantification of the impacts of these scenarios on long-distance modal shift, CO_2 emissions and final energy consumption is based on a transport model and the TREMOD framework. After an introduction to these models, changes in travel demand, CO_2 emissions and final energy consumption are shown. Finally, recommendations for actions are introduced and discussed.

2. MAIN BARRIERS TO THE ATTRACTIVENESS OF RAIL TRAVEL

The German railway network offers convenient and fast connections for most relations between the economic centres of the country. However, many passengers use other modes for long-distance travel. Comprehensive work on barriers to passenger rail use has been recently carried out by Blainey and Hickston (2012). They found manifold reasons why customers prefer other means of transport over rail travel. According to their research, there is a set of hard barriers, soft barriers and complementary barriers. We follow these dimensions, as all three of them require different actions to address their respective negative effect.

Hard barriers are such aspects that are relatively straightforward to measure or estimate and affect all passengers basically the same, although they might be valued differently by different individuals. The most important hard factors are travel time and travel costs, which we will shortly discuss.

Under the assumption of a restricted time budget, travel time is of high importance for mode choice. Therefore, a further reduction of travel times can improve the competitiveness of the railway system. It might be realized by construction of new high-speed-infrastructure or the further exploitation of unused potential in the timetable design.

The second important hard factor is travel costs. Rail travel is often perceived as being more expensive than car travel, as drivers tend to equate running costs with fuel costs only (Gardner and Abraham 2007). This might be a psychological effect, since the payment of railway costs is a more conscious action than the payment of car travel costs. Moreover, ticket prices are directly connected to the journey, whereas the costs for private car ownership occur at different irregular intervals: Costs include annual taxes, occasional maintenance and fuel costs, of which only the latter can in some cases be connected to a singular journey. Another factor is that the rail fare structure is often perceived as confusing due to the high degree of yield management in the pricing strategies. One crucial point in this debate is a fare reduction when committing to a certain departure time in advance to travelling. This has been a relatively recent development in the German travel market. The loss of flexibility has been criticized by some customer organizations (VCD 2009).

Beside hard barriers, *soft barriers* are also important. The valuation of these factors varies between individuals, destinations or trips. Examples are station facilities and on-board services. In this context it is important to consider that travel time can be used more efficiently by passengers in trains than in cars, given a certain amount of comfort on board. Deutsche Bahn, as cited in VCD (2012), states that "96% of the actual travel time can be efficiently used by passengers". Consequently, improving comfort on board by e.g. providing entertainment, wireless network or catering could be a powerful measure for modal shifts to rail.

Finally, c*omplementary factors* are related to activity and lifestyle choices and to a person's cultural and economic background. These are, for instance, the age of a person, their health condition and also the presence of luggage on a specific journey. Also, the influence of employers that tend to support car travel over public transport, e.g. by the provision of reserved parking lots, may be a relevant aspect. Finally, even the weather might affect travel behaviour. These aspects can only difficultly be implemented into a transport model. Table 1 gives a short overview on the types of barriers and some examples for each type.

Table 1: Barriers to rail use according to Blainey and Hickston (2012)

Factor Type	Explanation	Examples
Hard Factors	Factors that affect all passengers, with varying elasticities	Time, money
Soft Factors	Factors that are of varying importance to different travellers, trips and places	Station facilities, comfort, information provision
Complementary Factors	Factors that relate to the impact of lifestyle choices and the wider economic and cultural background of a person	Habits, age, culture

During the study, a workshop with stakeholders from industry, politics, customer groups and environment organisations was organized by the BMVI. The conclusion drawn from the workshop and the literature reviews was that travel costs and travel times are the most striking impact factors for mode choice in the long-distance travel market. Therefore, we focussed only on these factors in our research.

3. LONG-DISTANCE TRAVEL MARKET IN GERMANY

In the context of this paper, we define long-distance travel as journeys within Germany with a distance of more than 100 km. This part of the passenger transport market is of great importance: despite that only 1.2% of all trips inside Germany are long-distance travel by this definition, these relatively few trips account for more than 30% of the total passenger-distance. We used baseline year data from the Federal Traffic Forecast 2030 to identify the mode shares for long-distance travel in Germany for the year 2010. These data provides origin-destination-matrices with numbers of trips for each relation between Germany's 412 NUTS-3 entities (BMVI 2014). We identified those relations where distance exceeds 100 km and analysed the mode shares for the base year. Figure 1 illustrates the findings.

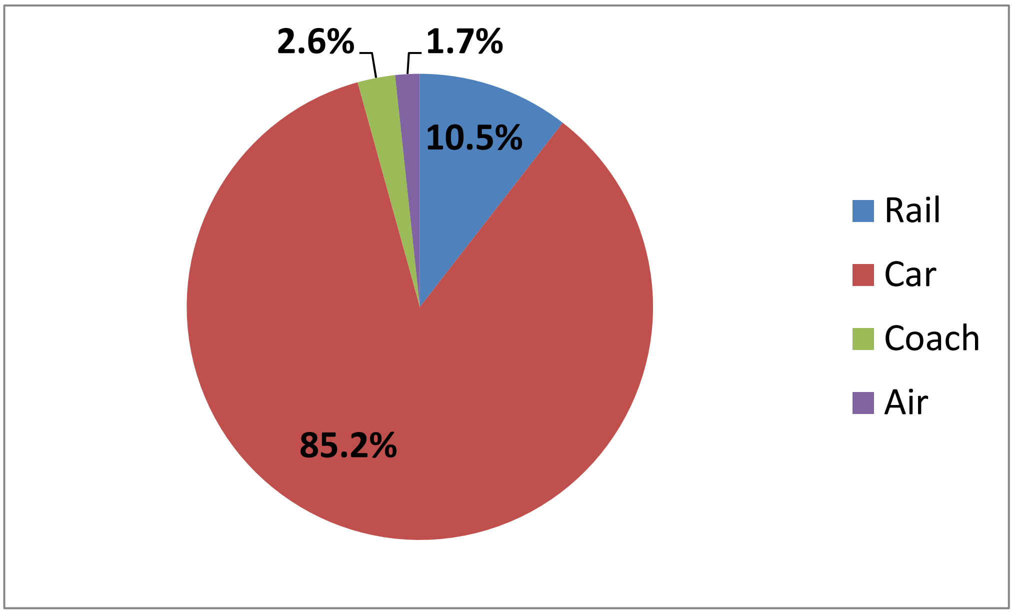

Figure 1: Long-distance travel in Germany 2010: Mode shares of long-distance trips in Germany (Source: BMVI 2014)

The private car is the predominant means of transport in long-distance travel. Main reasons for this are a very high availability of cars, relatively low costs and large storage space, which is important for holiday trips, the latter being a soft factor. Especially for trips from and to rural areas, car usage is required for acceptable travel times. Long-distance trips by rail are strongly dominated by city-to-city business trips. Coaches are predominantly used for holiday trips. On longer distances, air travel also plays a role, especially for business trips.

Despite these mode share findings, the rail system can offer a fast alternative for many relations: The extension of Germany's high speed rail network has been extensively funded by the government in the last decades. As of December 2017, it will be possible to travel the 600 km-long distance from Berlin to Munich in less than four hours with the ICE service on a newly built high-speed line. Similar average speeds are already being offered on other relations between the major economic centres of the polycentric country. This level of service makes rail travel competitive against the other modes of transport in terms of travel time.

The railway system is also well suited to become an important and promising component of a sustainable transport system: the largest proportion of long-distance passenger rail transport services is operated by electrified trains. Despite these advantages, the mode share of rail transport is subordinate in comparison to the private car on longer distances. The question arises, which options exist for improving the long-distance rail system in comparison to the alternatives that highly depend on the use of fossil energy (i.e. airplane, coach and auto). In chapter 2, the main barriers to the attractiveness of rail were shortly summarized and discussed. In the following we will explain the specific German situation, which could also have impeding effects on the mode share of rail.

One main advantage of the railway system is its possibility of achieving high average travel speeds. In the last decades, many high speed rail systems have been realised in Europe. On mainlines, speeds of 200 kmph and above have become common in Germany and among Western European railways. This makes travel times very attractive compared to cars, especially on long distances. However, there are some constraints to travel speeds that prevent a comprehensive high-speed rail system in Germany.

Due to historical reasons, the German railway infrastructure is mainly a mixed traffic network, where passenger and freight trains share the same infrastructure. Therefore, differences between driving patterns of goods trains, local passenger trains and high speed passenger trains limit the network capacity. The infrastructure does not allow the unlimited use of the vehicles' speed capabilities throughout the network. Railway speeds are determined by several conditions: Firstly, there are natural parameters, such as the topography of a line. In mountainous areas, narrower curve radii only permit lower speeds than straight lines in the lowlands and widening them is laborious and costly. Secondly, there are several significant slopes that slow down traffic on mainlines in the network. Another limitation of train speeds results from technical requirements. By law, the speed of conventional railways[1] is limited to 160 kmph in Germany. Higher speeds are allowed only if specific technical guidelines are fulfilled. These are, for example, advanced train control systems, the absence of level crossings and barriers at stations to prevent accidents with passing trains. Some mainlines are equipped with these systems, however, large investments would be needed to reach this standard across the network.

Beside these infrastructural and topographical restrictions, organisational aspects should also be considered. As in most European countries, railway operations and infrastructure are organised separately from each other. The infrastructure is mainly owned by the federal government and operated by DB Netz AG, a successor of the former national railway. The main business of the infrastructure operator is selling network capacity to transport companies. A fee per kilometre, which depends on the infrastructure quality and the intended type of use, is charged for use of the network.

The German long-distance rail market is still strongly dominated by the state-owned incumbent DB Fernverkehr AG, also a successor of the former national railway. This company still holds more than 99% of the market share. In the last two decades, several new rail passenger transport providers tried to establish in the long-distance segment, however only one competitor could succeed in the market with three daily connections between Hamburg and Frankfurt. The quasi-monopolist market is characterized by high entrance barriers such as a need for investments in rolling stock and legal requirements. Due to these insecurities, investors are hesitant to fund new companies in the railroad market. Germany’s constitution allows the federal government to intervene in the long-distance-travel market. However this right has not yet been used and no legal regulation for long-distance rail transport has been made.

Finally, it is important to note that in 2013 the German long-distance coach market was liberalised. For this reason, another competing long-distance transport alternative has emerged. Coach travel is characterised by very low fares and thus highly attractive for younger people. All of these conditions and restrictions have to be kept in mind in the process of scenario design and assessments in the context of this study.

4. SCENARIOS

In this study we define a baseline scenario and three alternative railway improvement scenarios. In these scenarios, different network and market conditions are assumed for the forecast year 2030. The forecast year was chosen in accordance to the recently developed infrastructure planning framework and the Federal Traffic Forecast 2030, which formed the basis for this study.

In the following, all scenarios will be briefly introduced. As discussed in chapter 2 and 3, the alternative scenarios are focused on the hard measures (travel time and travel costs), since these measures were identified as being the most important for raising the attractiveness of the long-distance passenger railway system. The goal of the three alternative scenarios is to identify the maximum mode shift towards rail only by means of positive intra-railway system measures (*pull measures*), i.e. there are no measures defined that reduce the attractiveness of alternatives such as car or airplane (*push measures*).

Baseline Scenario

The baseline scenario corresponds to the mentioned current Federal Traffic Forecast and is defined as a "business-as-usual"-scenario with regard to rail attractiveness. Besides a slower increase in ticket costs compared to the past years and the completion of several infrastructure projects, no further measures are included to increase the attractiveness of the railway system.

Travel times scenario

In our first alternative scenario, we assume that network quality allows for speeds of at least 160 kmph, where local situations do not prohibit this. This can be reached by moderate infrastructure improvements, especially on rural mainlines, and a more stringent timetable design.

Furthermore, technical guidelines recommend scheduling about 10-12 % of the running time as buffer time for unplanned delays (Heister 2006). However, the Federal Traffic Forecast2030 assumes much higher buffer times on several lines in its underlying transport supply model. For analysing the potential of these reserves, we reduce the buffer times to 12% on all lines. Therefore, the travel time scenario is a combination of infrastructure development for slower speed network sections and a network-wide schedule speed-up.

Travel costs scenario

The second alternative scenario evaluates the effects of reduced travel costs. Pricing systems of rail, bus and airplane services in the long-distance travel market are generally very complex, but this is not the focus of the present study. For this reason, we needed a robust approach for defining average travel costs per kilometre. This input variable was calculated roughly by dividing the total revenue of DB Fernverkehr, as published in their annual report (DB Fernverkehr 2015), by the total passenger-distance. This resulted in an average price of 0.129 Euro per kilometre.

In an extensive analysis, several main components of this average price could be identified: These are primarily infrastructure and energy costs and governmental duties Value Added Tax (VAT) and energy duties. Additionally, the price consists of a block of operational compounds such as labour expenditures, costs of materials, write-off and other costs. This block remains out of the scope of our study. The identified components of the customer price are illustrated in Figure 2.

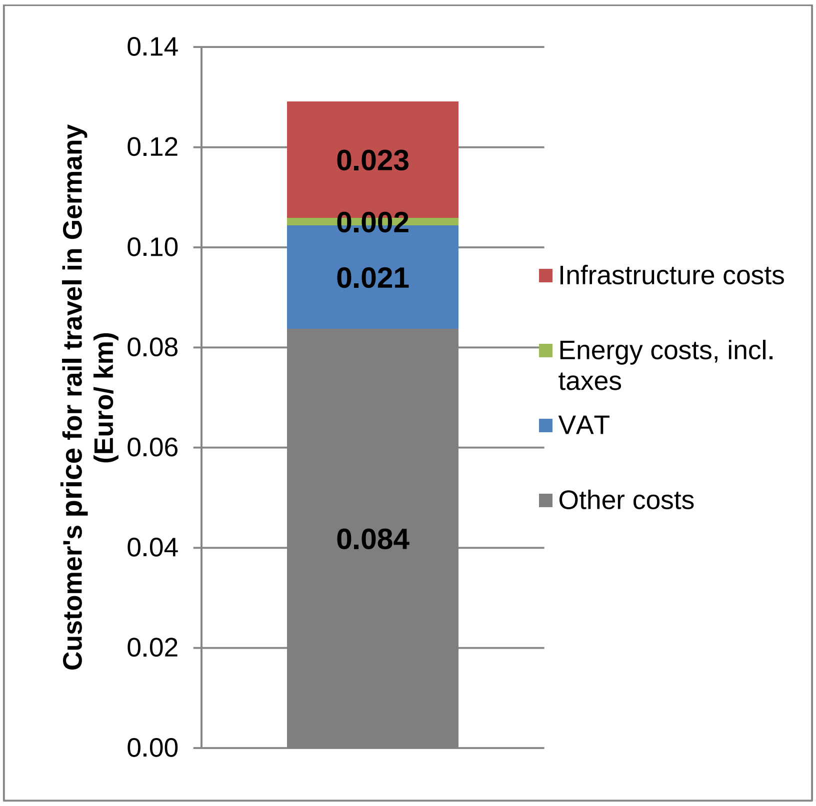

Figure 2: Components of customer's price for rail travel in Germany, Euro/ km

VAT and energy taxes can be influenced by governmental decisions. This makes them a possible field of action to achieve governmental goals.

In Germany, there is a twofold taxation of transport services. Public transport on distances below 50 km is valued like a basic need and therefore charged at a reduced VAT rate of 7%. Services on distances higher than 50 km are charged at the standard VAT rate of 19%. In contrast to this high tax rate in Germany, other European countries charge rail travel at lower rates. Denmark, Ireland and the UK exempt public transport as a whole from VAT.

The second main suggestion is a reduction of energy taxes. Today in Germany, there is a tax on electrical energy and a surcharge to finance the implementation of renewable energy. We suggest an exemption from both duties for train haulage energy. Compared to other countries in the EU, energy duties are exceptionally high in Germany. Although there is a reduction for rail transport, taxes still account for a not negligible amount of the customer's price.

Another proposal is a change in infrastructure financing. In the public discussion, a change back to a state-funded infrastructure is proposed. According to

EU regulations, access to the railway network must be provided free of discrimination and fees must be charged for using the network. However, there is a certain degree of freedom for the member states. There are several suggestions in Germany on how to implement a reduction of the infrastructure costs. We assumed that given some political will, it could be possible to reduce the infrastructure costs to half the value of today.

In the second scenario, we assumed the implementation of the following three actions:

- exemption of passenger rail travel from VAT
- exemption of electrical energy for traction current from the energy tax and the national surcharge for renewable energy
- change in the infrastructure funding

Under these assumptions, the average price per km decreases from 12.9 to 9.5 euro cents.

Maximum Scenario

Our third alternative scenario combines the two scenarios explained above. The main purpose of this highly optimistic scenario is to give an upper limit to the possible potential of political actions to raise the railway's attractiveness under the condition of using only *pull measures*.

5. QUANTIFYING THE IMPACTS

The use of transport and emission models is required to estimate the impacts of scenario-specific measures. These models are very complex and it is not possible to discuss them here in detail. However, a brief overview follows and could be helpful for understanding the general approach.

5.1 Transport Demand Model and Results

There are many different approaches to modelling the modal shift in long-distance trips within Germany. Most of the relevant concepts require a large amount of input data and its collection would have been too extensive for the discussed study. A different approach using a pivot-point model was devised.

In 2014 the Federal Traffic Forecast of Germany, commissioned by BMVI, was updated to the year 2030. The forecast is used for the government's current medium- and long-term infrastructure investment strategy. This transport demand data could be used as a basis for this study and describe mode- and purpose-specific origin-destination matrices for 412 traffic zones, which correspond exactly to the NUTS3 entities in Germany (as at 31 December 2010). In the study presented here only origin-destination-pairs with distance over 100 km were considered.

Calculating shifts between long-distance modes for different scenarios requires a mode choice model. In the course of updating the travel demand forecast to 2030 a value of time study was carried out for German travellers (Axhausen et al. 2014). The study provides a choice model that can be used for estimating mode shifts due to changes in different decision influencing variables such as travel time, travel cost etc.

These both data sets are the basis of the pivot-point model, which is used in this study. It uses the given trips of the forecast matrices as the starting points (base case) and the choice model provides the preferences of an incremental logit (Ortúzar and Willumsen 2011).

The calculation of scenario-specific mode shifts for long-distance travel within Germany is differentiated by the following modes and purposes:

Table 2: Mode and purpose differentiation

Modes	**Purposes**
Rail	Work
Coach	Education
Auto	Shopping
Air	Business
	Holiday
	Others

The application of the model shows that the measures implemented in the scenarios generate an effect on the travel demand. The changes of transport performances and corresponding mode shares are illustrated in Figure 3.

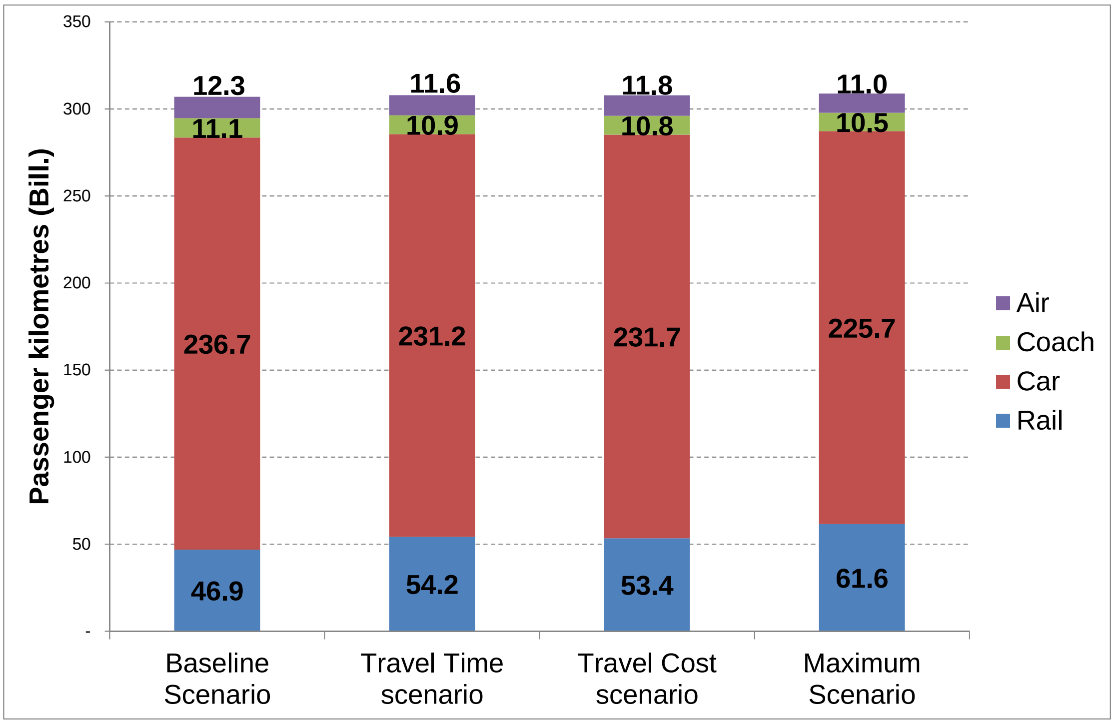

Figure 3: transport performances

Rail travel gains market share in all three alternative scenarios. As shown, the mode share of rail travel rises from 15% in the baseline scenario to 18% in the travel time scenario, 17% in the travel costs scenario and 20% in the combined scenario. Car mode share decreases from 77% to 75% in the first two alternative scenarios and to 73% in the combined scenario. Because of the smaller detour factor, the decrease in car passenger-distance is smaller than the increase of rail travel. Furthermore, a relatively small proportion of the passenger distance is actually shifted to rail transport. Car users appear to be the most sensitive customer group. This fact underlines that the main competitor of rail travel is the car and that the most effort should be made to attract car users.

5.2 Emissions Model and Results

Final energy consumption and CO_2 emissions[2] are calculated with the *TRansport Emission MODel TREMOD* (ifeu 2016). In TREMOD transport performance, energy consumptions, climate gas and air pollutant emissions of all motorized transport modes, including car, rail, public road transport and aviation in Germany are calculated in a time series from 1960 to 2014 and in scenarios up to 2050.

In this study, the baseline scenario for 2030 is based on the Federal Traffic Forecast and on the future development of the fleet composition and its characteristics. It includes assumptions on efficiency development, emission behaviour and usage patterns. The economic background is considered by making assumptions on future development of energy sources by type (power / fuel), origin (conventional or renewable generation) and characteristics (e.g. coal-oxygen content).

The final energy consumption and CO_2 emissions are calculated for all three alternative scenarios and the baseline scenario. The travel time and travel costs scenario generate an increase of long-distance rail travel demand of 2 and 3% respectively. The maximum scenario increases the modal share of rail by 5%. To calculate the emission and final energy consumption of the newly estimated long-distance rail demand, we supposed that one third of the additional demand would be served with longer trains. Furthermore, it was assumed that the other two thirds of the additional passenger distance can be served by the supply from the baseline scenario through a better use of the seating capacity. Therefore, the average seat-utilization (passenger-km per seat-km) increases from 51% in the baseline scenario to 57% in the travel time, to 56% in the travel cost and to 62% in the maximum scenario.

As illustrated above, transport demand is shifted to rail in the three alternative scenarios. This causes a decrease in transport demand of the other modes. Hence, final energy consumption and CO_2-emissions of these modes are reduced similarly. The results of the emission model are presented in Figure 4.

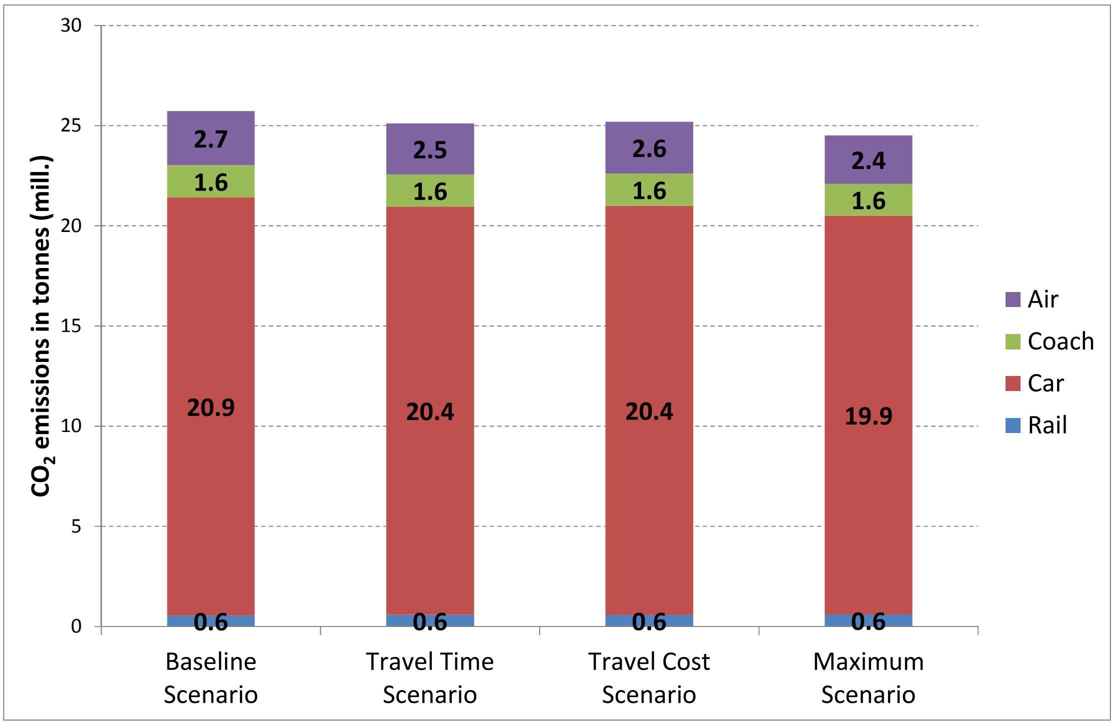

Figure 4: CO_2 emissions

The figure shows that CO_2 emissions caused by rail remain almost unchanged. While emissions of air and coach decrease slightly, car emissions decrease considerably. The reason for this is the more significant modal shift from car to rail. The total CO_2 emissions of long-distance travel in Germany decreases from 25.7 million tonnes to 25.1 (travel time scenario), to 25.2 (travel cost scenario) and to 24.5 (maximum scenario).

The results of the calculation of final energy consumption are shown in figure 5. It is obvious that changes are similar to CO_2 results. There is a small increase of final energy consumption of rail travel, but decreases for all other modes. Moreover, the total amount of final energy consumption decreases by up to 5% from 319 PJ to 304 PJ.

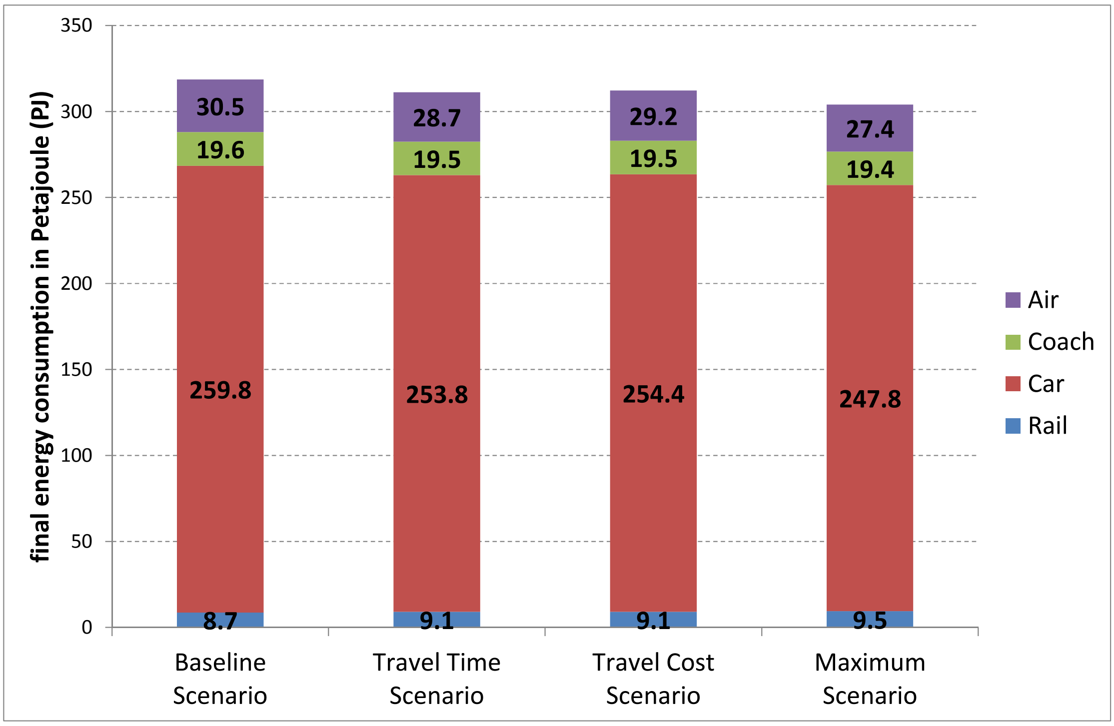

Figure 5: final energy consumption

Finally, it can be concluded that scenario-specific measures for attracting long-distance rail lead to slightly increased amount of emissions and energy consumption in the railway sector. However, the additional amount of emissions can be over-compensated by the decrease of emissions from the other modes. This leads to a decrease of the total amount of both CO_2 emissions and energy consumption in all three scenarios.

6. RECOMMENDATIONS FOR ACTIONS

One major goal of this study was to identify suitable actions for the government to promote the use of the railway system for long-distance journeys. For this reason, we evaluated different measures in three scenarios that might lead to an increase in rail use. These measures are part of two different fields of action – travel times and travel costs. It was shown that such measures have significant effects on modal shift. This section provides suggestions for measures by policy-makers.

Excluding rail services from VAT

A reduction of travel costs could be achieved if both chambers of the German parliament agreed on these measures. It will be mandatory to check whether the European jurisdiction allows these measures, as an exclusion from or reduction of VAT might be seen as a subsidy. However, examples from other European countries show that VAT reductions are tolerated by the European authorities. Today, the VAT rate for rail transport depends on the travelled distance, as government defines transport on distances below 50 km as a “basic need”. This historical differentiation is obsolete, as daily travel distances have increased especially in rural areas. To simplify the tax system and to set an incentive for rail use, we suggest excluding the rail service from VAT. This follows the example of the UK, Denmark and Ireland. In many other EU countries, public transport is charged a reduced VAT rate regardless of the travelled distance (European Commission 2016).

Reducing energy tax for rail services

Another suitable measure is the reduction of energy tax. Energy tax is basically a steering tax to encourage the use of sustainable energy. The emissions model shows that a modal shift to rail supports the overall reduction of CO_2 emissions. A further reduction or exemption of energy taxes for rail transport can support this intention.

Further railway infrastructure investments

The implementation of measures for accelerating rail travel will take a longer time. Infrastructure planning is a long-term process: In 2016, the federal infrastructure planning framework for the year 2030 was released by the federal government. The assumptions in our travel time and combined scenarios go even further than this. Their implementation could be a goal for after 2030, given the necessary financial possibilities.

Reducing the attractiveness of competitive modes of transport

The transport model results show that the effects on the modal split in all alternative scenarios remain at a limited extent. Reasons are on the one hand that only long-distance travel within Germany was considered and on the other hand that the presented study was limited to measures with direct effects on the railway system (*pull measures*). To achieve a higher impact on the modal split, we recommend measures with effects on the other modes. When reducing the railway costs, an accompanying increase of the car and airplane travel costs might strengthen the effects and lead to a greater modal shift. Actions on the identified soft and complementary barriers might also further influence the mode share of long-distance rail transport.

7. CONCLUSION

The main goal of this study was to evaluate measures to raise the attractiveness of long-distance rail transport in order to achieve a reduction of climate gas emissions and energy consumption in the transport sector. In accordance to the original goals of the study, only actions that take direct effect on the railway system were taken into account for the study. We developed three alternative scenarios, one focussing on travel times, one focussing on travel costs and one combining both fields of action.

The effects on transport demand were calculated using a transport model. An increase of about 4% in long-distance rail travel demand was the result. Subsequently, the applied emission model showed only moderate effects on energy consumption and climate gas emissions. Eventually, and as expected, the considered measures and their effects alone are not sufficient to fulfil the national energy strategy.

Finally, it has to be stated that all energy consuming sectors have to contribute to reach the ambitious goals of the German government. This also applies to the transport sector where long-distance travel is responsible for a high proportion of transport performance. The measures and actions discussed in this paper could be a part of a sustainable development of the transport sector.

NOTES

[1] "Conventional" refers to lines other than the designated high-speed (ICE) network

[2] CO_2-emissions are calculated as Well-to-Wheel (WtW) values, which include all emissions from energy supply and vehicle operation.

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