Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 4 (2014) 461 – 471

Transportation Research Procedia

www.elsevier.com/locate/procedia

Mobil. TUM 2014 "Sustainable Mobility in Metropolitan Regions", May 19-20, 2014

Promotion of Pedelecs as a Means to Foster Low-Carbon Mobility: Scenarios for the German city of Wuppertal

Frederic Rudolph [a] *

[a] *Wuppertal Institute for Climate, Environment and Energy, 42103 Wuppertal, Germany*

Abstract

The paper examines policies and measures that promote the usage of pedelecs and that contribute to climate friendly passenger transportation thereby. As pedelecs allow the rider to pedal at lower efforts, pedelecs provide the potential to increase the share of bicycle trips in metropolitan regions with hilly landscapes and with a significant share of medium commuting distances. The paper develops attitude-based mobility types and defines their specific pedelec affinity based upon differentiated reasons to use a pedelec. Thereafter policies and measures are examined that foster purchase and usage of pedelecs, and factors influencing the modal behaviour of (potential) attitude-based target groups are defined. Quantification of climate protection effects is conducted based on two scenarios for the German city of Wuppertal, a city known for its steep slopes. The first scenario assumes business as usual, and the second scenario is based on the introduction of ambitious policies and measures to encourage purchase and usage of pedelecs. Following a mixed-method approach, qualitative scenario assumptions are calculated by a quantitative model, which incorporates the analyses on attitude-based mobility types respective pedelec affinities.The results indicate that ambitious promotion of pedelecs significantly contributes to climate change mitigation. Compared to business as usual, ambitious policies and measures to purchase and use pedelecs reduce CO2-emissions of passenger transport in Wuppertal by 11 per cent in 2050. A spatially inclusive and comprehensive 30 kph speed limit proves to be particularly effective. In the scenario of ambitious promotion of pedelecs, interventions solely fostering the purchase of pedelecs significantly increase the modal share of pedelecs, whereas in a business as usual case such efforts remain ineffective. The traditional bicycle profits from the promotion of pedelecs, but its increased usage does not bring about similar climate protection effects.

Selection and peer-review under responsibility of Technische Universität München

Keywords: Pedelecs; modal behaviour; climate protection; policies and measures; attitude-based mobility types

* Corresponding author. Tel.: +49-202-2492-230; fax: +49-202-2492-263.
E-mail address: frederic.rudolph@wupperinst.org

Selection and peer-review under responsibility of Technische Universität München
doi:10.1016/j.trpro.2014.11.035

1. Introduction

Sales of pedelecs are continuously increasing in Germany since 2005. In the year of 2012, there have been around 400.000 sales. Compared to the four million sales of bicycles per year, every tenth bicycle was equipped with an electric motor in 2012 (ZIV 2012). More than 95% of all sales of electric bikes are pedelecs which achieve speed through a combination of electric power and muscularity (ibid.).

Pedelecs facilitate cycling through this combination and are of special interest for elderly and for people living in areas with mountainous topography (Puhe and Schippl 2010, p. 49). Pedelec users can move across longer distances more easily and quickly, therefore pedelecs might also be of relevance for daily commuters: almost 45% of the daily commuting distances in Germany are between five and twenty-five kilometres (infas and DLR 2010), i.e. a distance that can be bridged by bike. With these attributes, pedelecs have the potential to become an important transport mode in climate friendly urban transport.

Against this background, the paper discusses the question ‘which contribution in terms of CO2 emission reduction can be realised to achieve climate friendly mobility through the support of pedelec usage?’. The paper begins with constructing attitude-based mobility types and defines their specific pedelec affinity. Thereafter, the paper explores policies and measures to foster purchase and usage of pedelecs, and develops factors influencing the modal behaviour of (potential) attitude-based target groups.

The quantification of resulting climate protection effects is based on two scenarios for the German city of Wuppertal, a city known for its steep slopes. The first scenario assumes business as usual, and the second scenario is based on the introduction of ambitious policies and measures to encourage purchase and usage of pedelecs. Scenario development is supported by transport demand modelling, incorporating the analyses on attitude-based mobility types and pedelec affinities.

2. Material and methods

This paper defines target groups for pedelec usage as attitude-based mobility types who have certain symbolic-emotional affinities to traditional transport modes (car, public transport, bike) and who consider to purchase and use a pedelec as a result of their priorities and affinities. Hence, people may upgrade their mobility portfolio as the pedelec enters the market.

In the period between April 2011 and February 2012, a survey was conducted questioning 231 German residents with access to a private pedelec. The survey had the aim to identify the effects of mobility attitudes and values on purchase and usage of pedelecs and thereby to understand actual user behaviour patterns, such as trip purposes and distances covered. Moreover, the survey questioned requirements of daily life and their ramifications for pedelec usage. As the population of pedelec users in Germany is unknown, the survey’s representativeness could not be examined. However, significant mobility parametres correspond with numbers of representative German panel studies. According to the survey, the medial pedelec user is older than German average (52 years). This is in line with judgements of relevant experts that have been interviewed in the scope of this study (see below for the discussion of expert selection). As many pedelec users who contributed to the survey are retired, the average number of daily trips surveyed (3.0) is lower than the average number of German inhabitants (3.4, infas and DLR 2010).

The pedelec users were differentiated along symbolic-emotional dimensions (autonomy, privateness, experience and status, see next chapter) and their corresponding distinctness (Hunecke 2000, Hunecke 2006). Basis for the own classification of types were existing typologies in Germany (Boltze et al. 2002, Götz 2007, Hunecke 2006, Hunecke and Haustein 2007, Hunecke et al. 2008). Each mobility type has general attitudes and mobility preferences as well as specific requirements for the purchase and usage of pedelecs.

Mobile persons decide for a mode by considering the trip purpose and the existing local circumstances for transport and mobility. Such circumstances are travel money and travel time budget, comfort and traffic safety. Each mobility type has specific priorities because of specific mobility attitudes, and therefore his/her utility of travel time and travel money, comfort and traffic safety differs. According to the individual utility, a mobility type may prefer the pedelec over alternative modes for certain trips.

Policies and measures to foster the pedelec may affect these circumstances (travel money budget, travel time budget, comfort, safety) and consequentially shape the modal choice of the respective mobility type. Moreover, if addressing the symbolic-emotional dimension of mobility, policies and measures may also be able to influence the affinities of mobility types and in consequence influence the modal choice.

This paper defines two policy scenarios for the case of the German city of Wuppertal:

- A ‘business as usual’ (BAU) and
- a scenario, which assumes strategic and ambitious promotion of purchase and usage of pedelec (‘Pedelec Promotion scenario’).

The policies and measures which are presumed in the scenarios were elaborated by conducting interviews with 18 experts in the field of pedelec promotion. The experts were selected via snowballing. They represent different professional fields with different perspectives on pedelec usage and pedelec promotion: Politics, administration, associations, manufacturers, commerce, media, and academia. The experts were asked to name potential policies/measures and to discuss corresponding modes of action.

The model used to calculate the scenario results is based on the traditional sequential four-step model procedure of urban transportation planning, which computes trip generation, trip distribution, modal choice and route assignment. In the model used for this paper, trip generation is determined by the number of inhabitants and the average number of trips demanded per inhabitant in each of the 332 zones of Wuppertal. Additionally, the model accounts for commuters’ trips by including trips with origin or destination outside Wuppertal. Trip distribution is based on a gravity model function distinguishing different trip purposes. Hence, the interaction between an origin and a destination zone declines with increasing distance between them, but is positively associated with the amount of correlated structural data.

In computing trip generation and trip distribution, the model generates information about the above mentioned motifs of modal behaviour: travel time budget, travel money budget, comfort and traffic safety. Travel time is drived by the trip’s length, travel money is derived by considerung fuel consumption and commercial control over car parking space in the destination zone. Comfort is considered by taking into account the parking conditions for pedelecs at destination (i.e. whether it is theft-proof at ground level) and by considering upward slopes for each of the approx. 1.5 mio. daily trips with origin or destination in Wuppertal. Traffic safety is assessed by taking into account the infrastructural conditions of main routes in Wuppertal (bicycle tracks, safety at crossroads areas).

The typology of attitude-based mobility types in Germany was translated for Wuppertal by analysing a household survey in Wuppertal. This representative household survey, which had been conducted on behalf of the city of Wuppertal (Hoppe and Woschei 2012), included questions about attitudes, allowing to estimate mobility types’ distribution.

Based on the mobility types’ priorities and affinities, and distribution in Wuppertal, the scenarios assume a modal choice of the mobile persons in Wuppertal as a reaction on the respective policies and measures to be introduced. The method to determine the respective modal choice is a combination of pairwise comparison and verbal-qualitative argumentation about mobility type’s priorities w.r.t. the motifs: travel time and travel money budget, comfort and traffic safety (see Fig. 1). The concrete procedure to estimate the effects of the policies and measures on modal choice is as follows (see Rudolph 2014 for details):

- Based on the survey’s results, a modal share is defined, which may be attained under ideal local conditions for pedelec usage and which is differentiated along mobility types, trip purposes and distances.
- Values are given for travel time, travel price, comfort and safety. The respective value of the pedelec is compared with the corresponding value of private car, public transport and traditional bike.
- Weighting factors for travel time, travel price, comfort and safety are assigned to each mobilty type (see next chapter).

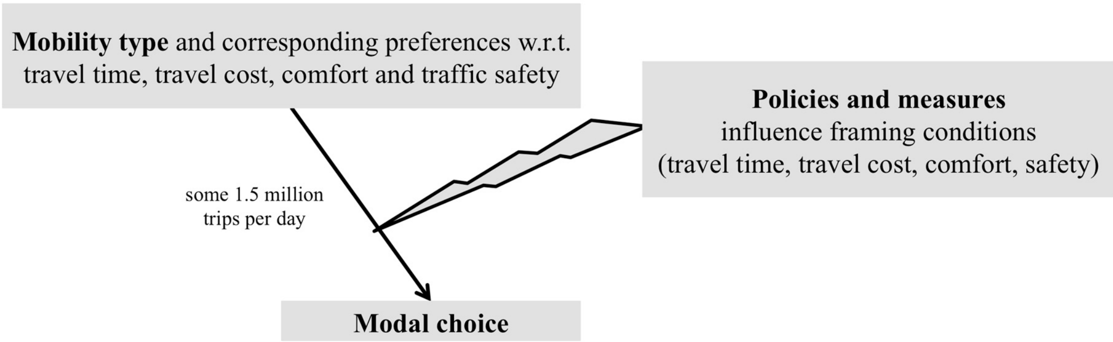

Fig. 1. Modal choice in the scenarios (own illustration).

3. Mobility Types and their Pedelec affinities

The affinity to purchase and use a pedelec differs along attitude-based mobility types. In applying the Theory of Planned Behaviour, which had been developed by Ajzen and Fishbein (1980), Hunecke (2000) could prove that considering the four symbolic-emotional dimensions: autonomy, privateness, experience and status significantly increases the ability to predict modal choice of individuals. The four dimensions have become the basis for the development of attitude-based mobility typologies under different conditions (Rudolph 2014).

'Status-conscious motorists' appreciate the car as a status symbol and have a tendency to feel unsecure in public transport and on the bicycle. They mainly use the pedelec for leisure trips and in case the cycle infrastructure is well developed, safe and if it provides comfortable, theft-proof parking space for the pedelec.

'Autonomic car enthusiasts' love to drive the private car. It serves as a symbol for self-determination and for individuality and they also appreciate its speed. This mobility type uses the pedelec very frequently, often for commuting purposes. The distances covered by pedelec often exceed 15 km. Obviously, autonomic car enthusiasts feel the pleasure of speed and self-determination not only when driving a car, but also when riding a pedelec.

'Adherents of public transport' prefer the public transport over the pedelec, whereas they do not have a symbolic-emotional affinity towards the car. These people purchase and use a pedelec only in exceptional cases, for instance if the local public transport does not provide appropriate service for certain often travelled connections.

'Bicycle fans' evaluate the symbolic dimensions of the car (status and self-dertermination) negatively. They prefer the bicycle over the public transport even if the latter provides a fast and well frequented connection. The pedelec might be their third or fourth bicycle and it might be used for certain specific reasons such as hilly landscapes or fading physical capabilities. The pedelec might also simply complete the own fleet.

'Self-determined, multimodal persons' perceive only little necessity to have a car. Public transport is used frequently or at least perceived as a viable option. Mobility as a whole is recognised as a means to an end. This types uses the pedelec for all trip purposes except transport of persons. Often, they use the pedelec for commuting and for shopping trips. In many cases, distances covered by pedelec exceed 10 kilometres per trip.

Quite similar, 'individual transport prefering persons' perceive the car not to be an imperative purchase, neither do they have emotions towards the car. In contrast to self-determined, multimodal persons this type evaluates public transport as a mode which cannot appropriately fulfil ther mobility requirements. The pedelec is therefore a viable option to be used, as it is fast and cheaper than the car.

'Car-dependent mobile persons' are of the mind that the private car is an indispensable part of daily life. These people purchase a pedelec to reduce the dependency of the car, as they realise that a number of trips (commuting at good weather, obtaining supplies) can be replaced by the pedelec, thereby reducing travel cost.

Table 1 summarises the mobility types' emphases of mobility by pedelec. The share of the respective mobility type as indicated in the left column has been analysed for the city of Wuppertal. The figures on mobility behaviour indicated in the right column reflect the above mentioned modeling procedure and the quantitative scenario assumptions.

Table 1. Mobility types and modal behaviour (Rudolph 2014).

Mobility type	Motifs for using the pedelec
Status oriented motorists (10% in Wuppertal)	Little pedelec-affinity (3% of pedelec users, little usage), as the car is prefered even under favorable conditions for the pedelec. If traffic safety and parking comfort are provided, than this moderatly increases pedelec usage (safety 75%, comfort 25%).
Autonomic car enthusiasts (15% in Wuppertal)	High pedelec-affinity (14% of pedelec users, high usage). Usage for long distances (commuting up to one third of trips depending on distance). Travel time is a crucial motif for modal choice. Theft-proof parking of pedelecs increases usage as well (travel time 75%, comfort 25%).
Adherent of public transport (20% in Wuppertal)	Little pedelec-affinity (5% of pedelec users, little usage). Compared with public transport, travel time benefits for frequently used trips must significantly be higher with pedelec, which might be the case for trips between 5 and 15 km (travel time 75%, safety 25%).
Bicycle fans (2% in Wuppertal)	High pedelec-affinity (14% of pedelec users, high usage). Most important criterion is faster traveling than with traditional bicycle, which is the case for trips farther than 2 km. However, the traditional bicycle remains important part of the mobility portfolio (travel time 67%, comfort 33%).
Self-determined, multimodal persons (13% in Wuppertal)	Medium pedelec-affinity (16% of pedelec users, medium usage). Travel time, travel money, comfort and traffic safety generally play an equal role with differences along the trip purposes. The pedelec is equally used for different purposes (25% weighting for each motif).
Individual transp. prefering persons (20% in Wuppertal)	High pedelec-affinity (12% of pedelec users, high usage). Travel money and travel time are crucial criteria, whereas traffic safety is merely considered (travel time 50%, travel price 40%, comfort 10%).
Car-dependent mobile persons (21% in Wuppertal)	Medium pedelec-affinity (36% of pedelec users, medium usage). Travel time is crucial. In case trip length is similar with car and pedelec, pedelec is prefered as it reduces travel cost. However, plenty of reasons may inhibit its usage, in particular theft-proof parking, traffic safety, weather and transport of goods/persons (travel time 40%, other motifs 20% each).

4. Mechanisms in the Promotion of Pedelecs

Modal choice is made up of two separate decision processes in sequence: Purchase of a specific vehicle or access to a specific system, and the frequency with which that vehicle or system is used for specific journeys.

Intervention to promote pedelecs can incentivise either their purchase or their use, or it can influence both decisions. Tax-based incentives, for example, are aimed at the purchase decision, whereas charging for parking mainly affects route choices. Each intervention has specific effects. Possibilities include shortening pedelec journey times relative to other transport modes, enhancing road safety and convenience, and inducing price signals that give pedelecs a further comparative advantage over cars. Finally, modal choice is also guided by attitudes. Depending on the target group, therefore, specific modal behaviour emerges in line with the conditions provided and can be influenced via policy instruments and measures.

Table 2 presents policy instruments/measures and their potential effect in promoting pedelecs. The right column shows the impact on factors driving modal choice from the perspective of pedelec users. These can relate to journey time, cost, convenience and safety or – as expressed in the words ‘pedelec affinities enhanced’ – can reflect the fact that people also have symbolic/emotional attitudes to mobility and that these can be positive towards pedelecs.

Table 2. Mechanisms in pedelec promotion (own compilation)

Type of intervention	Intervention examples	Effects on purchase and use of pedelecs
Organisational	Rental schemes, enterprise mobility management, sustainable procurement, combination with local transport	Enhance pedelec affinity, may cut journey times
Investment	Laying and upgrading paths and parking facilities, pedelec research and development	Cut journey times, improve convenience
Informational	Building awareness and acceptance, information, marketing ideas, road education, technical services	Enhance pedelec affinity, improve safety and convenience
Fiscal policy	Increase price of motorised private transport, charging for parking, equal tax treatment/tax incentives, purchase subsidies	Cut purchase, running and journey costs
Regulatory	(General) 30 kph speed limit, clear zones/green zones, safety requirements, requirements for parking facilities, standardised charging, separate vehicle class for pedelecs, ban on two-strokes	Cut pedelec journey times relative to motorised private transport, improve safety and convenience, enhance pedelec affinity

5. Scenarios for the Wuppertal Case Study

For the Wuppertal case study, the implementation of potential policy instruments and measures at city level is assumed in two scenarios and it is estimated how the city's modal split changes in each scenario. The first policy scenario assumes business as usual (BAU) with pedelecs not explicitly promoted. The second policy scenario shows the climate change mitigation potential achievable by means of a modal shift with active promotion of pedelecs especially at local level.

As mentioned above, for a discerning and consistent analysis of the effects of intervention, a transportation model is used applying a four-step algorithm. The simulation model incorporates some 1.5 million personal transport journeys a day starting and/or ending in Wuppertal,† with information on journey purpose, distance, inclines, parking situation at start and end point, and transport mode.

Wuppertal's city transportation infrastructure is car-centric. In the modal split, cycling (pedelec and bicycle) accounted for only 1.6 percent of all journeys in 2012 (see Fig. 2 and Hoppe and Woschei 2012, p. 31). This highlights the huge potential for boosting cycle use.

5.1. Scenario Assumptions

The BAU scenario assumes no more than piecemeal improvement in cycling infrastructure up to 2050, consisting of cycle lanes being marked out in roads and one-way streets being gradually made two-way for cycles. This is because the city's budget is scant and local policy makers are not willing to shift priorities towards cycling (Böhler-Baedeker et al. 2012).

The Pedelec Promotion scenario first assumes that a network of main cycle routes will be set up by 2020. It also assumes that the city will introduce snow clearing on all cycling infrastructure from 2015. It is further postulated that the speed of pedelecs and motorised private transport will be harmonised from 2030 by the introduction of a 30 kph speed limit across the city, including arterial roads, combined with a policy change in which the cut-out speed for the pedal assist on a pedelec classed as a bicycle is raised by the European Commission from 25 kph to 30 kph.

† Journeys involving vacation travel or air travel or spanning multiple days are not included.

As the city establishes favourable conditions for bicycle and pedelec usage, the level of bicyle sales in Wuppertal rises by 2030 and equals the German average of 2012. The share of the pedelec in 2030 amounts to 30% of all bicycles. This share is expected to be a long term potential of pedelec diffusion in Germany (Preißner et al. 2013).

Various fiscal incentives are additionally assumed to encourage pedelec purchase and use. The most important of these is abolition of the reduced rate of tax on the benefit from the use of a company car while introducing the same privilege for pedelecs by 2030. It is also assumed that combustion engined two-wheelers will be banned by that point and the use of pedelecs as an alternative will be the subject of a promotion campaign. However, these measures are only assumed to have a minor effect (up to 5 per additional demand), as experts free rider effects (own expert interviews).

The focus in the period from 2030 to 2050 in the Pedelec Promotion scenario is on improvements in the parking situation for pedelecs. As a result of policy instruments and private initiative, employers, schools, restaurants and shops will have special pedelec parking racks. As a result, lack of theft-proof parking at ground level is no longer a criterion to refrain from the pedelec.

It is also assumed that promotion campaigns and awareness building will continue for a range of target publics. Research suggests that such ‘soft’ measures may have an impact on mobility behaviour as complementing, reinforcing elements of infrastructural (‘hard’) measures (Bamberg et al. 2011, Richter et al. 2009). The Pedelec Promotion scenario therefore assumes that the share of mobility types having positive symbolic-emotional attitudes towards the car and public transport decreases by one per cent per year, whereas the share of ‘bicycle fans’ increases correspondingly. The mobility type’s share develops from 1.6 per cent in 2012 to 6.6 per cent in 2050.

5.2. Scenario Results

The transport demand simulations show that compared with the BAU scenario, the strategic, ambitious promotion of pedelecs results in pedelecs accounting for a significantly larger percentage of journeys starting and/or ending in Wuppertal. Conventional bicycles likewise benefit.

In the BAU scenario, the potential for bicycle mobility, with or without electric pedal assist, comes into play in response to the growing infrastructure and on journeys upwards of two kilometres. Bicycles and pedelecs consequently double their share of the modal mix from 1.6 percent in the 2012 base year to 3.2 percent in 2050. This share remains limited, however, because about one in four journeys are made on foot (25.8 percent) and about one in six by bus or rail (17.5 percent). Cars continue to account for just over half of all journeys in 2050 (53.5 percent). Both the bicycle and the pedelec thus remain only marginally utilised transport modes in the BAU scenario.

Looking at total travel, it emerges that even the relatively low level of activities to promote cycling in the BAU scenario has a minor climate change mitigation effect. The bicycle share of total kilometres travelled rises from 0.9 percent in 2012 to 2.2 percent in 2050, and the pedelec share from 0.0 percent to 0.9 percent.

This means, however, that the low level of cycling promotion in the BAU scenario falls short of ambitious climate change mitigation targets. Cars still account for 72.4 percent of all person-kilometres in 2050. This represents a 3.7 percent decrease in travel by motorised private transport relative to the 2012 base year.

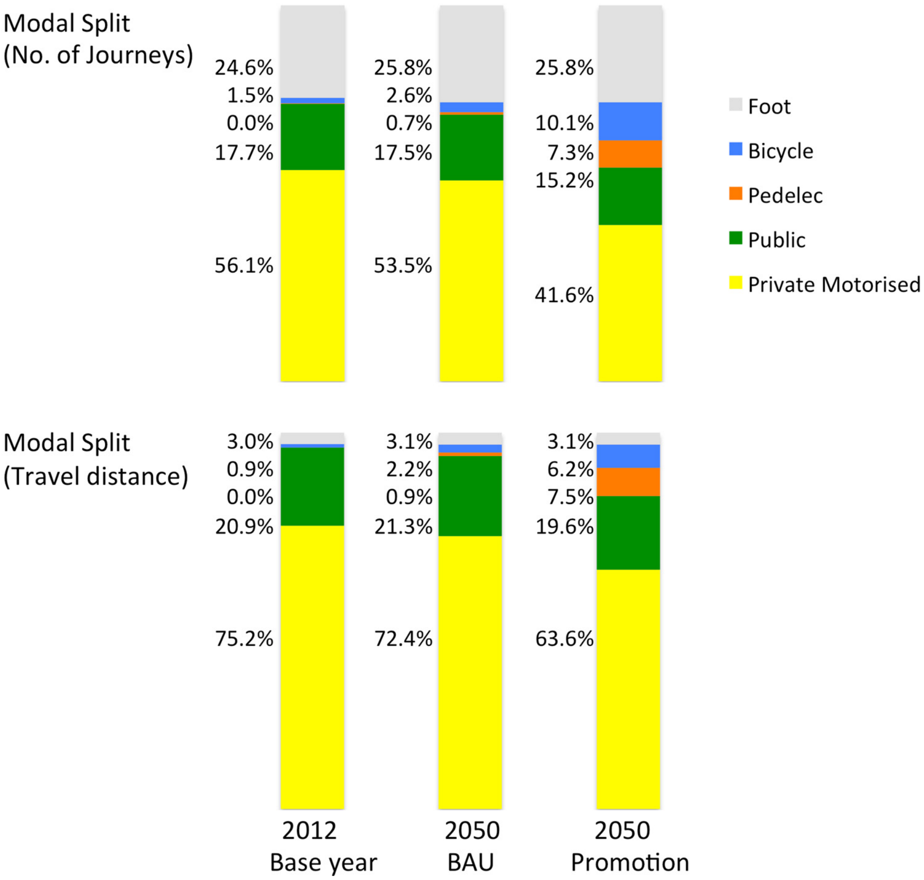

Fig. 2. Modal split in 2050 under the two scenarios (Rudolph 2014).

In the ambitious Pedelec Promotion scenario, the combined number of journeys travelled by bicycle and pedelec represents a 3.2 percent share of the modal split in 2020, which is already higher than the combined total for bicycles and pedelecs under the BAU scenario in 2050. This largely reflects the similar level of infrastructure development at the two points in time under the two different scenarios.

By 2050, the share accounted for by the bicycles and pedelecs increases to 17.4 percent of all journeys starting and/or ending in Wuppertal. Within this combined figure, bicycles, at 10.1 percent, overtake pedelecs, at 7.3 percent. In other words, even though the forms of intervention assumed in this scenario are ones explicitly intended to promote pedelecs, bicycles benefit most in terms of the share of the number of journeys.

This is mostly due to the larger number of bicycle owners. The pedelec ownership rate in the Pedelec Promotion scenario is only 35.2 percent, whereas all Wuppertal residents are assumed to have access to a bicycle. The 30 kph general speed limit, as a regulatory instrument affecting infrastructure, also benefits bicycles. A bicycle is not as fast as a pedelec and cannot compete with the convenience of one uphill. But as bicycles are less expensive to buy and few people choose to do without a car, when it comes to weighing the factors motivating modal choice, the pedelec has to match up to the benefits of bicycle and car as a combined package.

Given the high purchase price, pedelec owners also always face the issue of finding theft-proof parking. This is plain to see in the marked rise in pedelec use between 2030 and 2050. Not until 2050, when suitable pedelec parking facilities are assumed to be generally available in sufficient number, does the pedelec share of journeys reach the same order of magnitude as the bicycle.

The pedelec share of travel distance in person-kilometers, at 7.5 percent, is on a par with the pedelec share of journeys (7.3 percent), whereas bicycles account for a significantly smaller percentage of kilometres travelled than journeys (6.2 percent of person-kilometres versus 10.1 percent of journeys). Pedelecs therefore have a greater climate change mitigation effect than bicycles.

The percentage of travel distance and journeys accounted for by motorised private transport falls sharply in the Pedelec Promotion scenario, by 14.5 percentage points and 11.6 percentage points respectively. By contrast, the share of public transport remains relatively stable. This is a result of the mobility types' behaviour: 'Adherents of public transport' are less sensitive towards pedelecs than other mobility types.

Ambitious promotion of the pedelec can thus drive a sizeable modal shift. It goes without saying that a pedelec promotion strategy is not enough on its own to reverse the modal split entirely in favour of green choices. Additional push and pull strategies are needed to bring about any further shift. Even in the Pedelec Promotion scenario, motorised private transport, at 63.6 percent of all person-kilometres in 2050, still accounts for the majority of CO2 emissions from personal transportation in Wuppertal.

Fig. 3 illustrates the climate change mitigation effect of the activities assumed under the Pedelec Promotion scenario. The left and right bars show average per capita CO2 emissions in Wuppertal for 2012 and 2050. In total, annual per capita emissions from personal transportation in the city falls from 1.50t CO2 in 2012 to 0.46t CO2 in 2050 – a decrease of 1.04t CO2 or 69 percent. The Pedelec Promotion scenario sees CO2 emissions drop even more sharply in absolute figures, with emissions in 2050 some 75 percent down on the 2012 figure of 523,000t. This is because the population of Wuppertal is shrinking.

The three middle bars in the chart combine the mitigation impact of various forms of intervention and other factors under the headings of avoidance, shift and improvement. 'Improvement' takes in all vehicle-related changes, such as vehicle efficiency and fuel technology, and accounts for the largest contribution with a CO2 emission cut of 82 percent or 0.86t.‡ 'Shift' brings together the impact of all policy instruments and measures and delivers a reduction of 0.19t CO2 per capita or 19 percent. Under 'avoidance', additional journeys, most of all leisure-related journeys by older people, produce 0.01t CO2 per capita in additional emissions per capital compared with 2012 (an increase of one percent). The net outcome is an 11 percent reduction in CO2 emissions under the Pedelec Promotion scenario in 2050 compared with the BAU scenario.

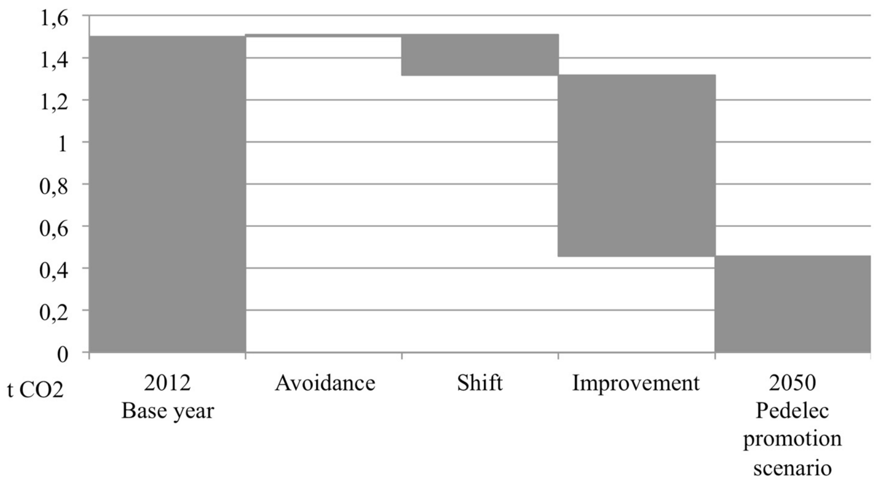

Fig. 3. Per capita CO_2 reductions in Pedelec promotion scenario (Rudolph 2014).

‡ The analysis here is largely based on the Tremod model (see Knörr 2011). The improvement heading includes emission reductions across all modes, including pedelecs. Even at today's fuel mix, pedelecs nonetheless come close to emission-free, at around 8 g CO_2/km.

Among the forms of intervention to promote pedelecs, infrastructure-related instruments have the largest modal shift and hence climate change mitigation impact. Creating a network of main cycling routes, which in Wuppertal specifically is achieved by following the valley axis, harmonising the speeds of motorised private transport and pedelecs by introducing a standard speed of 30 kph within city limits (i.e. a general 30 kph speed limit) and the provision of parking facilities suitable for pedelecs outweigh the impact of the other instruments and measures several times over. Harmonising the speeds of motorised private transport and pedelec has the biggest impact, accounting for 65 percent of the modal shift. The main cycle route network contributes 14 percent and providing pedelec parking facilities yields 12 percent.

Forms of intervention that solely increase the pedelec purchase rate have only a small impact, with the combined effect of fiscal incentives, banning combustion engined two-wheelers and promotion campaigns accounting for only six percent of the modal shift. There are two reasons for this. Firstly, none of these activities results in a complete change in price structure relative to competing modes. Secondly, people who do not purchase a pedelec can still benefit from the infrastructure-related instruments if they use a conventional bicycle instead. Use of a bicycle likewise has the effect of reducing emissions.

In addition to the instruments and measures referred to in section 4, the ‘shift’ heading (Fig. 3) also includes the impact of external factors. These comprise peak oil, climate change per se, and the trend towards multimodal transport. Phases of very high fuel prices and the future decrease in the number of days with frost or rain operate in favour of the pedelec overall and hence indirectly in favour of climate change mitigation. A trend towards multimodal transport, at least in Wuppertal, results in a slight rise in greenhouse gas emissions as many people today choose the monomodal and climate-friendly option of public transport. The net effect of these external factors is positive, however, with about two percent of the total modal shift.

6. Conclusions

The technological advance represented by the pedelec over the bicycle is not a climate policy no-brainer, but needs to be actively exploited by policy choices for climate change mitigation. Policymakers have at their disposal a selection of effective instruments and measures for the promotion of pedelecs.

Infrastructure-related activities lay the basis for success. A general 30 kph speed limit, including on arterial roads, turns out to be especially effective as it equalises motorised private transport and pedelec journey times and enhances cycling safety.

By promoting pedelecs, cities can tip the balance of emissions in personal transport and hence become less dependent on waiting for improvements in car technology, which are determined by automotive industry decisions and at higher policy levels.

References

Ajzen, I., Fishbein, M. (1980) *Understanding attitudes and predicting social behavior.* Englewood Cliffs, NJ: Prentice Hall.

Bamberg, S. et al. (2011) Behaviour theory and soft transport policy measures, *Transport Policy* 18 (2011), 228–235.

Boeler-Baedeker, S. et al. (2013) Strategien zur Stärkung des Radverkehrs unter schwierigen Rahmenbedingungen. Analysen zu Hemmnissen und Potenzialen am Beispiel der Stadt Wuppertal, Wuppertal: Wuppertal Institut für Klima, Umwelt, Energie.

Boltze, M. et al. (2002) Grundlagen für die Beeinflussung des Verkehrsmittelwahlverhaltens durch Direktmarketing, Darmstadt: Technische Universität Darmstadt, Fachgebiet Verkehrsplanung und Verkehrstechnik.

Götz, K. (2007) Mobilitätsstile. In: Schöller, O., Weert, C., Knie, A., (eds.) Handbuch Verkehrspolitik. Wiesbaden: Verlag für Sozialwissenschaften, p. 759–784.

Hoppe, R., Woschei, K. (2012) Verkehrsbefragung 2011 Stadt Wuppertal, Köln: Planungsgesellschaft Verkehr Köln.

Hunecke, M. (2000) Ökologische Verantwortung, Lebensstile und Umweltverhalten, Heidelberg: Asanger.

Hunecke, M. (2006) Zwischen Wollen und Müssen. Ansatzpunkte zur Veränderung der Verkehrsmittelnutzung. *Technikfolgenabschätzung – Theorie und Praxis*, 3 (15), p. 31–37.

Hunecke, M., Haustein, S. (2007) Einstellungsbasierte Mobilitätstypen: Eine integrierte Anwendung von multivariaten und inhaltsanalytischen Methoden der empirischen Sozialforschung zur Identifikation von Zielgruppen für eine nachhaltige Mobilität. *Umweltpsychologie*, 11 (2), p. 38–68.

Hunecke, M. et al. (2008) MOBILANZ - Möglichkeiten zur Reduzierung des Energieverbrauches und der Stoffströme unterschiedlicher Mobilitätsstile durch zielgruppenspezifische Mobilitätsdienstleistungen, Bochum/Lüneburg/Wuppertal.

Infas, DLR (2010) Mobilität in Deutschland 2008. Tabellenband, Bonn und Berlin.
Knörr, W. (2011) Aktualisierung "Daten- und Rechenmodell: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2030" (TREMOD, Version 5.2) für die Emissionsberichtserstattung 2012 (Berichtsperiode 1990-2010), Heidelberg: ifeu.
Preißner, C., Kemming, H., Wittowsky, D. (2013) Einstellungsorientierte Akzeptanzanalyse zur Elektromobilität im Fahrradverkehr, Dortmund: Institut für Landes- und Stadtentwicklungsforschung gGmbH.
Puhe, M., Schippl, J. (2010) Urban Transport. Interim Report – Phase II, Karlsruhe: European Technology Assessment Group.
Richter, J., Friman, M., Gärling, T. (2009) Soft transport policy measures 1: Results of implementations, Karlstad: Karlstad University Studies.
Rudolph, F. (2014) Klimafreundliche Mobilität durch Förderung von Pedelecs. Lokale Langfristszenarien über die Wirkung von Instrumenten und Maßnahmen am Beispiel der Stadt Wuppertal. Wuppertal: Bergische Universität Wuppertal.
ZIV (2012) Radfahren weiter im Trend. Information des ZIV zum 1. Halbjahr 2012, Bad Soden: ZIV.