

The Effectiveness of Strategies to Reduce External Costs from Commuting in Central Europe

Silvio Nocera(✉) and Francesco Bruzzone

IUAV, University of Venice, Santa Croce, 191 – I, 30135 Venice, Italy
nocera@iuav.it

Abstract. Transportation is a major source of both primary pollution and greenhouse gas emissions, and has been hence frequently the object of past analyses at several levels. This paper examines the outcomes of numerous previous strategies that dealt with one or more of the multiple dimensions of commuting (green technologies, transport management, urban planning and behavior changes etc.) to check their results, and to introduce the first outcomes of the European project SMART-COMMUTING. The core of the paper is the accurate description of such strategies, including the estimation of the emission ranges under different modal scenarios in the different locations. The discussion regards on the other hand their efficiency to reduce the external costs of commuting, with the aim of offering transport planners, stakeholders and policy makers a way of substantiating their future strategies about commuting.

Keywords: Transport external costs · Smart commuting · Emission reduction

1 Introduction

The transport sector is responsible for around 65% of global oil consumption and for around 25% of global Greenhouse Gas emissions [1–4]. Furthermore, road transportation accounts for between half and three-quarters of total emissions from the transport sector (depending on the study area), and its impact could be even greater in urban areas [5]. Considered the increasing urbanization trend [6] and taken into account that the worldwide number of automobiles is forecasted to triple by 2050 [7], effects such as air pollution, noise pollution, congestion and accidents are destined to increase. It is therefore evident that a strategy to tackle the tendency towards increasing energy consumption and emissions is needed.

Both academic and political institutions have in fact started to extensively address the transportation emission issue and have come up with several different goals, strategies and policy options to reduce GHG emissions from the transport sector. Strategies include mobility management, which reduces traffic volumes through a variety of measures, clean vehicle strategies, which reduces energy consumption and emissions per kilometer through technical improvements [8], and others which focus on land use planning and more in general on the built environment [3]. Commuting, thanks to its regular pattern, its close connection with congestion problems, and its

© Springer Nature Switzerland AG 2019
S. Misra et al. (Eds.): ICCSA 2019, LNCS 11620, pp. 105–119, 2019.
https://doi.org/10.1007/978-3-030-24296-1_11

association with people's choices about locations of work and housing, has long been an important target of transport policy and urban planning [9].

The European Commission has as well developed an Energy, Climate and Environment strategy, and has included the reduction of GHG emissions from the transport sector as part of its targets and strategies, reiterating its commitment to low-carbon transport in 2011 [10] and thus launching several different projects, among which Smart Commuting, part of the Interreg Central Europe program. The Smart Commuting Project aims at improving mobility planning capability in participating functional urban areas with the goal of cooperating in the development of a low-carbon strategy to lower CO_2 emissions from the transport sector. Smart Commuting presents a transnational strategy containing different measures, among which the different project partners (municipalities) choose those which best match their needs and whose outcomes are best effective for the accomplishment of the project's goals [11].

This paper will first present the outcomes of several studied or implemented strategies, which dealt with the multiple dimensions of commuting (mobility management, technology improvements, land use planning, behavioral changes, etc.), and will then include the measures identified by Smart Commuting project's transnational strategy into possible external costs and GHG emission mitigations strategies, to estimate their effectiveness at lowering emissions and more in general external costs of commuting in different geographical contexts.

2 Commuting External Costs

Passenger transportation generates a number of negative externalities on the physical and social environment in which it takes place. It is well known that very often the most convenient transport option for individuals is by far not the best option for society, in terms of environmental sustainability as well as in terms of economic expenditure. According to Move [12] and Liew and Chu [13], external costs are generated by individuals, but borne by either the agency (government) or society. The external cost is the difference between total and private (internal) costs reflecting all costs occurring due to the provision and use of transport infrastructure, such as wear and tear costs of infrastructure, capital costs, congestion costs, accidents costs, environmental costs.

Various cities have started informing citizens about how much their choice to commute or move using motorized transport costs to society. The City of Vancouver (Canada), for example, has published and promoted some independent studies, which show how for an individual 1$ expenditure on buses society pays 1,50$, whereas for an individual 1$ expenditure on car transport society pays 9,20$. Active transportation on the contrary requires much smaller societal investments (lower than 0,10$ for each 1$ individually spent). Such figures are pretty much confirmed by Glazebrook [14] whose report stated that the "out-of-pocket" cost for car users in Sydney (Australia) was only about one-sixth of the total cost. If faced with full costs, motorists transport mode selection would therefore be different in many cases [13]. The external costs of transportation and of urban passenger transport specifically are studied by many different authors and institutions: congestion, air pollution, accidents and noise are the

main externalities on which all scholars and reports agree (among others [12, 15–19]). Besides the four cited external cost categories, others which are often considered in recent works are: climate change costs, costs of up- and downstream processes and marginal infrastructure costs. Maibach et al. [16] also include costs for nature and landscape preservation and rehabilitation, for soil and water pollution, and for energy dependency. Liew and Chu [13] interestingly include among external costs the category "government subsidies", both addressed to public and private transport.

Generally speaking, though, internalization and/or reduction of external costs of urban transport are themes which are not yet mastered by the general public despite their great impact on everyday life and on government expenditure. Scientific literature and governance and research institutions, on the contrary, have studied the topic extensively and have defined, estimated and evaluated both major external costs and their internalization or reduction strategies. It is however surprising to note that literature seems not to have concentrated on the specific aspect of the external costs generated by commuting, while the distinction between passenger and freight transport has been made. Commuting "rush-hours", in facts, are the moments in which transport infrastructure and services are mostly exploited and in which their residual capacity is put at risk. This aspect is well stressed by the general press (e.g. Business Insider [20]) but seems not to be part of scientific literature yet.

Rather than on internalization strategies, this paper concentrates on the reduction of external costs of commuting by acting on the factors which combined contribute to causing such costs (such as environmental quality, congestion, modal share, social equity and others). Reduction strategies and internalization strategies are clearly related as lowering or removing cost-causing factors erases the necessity to internalize such costs. It is however not completely true that externalities reduction strategies and cost internalization strategies always pursue the same objectives: whereas modal shift towards public transit is often considered a success for the first goal [21–24] – we will discuss this point further in this paper - for the second it might result in the intensification of some of the cost factors (typically, subsidies) even while soothing other negative effects such as for example congestion and air pollution.

3 External Cost Reductions Strategies: A Literature Review

Different authors have studied policy instruments aiming at reducing transport emissions in order to understand their effectiveness and/or have come up with strategies and instruments which could serve to achieve political and institutional strategies (such as emission reduction goals), or to tackle increasingly relevant issues such as congestion and pollution. In this section, we will review some examples of policy and strategies classification, simulation and outcomes, with the aim to identify a proper framework in which to place Smart Commuting Project's measures so to estimate their effectiveness in lowering GHG emissions.

Available research concentrates on three different types of mitigation options: some studies investigated the impact of urban design on emissions with varied results, but giving as a general assumption that urban planning policies by themselves yield modest

emission reductions. Other studies investigated the impact of using alternative technologies such as low carbon fuels, hybrid and electric vehicles, while incorporating life-cycle emissions. Travel demand management policies are the third relevant literature sector [25]. Scenario analysis has moreover been used to integrate the economic, technological and transportation demand changes that affect GHG emissions, thus combining the three abovementioned sectors [1]. In those cases, authors underline how acting through comprehensive strategies is more effective compared to concentrating on one sector only (either the built environment, vehicle technology or transport demand management). Hickman et al. [26], for instance, found that in the Oxfordshire area low emission vehicles and alternative fuels could reduce CO_2 emissions by 37,4% compared to a BAU scenario with a 2030 horizon, while the inclusion of other policy packages (such as driver education, different freight management and slower speed driving) could result in a 48,3% reduction over the same BAU level.

Regarding the planning sector, there is an ongoing debate on whether the most effective urban form to reduce emissions is a polycentric or a monocentric approach. While most authors agree on the fact that a compact city is more efficient compared to a sprawl situation, the mono-, dual-, or polycentrism of a city appears to respond differently to different study approaches and – above all – to different geographical contexts [3, 5, 9, 27–31]. Some of the authors also mention that urban development strategies should consider social geography and socioeconomic aspects, since they strongly affect people's commuting habits and choices [9, 32].

The debate on the effectiveness of the other two possible strategies, that is cleaner vehicle strategies and travel demand management strategies, has been carried on by most authors as either a comparison between scenarios ascribable to the two groups or as an integrated approach between policies from both strategies, seeking for the most effective combination. Still, some articles are available where the purpose is to establish whether cleaner vehicles strategies or travel demand management strategies are most effective (for instance [33]).

Findings related to cleaner technology implementation are not very homogeneous. Most authors agree when saying that cleaner vehicle technology by itself is not sufficient to achieve emissions reductions coherent with politically declared local and national targets, but while in some cases the role acknowledged to technology resulted in satisfying emission reduction gains [1, 34] in most cases it is only regarded as part of a much broader strategy and its standalone impacts are evaluated as not very significant (among others [8, 35]). It must moreover be noted that converting existing vehicle fleets to cleaner technologies (in developed countries) or using cleaner technologies for expanding vehicle fleets (in rising economies) does not tackle primary issues such as congestion and travel time, which will rather stay like they are or grow worse as a business-as-usual scenario, even with green vehicles substantially developing.

Some authors give evidence of the relevance of the role of active transportation. As part of an integrated strategy, walking and cycling – having a zero-emission level – are often keys to obtaining predetermined goals [1, 3, 34, 35] and are included in most of the articles on the topic of lowering emissions. Some other authors, however, given their particular contexts of study, assign to active transportation an even more relevant role in cutting emissions and identify the shift towards active transportation as being one of the most effective possibilities [36, 37].

After discussing in general terms the scholars' attitude and research orientations with regard to urban transport emission and energy consumption reductions, with a specific focus on commuting patterns, in the next section of this work we will try to identify an appropriate way to classify Smart Commuting project's measures and strategies so to evaluate their effectiveness. For this purpose, the works of Nakamura and Hayashi [38], (which refers to the CUTE project [39]), and the ones published by the German Agency for Technical Cooperation (*Deutsche Gesellschaft für Technische Zusammenarbeit* GTZ, [40–42]) provide a good classification framework, which when adapted reveals itself to be suitable to the various cities partner of Smart Commuting project as well to the different measures and strategies which are part of the project itself. GTZ in their works summarized the possible strategies towards a more sustainable urban transport system as AVOID (reducing unnecessary travel demand), SHIFT (shifting transport to low-carbon modes) or IMPROVE (improving intensity of transit-oriented emissions) strategies. Instruments are instead classified by Nakamura and Hayashi [38] as being related to technology, regulation, information or economy. The authors provided an overview of trends and effects of low-carbon measures for urban transport, in order to understand their feasibility and effectiveness and their affinity to CUTE project's strategies. The authors' conclusions indicate that cities pursuing AVOID and SHIFT strategies seem to prefer – them being more effective – first stage instruments, whereas more developed context aiming at IMPROVE strategies concentrate on later-stage strategies. They also underline how no generic strategy is valid for all cities: specific policy packages should be designed.

Starting from the instruments classification presented by Nakamura and Hayashi and integrating it with other available literature and with GTZ's results, we can divide Smart Commuting project's measures in five different categories: planning instruments, regulatory/governance instruments, economic instruments, information/ict instruments, vehicle/hardware technology instruments. Table 1 shows the categories to which each measure of Smart Commuting belongs.

We can then trace back every proposed measure of Smart Commuting project to a more general category of instruments (often referred to as "policy packages" in literature). This is because the specific effects and impacts of such policy packages have been to some extent discussed by scholars and it is therefore easier to investigate them with reference to Smart Commuting project's context. Sticking to policy instruments categories described by Hickman et al. [35] and Litman [33], measures part of Smart Commuting project can be more specifically framed into the following policy packages, as detailed in Table 2: 1-Public transport development, 2-Active commuting incentive, 3-Urban and strategic planning, 4-Ride-sharing growth and incentive, 5-Information Communication Technologies, 6-Behavioral interventions/education, 7- Technology advancements.

Table 1. Synthesis of the measures which are part of smart commuting project and allocation into measure categories

	Planning instruments	Regulatory and governance instruments	Economic instruments	Information and ICT instruments	Vehicle and hardware technology improvements
Incentive app for cycling				X	
Bike park roof	X				
Bus/tram stop roof and benches	X				
Pedestrian-friendly access to bus/tram stops	X				
Backside exit of railway stations	X				
New stations/stops	X				
Non profit car sharing		X		X	
Bike sharing (fixed station)	X	X		X	
Car pooling		X		X	
Electric vehicle charging spots	X				
Mutual learning		X		X	
Awareness raise in clean/active mobility				X	
Mobility education				X	
Participatory processes for strategy-building				X	
Mobility service points	X			X	
Mobility information portal				X	
Bike parks at schools	X				
Bike repair corners	X				
Teleworking incentives		X			
Companies' mobility plans	X			X	
Coordination between transit and workers' shifts	X	X			
Companies' employees car pooling				X	
Electric vehicle incentives			X		X
Workplaces relocations (closer to transit stops)	X		X		

Table 2. Allocation of measures into policy packages which are useful for a more clear discussion of their effectiveness

	1- Public transport development	2- Active commuting incentive	3- Urban and strategic planning	4- Ride share growth and incentive	5- Information communication technologies	6- Behavioral interventions and education	7- Technology advancements
Incentive app for cycling					X		
Bike park roof		X					
Bus/tram stop roof and benches	X						
Pedestrian-friendly access to bus/tram stops	X						
Backside exit of railway stations	X						
New stations/stops	X						
Non profit car sharing				X			
Bike sharing (fixed station)		X					
Car pooling				X			
Electric vehicle charging spots							X
Mutual learning						X	
Awareness raise in clean/active mobility						X	
Mobility education						X	
Participatory processes for strategy-building			X				
Mobility service points			X				
Mobility information portal					X		
Bike parks at schools		X					
Bike repair corners		X					
Teleworking incentives					X		
Companies' mobility plans			X				
Coordination between transit and workers' shifts	X						
Companies' employees car pooling				X			
Electric Vehicle incentives							X
Workplaces relocations (closer to transit stops)			X				

4 The Effectiveness of Smart Commuting Project's Externality Reduction Strategies

According with the above-mentioned policy packages, this paragraph describes which measures Smart Commuting project has identified for each package and brings evidences of how such measure could be effective at reducing impacts and external costs from commuting, particularly focusing on the geographical contexts of Smart Commuting project's partner cities.

Regarding policy package "1- Public transport development", the measures proposed by Smart Commuting project are: installation of shelters, benches and information displays at transit stops; access improvement to transit stops (for the elderly and the impaired especially); new exit for train stations (to improve accessibility); additional stop/station for transit services (to increase the number of potential users); fostering coordination between transit schedules and workers' shift hours; fostering coordination between transit service and school buses service. All of these measures have to do with accessibility and attractiveness of the public transit system, either strictly or in a broader sense; which is, improving accessibility through inclusion of disadvantages categories among potential users and by widening the basin of potential users; and improving attractiveness through stops and stations improvements (weather shelters, real-time information screens and seating) [11].

The identified and described measures are effective in reducing emissions and congestion from the transport sector in urban areas and specifically in the contexts of Smart Commuting Projects' partners, which are all mid- or small sized European cities, since – as it is highlighted in the project's Deliverable D.T1.2.1 "Transnational strategy to change commuting models in the FUAs" [11] - the provision of additional transport facilities within a certain radius from homes and job location strongly affects the willingness of people to make use of such facilities and to cover on foot the distance to reach them. All reviewed authors, when discussing transit as a modal choice, agreed that accessibility in terms of walking time and quality of the walking itinerary has a decisive role. There is some discussion on the exact distances and times that people are willing to walk as they are strongly affected by a variety of factors, including culture, climate, and other context-specific aspects. Cervero [43] finds that for distances over circa 1 km walking is not considered as an option to access transit by the majority of users. As Smart Commuting project's Deliverable D.T1.2.1 [11] underlines, in an unfriendly walking environment such distance is much lower. Taking into account 600 meters (10-minute walk) as a maximum accessibility radius for transportation facilities, it is evident how the provision of additional stops and stations in urban and peri-urban areas can effectively increase the number of potential transit users. Chien and Qin [44] also underline how the correct localization of transit stops can help in reducing the cost of providing transport service, thus tackling another of the external costs of commuting identified by scholars. Litman [45], moreover, values waiting areas improvements in terms of users' willingness to pay, finding that the improvement of users' waiting experience could lead to a 3,3% additional fare (incl. the installation of ticket vending machines, otherwise 2,4%).

Policy package two is centered on incentivizing and encouraging active commuting. The measures proposed by Smart Commuting project are the installation of shelters for bike parks, the implementation of a fixed-stall bike sharing system, the provision of bike parking facilities at schools, and the diffusion of bike repair corners. The diffusion of active transportation is by far the most effective strategy towards the reduction of emissions, congestion and externalities from transportation in general, including health costs and accidents costs ([9, 26, 34, 36, 37, 46] and others). Lindsay et al. [46] for example found that shifting to biking just 5% of New Zealand's annual vehicle kilometers would result in a total yearly saving of 200 millions NZ dollars. The issue, however, is that not every trip can be done by bike or on foot or that anyways not all users are willing to do so. The provision of a bike sharing system and other bike-incentive facilities, in the context of European mid-sized cities, can be effective in increasing the modal shift of biking. It must though be researched whether new bikers will be subtracted from private transportation or from public transit, which would still be effective but would consistently reduce the potentiality of the shift towards active modes. Mrkajic et al. [47] studied the provision of bike parking infrastructure at a university facility in Novi Sad, using EFC's [48] data to estimate emissions. They found that bike parking provision was effective in shifting students' commute to biking and estimated yearly CO_2 emissions savings as 1845,9kgs. Buehler [49] used chi-square tests and found that significantly more individuals commute by bike if employers provide cyclist showers, bike lockers, and bike parking. He also found that the share of bike commuters is greater in the urban core, at higher population densities, and in areas with more bike paths and lanes. Lastly, he stated that in the area of Washington, DC (USA) more individuals commute by bike during the warmer summer months. This is also found by other studies which deal with areas with rough winter climate (e.g. [37]) but could not be an issue of relevance in some of the cities which are part of Smart Commuting project, given the different environmental conditions.

Regarding policy package three, which focuses on urban and strategic planning, the measures proposed by Smart Commuting project are: the provision of mobility service points, the preparation of companies' mobility plans, the promotion of participatory processes among citizens for strategy building, incentives for workplaces relocations to gain higher public transit accessibility. Despite the four measures being very different from each other, they are all converging on the need of strategic location of attractors and on the need to plan public transit and urban development with an orientation towards operations sustainability. The idea here is again to increase transit availability and accessibility, through economic support for relocating workplaces at more acceptable and incentivizing distances from public transit facilities and through the facilitation of mobility usage thanks to the concentration of all mobility-related offers and services at strategic locations. Moreover, the project aims at involving the general public in mobility planning (public and private) so that strategies can be shared and can be perceived as part of everyone's identity. It is however hard to quantify benefits from measures such as those, given that they surely contribute to a general performance enhancement.

Policy package four insists on growth and incentive of ride sharing, proposing the implementation of a no-profit car sharing system (suitable for mid-sized towns) and the promotion of car pooling and of co-workers ride sharing (also through a specific online platform). The potential of car sharing and car pooling in terms of motorization rate

reduction is noticeable. According to Baptista et al. [50] one car-sharing vehicle takes the place of approximately six privately owned cars, leading to various advantages among which: lower consumption of physical and economic resources, contribution to the reduction of energy and environmental impacts, direct benefits from the changes on vehicle ownership and usage patterns, also meaning less congestion and less space usage. Privately operated free-floating car sharing, however, only works in densely populated cities. Such systems are not applicable to peripheral residential locations, where a significant fraction of long-distance commuters originates (see e.g. [51]). This is also true for concepts where sharing is a question of private coordination, such as peer-to-peer car sharing or ridesharing among coworkers or cohabitants [52]. Public input for car sharing in mid-sized cities is fundamental to grant the system's effectiveness and sustainability and could remedy to its natural economic characteristic of being suitable to high-density contexts only. A web platform for ride-sharing and car pooling could moreover allow this type of transport choice to broaden its appeal, making it able to compete with one of the greatest advantages of private car usage: immediate access to door-to-door transportation [53]. Literature shows that given that in the western world the vast majority of car trips are done by single individuals, with an average vehicle occupancy of just 1.3 [11, 54]. Ride-sharing could significantly contribute to traffic volume reduction, even when considering constraints such as people's unwillingness to sharing their commute with strangers and therefore limiting ride-sharing to friends, colleagues, or friends of friends [54]. In the context of Smart Commuting Project's partner cities, ride-sharing between co-workers or between acquaintances could produce relevant benefits.

Regarding policy package five (Information Communication Technologies), the measures proposed by Smart Commuting project are: the launch of a mobile app for cyclists (with an incentive mechanism), the creation of a comprehensive mobility service web portal, incentives to tele-working practices. Again, the measures are different from each other but all fall under the common "ICT" hat. In fact, this policy package inevitably has relations with many of the proposed measures as information communication technologies are gaining an increasingly relevant role in everyday commuting patterns and actions, from the choice of the best itinerary to better usage of travel time and economic resources, independently from the usage of private, public or shared means of transport. Mobility-as-a-service is becoming a commonly known concept. The integration – from a policy perspective as well as from a customer-oriented perspective – of all transport and mobility options has been proven to be a fundamental step towards the increase of attractiveness of alternatives to private motorized transport [55]. In this discourse fit some efforts which have been done to fully include private and shared bike mobility within cities' mobility offer, both in terms of infrastructure and service. There are several examples of private or public institutions which have launched mobile applications or other programs to pay commuters for biking to work [56]. According to policy makers, this is still more convenient than having society to pay for external costs generated by less optimal modal choices, as discussed previously in this paper. The success of such efforts have not yet been clearly discussed, also given that initiatives are in most cases relatively recent. There is however a discussion on whether paying commuters to bike to work can be effective in shifting users from more impacting modes. According to some sources, in

fact, users willing to participate in this sort of programs already bike to work or use other low-impact modes. It was demonstrated that unless the program is accompanied by other policy measures, such as the reduction of parking space and the increase of parking price, the shift from private motorized transport to biking is hardly obtainable [57]. Tele-working is another impact-reducing option which has been available by the large-scale diffusion of technology. Tele-working introduction for existing businesses has not been discussed widely in terms of emission reduction potential. Smart commuting [11] hints that considering a single worker and a five-days working week, one day of tele-working corresponds to a weekly 20% emission reduction. This is true from an individual perspective but not generally accurate if the worker – for example – uses for its commute a transit vehicle which rides anyways. Even when broadening the horizon and considering a whole working population with mixed commuting habits, though, it has been demonstrated that the option to telecommute is vital in keeping environmental impacts under control [37].

Mutual-learning practices among administrations and policy makers, awareness raise in clean and active mobility and related health gains, mobility education in schools are all measures recognized as significant by the project Smart Commuting and are grouped together in policy package six, which deals with behavioral and educational interventions. Vertical and horizontal coordination among stakeholders is often indicated as an effective strategy to improve conditions and performances, not only in the transport sector but more broadly in the field of planning and policy making. On topics related to climate change, emissions and environment, public awareness is not ideal as they are not yet – or have not been until recently – part of the daily debate. It is therefore important to foster awareness about individual, societal and environmental benefits from active mobility and from the various commuting alternatives to private cars. All reviewed authors agree on the fact that behavioral change has a very relevant if not prevailing impact on the success of emissions containment strategies, regardless if hinged on travel-demand-management or on the provision of new transport services and infrastructures. Education and awareness raise, together with the provision of valid and valuable alternatives, are the first steps to ensure success of the mental and modal shift towards cleaner transport practices.

Finally, policy package seven deals with the topic of technology advancements. The measures proposed by Smart Commuting project are: installation of electric vehicles charging spots, incentives to the diffusion of electric vehicles. Scientific discussion on benefits from Electric Vehicle implementation strategies is abundant. It is generally agreed that for developed economies – such as European ones – the shift towards electric vehicles is cost-effective [58] and scope-effective, meaning that it contributes significantly to overall emissions reduction achievements. This is mainly because developed economies have cleaner and more efficient energy procurement strategies and higher technology levels [35, 38], in addition to higher expenditure capacity to procure electric vehicles, currently expensive. Public input to foster a widespread EV charging grid, plus incentives to acquire public and private EVs, would therefore be likely to produce relevant advantages in the contexts of Smart Commuting Project's Functional Urban Areas. Impacts, though, can only be estimated when relating measures to their local and national energy market and policies.

5 Conclusion

The scientific community is very active on the topic of the limitation of the negative impacts from the transport sector and, even though a specific focus on commuting is only sometimes to be found, it is acknowledged that the movement of fixed-schedule workers and students has a great impact on the mobility system since it constitutes one of the parts of its highest stress peaks, especially in terms of congestion and space-related issues.

This paper has identified some of the best strategies aiming at reducing externalities from commuting, also highlighting how and when they have proven to be effective - even with a relatively small resource investment. It has also been seen, though, that integrated strategies, in which demand-management measures are flanked by the insertion of greener technologies, appear to be generally much more successful in terms of final outcomes.

The discussion in this paper was on the Smart Commuting project, that proposes a variety of measures which can be promisingly effective in tackling transport externalities, and that have specifically been tailored for each single partner for solving local issues. It must however be underlined that an effort to integrate such measures into broader local, regional and national strategies is still needed to comment on the effective potential of the single measures: a first focus on Smart Commuting project's partner cities, located in mid-Europe, seems to confirm the well-known result that great achievements can be obtained by an increased integration between public transit, private and shared motorized transportation, and active transportation. The first outcomes of the project seem to confirm this to a considerable extent. Still, though, more incisive measures, the integration of IT systems, and an input for broader strategies seem to be desirable to grant higher effectiveness of the cities' efforts in reducing impacts and externalities of commuting.

Mapping the responsiveness of each commuting measure against potential externalities represents an important avenue for future research within and outside the Smart Commuting project, aiming at helping policy makers to integrate their knowledge surrounding expectations about the outcome of each measure, thus making better decisions for the sake of the community.

Acknowledgement. This research has been partially funded through the Interreg Central Europe Programme (2014–2020), Priority Low carbon Cities and Regions, under Project Smart Commuting.

References

1. Al-Rijleh, M.K., Alam, A., Foti, R., Gurian, P.L., Spatari, S., Hatzopoulou, M.: Strategies to achieve deep reductions in metropolitan transportation GHG emissions: the case of Philadelphia. Transp. Plann. Technol. **41**, 797–815 (2018)
2. Long, S., Klungboonkrong, P., Chindaprasirt, P.: Impacts of urban transit system development on modal shift and greenhouse gas emission reduction: a KhonKaen, Thailand case study. Eng. Appl. Sci. Res. **45**(1), 8–16 (2018)

3. Zahabi, S.A.H., Miranda-Moreno, L., Patterson, Z., Barla, P., Harding, C.: Transport greenhouse gas emissions and its relationship with urban form, transit accessibility and emerging green technologies: a montreal case study. Soc. Behav. Sci. **54**, 966–978 (2012)
4. Zeng, Y., Tan, X., Gu, B., Wang, Y., Baoguang, X.: Greenhouse gas emissions of motor vehicles in Chinese cities and the implications for China's mitigation targets. Appl. Energy **184**, 1016–1025 (2016)
5. Chow, A.S.Y.: Spatial-modal scenarios of greenhouse gas emissions from commuting in Hong Kong. J. Transp. Geogr. **54**, 205–213 (2016)
6. Savelsbergh, M.W.P.M., van Woensel, T.: City logistics: challenges and opportunities. Transp. Sci. **50**(2), 579–590 (2016)
7. IEA/OECD: Transport, Energy and $CO_{2:}$ moving towards sustainability (2009)
8. Liu, X., Ma, S., Tian, J., Jia, N., Li, G.: A system dynamics approach to scenario analysis for urban passenger transport energy consumption and CO_2 emissions: a case study of Beijing. Energy Policy **85**, 253–270 (2015)
9. Garcia-Sierra, M., van den Bergh, J.C.J.M.: Policy mix to reduce greenhouse gas emissions of commuting: a study for Barcelona, Spain. Travel Behav. Soc. **1**, 113–126 (2014)
10. Luè, A., et al.: Future priorities for a climate-friendly transport: a European strategic research agenda towards 2030. Int. J. Sustain. Transp. **10**(3), 236–246 (2016)
11. Lemmerer, H., Nocera, S., Shibayama, T., Tonin, S.: Transnational strategy to change commuting models in the FUAs. Deliverable D.T1.2.1 of SMART COMMUTING, Co-funded by Interreg Central Europe (2018)
12. Ricardo, AEA.: Update of the Handbook on External Costs of Transport (2014)
13. Liew, N., Chu J.: How much is your daily commute? Developing a working model to estimate the total travel cost. In: Australasian Transport Research Fortum 2016 Proceedings (2016)
14. Glazebrook, G.: Taking the con out of convenience: the true cost of transport modes in Sydney. Urban Policy and Res. **27**(1), 5–24 (2009)
15. Mayeres, I., et al.: The External Costs of Transportation. Final report. Sustainable Mobility Programme, Federal Office for Scientific, Technical and Cultural Affairs, State of Belgium, Prime Minister's Services (2001)
16. Maibach, M., et al.: In: Handbook on Estimation of External Cost in the Transport Sector. Version 1.0. CE Delft (2007)
17. Danish Ministry of Transport: External Costs of Transport. 1st Report – Review of European Studies (2004)
18. Gibbons, E., O'Mahony, M.: External cost internalization of urban transport: a case study of Dublin. J. Environ. Manag. **64**, 401–410 (2002)
19. European Environmental Agency. https://www.eea.europa.eu/data-and-maps/figures/marginal-external-costs-of-freight-transport-minimum-and-maximum-values-per-transport-mode-euro-10-vehicle-km-for-road-freight-euro-vehicle-km-for-other-modes. Consulted 09 January 2019
20. Business Insider. https://www.businessinsider.com/traffic-jams-commuting-world-cities-pictures-2018-1?IR=T#paris-france-10. Consulted 09 January 2019
21. Nocera, S.: Un approccio operativo per la valutazione della qualità nei servizi di trasporto pubblico/an operational approach for quality evaluation in public transport services. Ingegneria Ferroviaria **65–4**, 363–383 (2010)
22. Nocera, S.: The key role of quality assessment in public transport policy. Traffic Eng. Control **52–9**, 394–398 (2011)
23. Eboli, L., Forciniti, C., Mazzulla, G.: Spatial variation of the perceived transit service quality at rail stations. Transp. Res. Part A: Policy and Pract. **114**, 67–83 (2018)

24. Calvo, F., Eboli, L., Forciniti, C., Mazzulla, G.: Factors influencing trip generation on metro system in Madrid (Spain). Transp. Res. Part D: Transp. Environ. **67**, 156–172 (2019)
25. Libardo, A., Nocera, S.: Transportation elasticity for the analysis of Italian transportation demand on a regional scale. Traffic Eng. Control **49–5**, 187–192 (2008)
26. Hickman, R., Ashiru, O., Banister, D.: Transport and climate change: simulating the options for carbon reduction in London. Transp. Policy Paper **17**, 110–125 (2012)
27. Cirilli, A., Veneri, P.: Spatial structure and carbon dioxide (CO_2) emissions due to commuting: an analysis of Italian urban areas. Reg. Stud. **48**(12), 1993–2005 (2014)
28. Li, X., Mou, Y., Wang, H., Yin, C., He, Q.: How does polycentric urban form affect urban commuting Quantitative measurement using geographical big data of 100 cities in China. Sustainability **10**, 4556 (2018)
29. Schwanen, T., Mieleman, F.M., Dijst, M.: Travel behaviour in Dutch monocentric and policentric urban systems. J. Transp. Geogr. **9**, 173–186 (2011)
30. Wang, M., Madden, M., Liu, X.: Exploring the relationship between urban forms and CO_2 emissions in 104 Chinese cities. Am. Soc. Civ. Eng. **143**, 1–8 (2017)
31. Yang, L., Wang, Y., Bai, Q., Han, S.: Urban form and travel patterns by commuters: comparative case study of Wuhan and Xi'an. Am. Soc. Civil Eng., China (2017)
32. Modarres, A.: Commuting and energy consumption: toward an equitable transportation policy. J. Transp. Geogr. **33**, 240–249 (2013)
33. Litman, T.: Comprehensive evaluation of transport energy conservation and emission reduction policies. Transp. Res. Part A Policy and Pract. **47**, 153–166 (2012). Victoria Transport Policy Institute
34. Harwatt, H., Tight, M., Timms, P.: Personal transport emissions within London: exploring policy scenarios and carbon reductions up to 2050. Int. J. Sustain. Transp. **5**(5), 270–288 (2011)
35. Hickman, R., Ashiru, O., Banister, D.: Transitions to low carbon transport futures: strategic conversations from London and Delhi. J. Transp. Geogr. **19**, 1553–1562 (2011)
36. Lopes Toledo, A.L., Lèbre La Rovere, E.: Urban mobility and greenhouse gas emissions: status public policies and scenarios in a developing economy City Natal Brazil. Sustainability **10**, 3995 (2018)
37. Mathez, A., Manaugh, K., Chakour, V., El-Geneidy, A., Hatzopoulou, M.: How can we alter our carbon footprint? Estimating GHG emissions based on travel survey information. Transportation **40**(1), 131–149 (2013)
38. Nakamura, K., Hayashi, Y.: Strategies and instruments for low-carbon urban transport: an international review on trends and effects. Transp. Policy **29**, 264–274 (2013)
39. World Conference on Transport Research Society and Institute for Transport Policy Studies: Urban Transport and the Environment. An International Perspective. Emerald Group Publishing Limited (2004)
40. Dalkmann, H, Brannigan, C.: Transport and Climate Change. Module 5e. Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH (2007)
41. Bongardt, D., Breithaupt, M., Creutzing, F.: Beyond the Fossil City: Towards low Carbon Transport and Green Growth. Sustainable Urban Transport Technical Document #6. Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH (2011)
42. Strompen, F., Litman, T., Bongardt, D.: Reducing Carbon Emissions through Transport Demand Management Strategies. A review of international examples. Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH and Beijing Transportation Research Center (2012)
43. Cervero, R.: Walk-and-ride: factors influencing pedestrian access to transit. J. Public Transp. **3**(4), 1–23 (2001)

44. Chien, S.I., Qin, Z.: Optimization of bus stops locations for improving transit accessibility. Transp. Plann. Technol. **27**(3), 221–227 (2004)
45. Litman, T.: Valuing transit service quality improvements. J. Public Transp. **11**(2), 43–63 (2008)
46. Lindsay, G., Macmillan, A., Woodward, A.: Moving urban trips from cars to bicycles: impact on health and emissions. Aust. and N.Z. J. Public Health **35**, 54–60 (2010)
47. Mrkajic, V., Vukelic, D., Mihajlov, A.: Reduction of CO_2 emissions and non-environmental co-benefits of bicycle infrastructure provision: the case of the University of Novi Sad, Serbia. Renew. Sustain. Energy Rev. **49**, 232–242 (2015)
48. Blondel, B., Mispelon, C., Ferguson, J.: Cycle more often to cool down the planet. Quantifying CO_2 savings of cycling. European Cyclists' Federation ASBL (2011)
49. Buehler, R.: Determinants of bicycle commuting in the Washington, DC region: the role of bicycle parking, cyclist showers, and free car parking at work. Transp. Res. Part D **17**, 525–531 (2012)
50. Baptista, P., Melo, S., Rolim, C.: Energy, environmental and mobility impacts of car-sharing systems. Empirical results from Lisbon. Portugal. Soc. Behav. Sci. **111**, 28–37 (2014)
51. Firnkorn, J., Mueller, M.: Selling mobility instead of cars: new business strategies of automakers and the impact on private vehicle holding. Bus. Strategy Environ. **21**, 264–280 (2012)
52. Steiniger, K.W., Bachner, G.: Extending car-sharing to serve commuters: an implementation in Austria. Ecol. Econ. **101**, 64–66 (2014)
53. Agatz, N., Erera, A., Savelsbergh, M., Wang, X.: Optimization for dynamic ride-sharing: a review. Eur. J. Oper. Res. **233**, 295–303 (2012)
54. Cici, B., Markopoulou, A., Frias-Martinez, E., Laotaris, N.: Assessing the potential of ride-sharing using mobile and social data: a tale of four cities. In: Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing, 201–211 (2014)
55. European Platform on Mobility Management. http://www.epomm.eu/newsletter/v2/content/2017/1217_2/doc/eupdate_it.pdf. Consulted 02 July 2019
56. Various News Agencies. https://www.reuters.com/article/us-france-bicycles/france-experiments-with-paying-people-to-cycle-to-work-idUSKBN0ED1O120140602. https://www.fastcompany.com/3069271/this-app-lets-your-company-pay-you-to-bike-to-work. https://www.theguardian.com/world/2018/mar/07/new-zealand-cycle-cash-10-a-day-employees-work-company; all visited 18 January 2019
57. CityLab: https://www.citylab.com/transportation/2015/03/the-problem-with-paying-people-to-bike-to-work/388099/, visited 18 January 2019
58. Hartgen, D.T., Fields, M.G., Scott, M., San Jose, E.: Impacts of Transportation Policies on Greenhouse Gas Emissions in U.S. Regions. Policy Study, 387 (2011)