Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2022) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

E-mobility solutions for urban transportation: User needs across four continents

George Panagakos[a,*], Mirko Goletz[b], Marc Hasselwander[b], Alvin Mejia[c], Elina Aittoniemi[d], Michael Bruhn Barfod[a], Subash Dhar[e], Maria Rosa Muñoz Barriga[c], Talat Munshi[e], Jyoti Prasad Painuly[e], Shritu Shrestha[c], Anne Silla[d], Edmund Teko[f], Guilhermina Torrao[d], Stefan Werland[c], Kathleen Dematera[g]

[a]*Technical University of Denmark, Akademivej, Building 358, 2800 Kongens LyngbyCity, Denmark*
[b]*Deutsches Zentrum für Luft- und Raumfahrt (DLR), Rudower Chaussee 7, 12489 Berlin, Germany*
[c]*Wuppertal Institute for Climate, Environment and Energy gGmbH, Döppersberg 19th, 42103 Wuppertal, Germany*
[d]*VTT Technical Research Centre of Finland Ltd, Tekniikantie 21, 02044 Espoo, Finland*
[e]*Technical University of Denmark, Marmorvej 51, 2100 Copenhagen Ø, Denmark*
[f]*Urban Electric Mobility Initiative, Kopenhagener Strasse 47, 10437 Berlin, Germany*
[g]*Clean Air Asia, 505 Robinsons Equitable Tower, ADB Ave. Ortigas Center, Pasig, Metro Manila, Philippines*

Abstract

Aiming at setting up a global platform for e-mobility solutions, the EU-funded project SOLUTIONSplus (2020–2023) established nine living labs in Africa, Asia, Europe, and Latin America to test innovative solutions involving new services, business models, vehicle types, and charging systems. A user needs analysis was undertaken in all project cities. The paper summarizes the main findings of this analysis and investigates the effect of the external environment on user needs. The perceived importance of electric vehicles in the mobility patterns, quality of life, and city environment is examined, along with the expected challenges in the respective market penetration. The correlation of these perceptions with selected external factors is also analyzed to draw recommendations on e-mobility promoting efforts that are aligned with the preferences and priorities of the local stakeholders.

* Corresponding author. Tel.: +45-45-25-6514.
E-mail address: geopan@dtu.dk

2352-1465 © 2022 The Authors. Published by ELSEVIER B.V. This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the Transport Research Arena (TRA) Conference

Keywords: electric vehicle; urban transport; user needs; developing countries; city environment; e-mobility promotion

1. Introduction

Global transport emissions account for 24% of direct CO_2 emissions from fuel combustion, highlighting the need for greater international policy focus on sustainable e-mobility solutions. E-mobility is viewed as a means of bringing global energy-related carbon dioxide emissions to net zero by 2050 and giving the world a chance of limiting the global temperature rise to 1.5 °C (IEA, 2021). At the same time, cities aim to shift towards low-carbon urban mobility, decrease air pollution, and promote active modes of transport.

Electric vehicles (EVs) have become increasingly common in urban environments. E-mobility includes several vehicle types based on model size and load capacity, such as e-buses, e-passenger cars, and Light Electric Vehicles (LEVs) such as 3- and 4-wheelers, e-bikes and e-scooters (Brost et al., 2022). Over the past 10 years, electric car deployment has been growing with the global stock of electric passenger cars passing 5 million in 2018, from those, 45% were in China (2.3 million), 24% in Europe, and 22% in the United States (refer to Fig. 1).

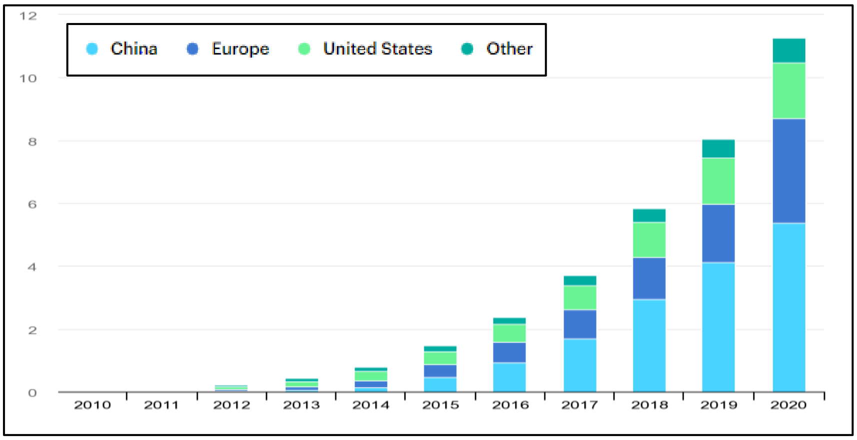


Fig. 1. Global electric vehicle stock by region, 2010-2020 (Source: IEA, 2021)

In an effort to minimize air pollution and fossil fuel consumption, the leading countries in terms of e-mobility (China, USA, Norway and Germany) have offered substantial subsidies and incentives to upgrade their fleets to EVs. However, this is not the case in other parts of the world. In India, for example, Tesla Inc. could not enter the market due to local sourcing norms and supply issues, while charging infrastructure remains critical for EV adoption (Singh et al., 2021). It follows that policy actions can have an important role to play in promoting and enabling the implementation of e-mobility solutions.

Acknowledging this fact, the SOLUTIONSplus project brings together decision-makers of all levels including private and public institutions, governmental agencies, and international agencies with the aim of kick-starting the transition towards low-carbon urban mobility. The project is built around demonstration activities in nine cities of four continents to test different types of innovative and integrated e-mobility solutions, complemented by scaling up and replication activities. The table below summarizes the main (technical) components of the demonstration activities, as well as the intended final users of the solutions.

Table 1. Technical content and targeted users of the SOLUTIONSplus demonstration projects.

City	Description	Summary of technical components	Targeted final users
		Africa	
Dar es Salaam, Tanzania	Electrifying 3-wheelers providing feeder services to the BRT	• E-3-wheelers (35 units) • E-bicycles (10 units)	• BRT Commuters

Kigali, Rwanda	E-2-wheelers for enhancing first- and last-mile connectivity	• Shared e-bikes (50 units) • E-moto-taxis (15 units) • MaaS app	• Public transport commuters
Asia			
Hanoi, Vietnam	E-mopeds and e-bikes to strengthen last-mile connectivity to public transportation	• e-mopeds (50 units) • e-bikes (10 units) • E-moped/e-bike sharing app	• BRT commuters
Kathmandu, Nepal	Bus retrofitting to e-bus	• Retrofitted e-bus (1 unit)	• Local public transport operator
	Redesign e-3-wheelers	• Redesigned 3-wheelers (9 units)	• Local transport operator • Cargo/delivery services companies • Waste collection companies
	E-shuttle van	• E-shuttle van (1 unit)	• Municipality
Pasig, Philippines	Shared multi-purpose vehicles	• Locally developed smart, multi-purpose e-quadricycles (15 units) and flexible electric vans (5 units) • E-vehicle/services sharing app	• Local government (pass. & cargo) • Philippine Postal Corporation (cargo) • SMEs (cargo)
Europe			
Hamburg, Germany	Integrating e-scooters with public mass transport	• E-kick-scooters (250 units) • Sharing app	• Public transport commuters in suburban areas (first- and last-mile service)
Madrid, Spain	Cutting edge technology for smart charging	• Inverted pantographs (3 units) • Software for monitoring and controlling the power network, bus availability and operational efficiency • Installation of DC charging point (1 unit)	• Municipal public transport operator
Latin America			
Montevideo, Uruguay	Locally designed light electric freight vehicles	• Locally designed and assembled light vehicles – E-cargo bikes (5 units) – E-tricycles (4 units) – E-quadricycles (2 units) • Charging solutions for light electric freight vehicles	• Local businesses with needs related to cargo movements
	Multimodal charging hub	• Opportunity charging for e-buses • Integration of charging points for other modes • Overall improvement of terminal	• Local public transport operators
Quito, Ecuador	Multimodal e-mobility hub in the Historic Centre of Quito	• Locally designed and assembled light electric vehicles – E-cargo bikes (10 units) – E-quadricycles (10 units) – E-buggies/delivery vans (2 units)	• Businesses located in the Historic City Centre (restaurants and cafeterias; delivery companies; big retailers; and waste pickers)
	Charging equipment for e-buses	• DC charging equipment	• Municipal public transport operator
	Mobility-as-a-Service	• MaaS app	• Commuters

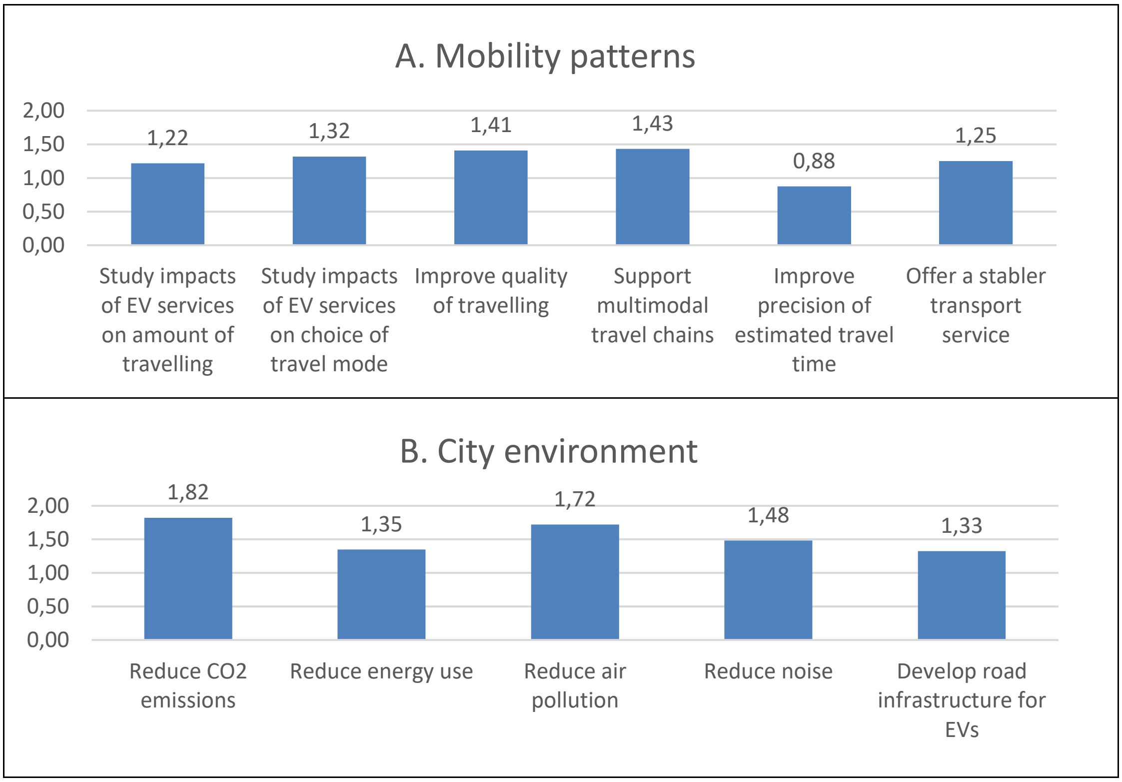
A user needs analysis was undertaken by the project consortium in each of these living labs to identify the stakeholders involved and verify the suitability of the planned interventions. The analysis was conducted through an online self-completion survey, supplemented by expert interviews. Relevant stakeholders included representatives from institutions representing government authorities (national, regional, local), transportation companies and operators (public, and private), e-vehicle manufacturing and servicing companies, entities that work in the sphere of electricity and charging, academia and NGOs. Data collection took place between November 2020 and January 2021. There were 90 valid responses from nine cities in total.

The aim of this paper is to: (i) summarize the main user-needs related findings of the living labs, and (ii) investigate the effect of the external environment on these needs through a horizontal analysis cutting across cities. More specifically, the paper presents the results of the user needs analysis with regard to the perceived importance of EVs to affect the mobility patterns, quality of life and the city environments examined. It also covers the expected challenges in penetrating the respective local markets. Furthermore, an effort is made to correlate these perceptions with external factors such as air pollution and the level of city traffic. The findings contribute in selecting strategic orientations for the promotion of e-mobility in urban transportation that are aligned with the preferences and priorities of the local stakeholders. The paper is structured in three sections. Following this introduction, Section 2 presents the analysis, while Section 3 concludes.

2. The analysis

2.1. Perceived importance of electric vehicles

Among others, the SOLUTIONSplus survey on user needs analysis included three questions investigating stakeholder perceptions in relation to: (i) mobility patterns, (ii) city environment, and (iii) quality of life. A list of project objectives was suggested for each one of these areas, and the stakeholders were asked to assess the importance of these objectives on a Likert scale ranging from -2 (“not important at all”) to +2 (“very important”). The objectives assessed and the corresponding scores are shown in Fig. 2. The main findings are summarized below together with interesting arguments expressed during the supporting interviews.



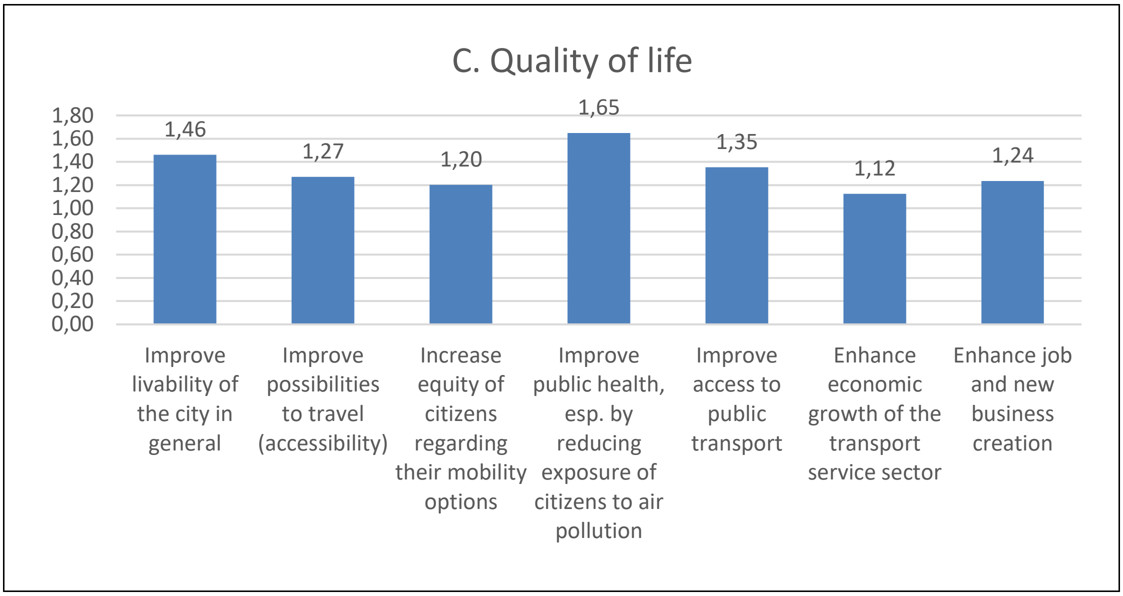


Fig.2. Stakeholder perceptions of the importance of project objectives

All six objectives in the area of mobility patterns were scored positively, indicating that overall they were perceived as important. The highest score (1.43) was given to the "support of multimodal travel chains," as the scheduled demonstrations in several project cities concern the first/last mile transport. With a score of 1.41, the importance of e-mobility in "improving the quality of travelling" was also highly rated. The role of e-mobility in "improving precision of the estimated travel time" was valued as the least important aspect by far, which is not surprising given the heavy traffic conditions in many of the project cities. When it comes to the expert interviews, it was widely seen that having a broader set of innovative electrified modes available would increase multimodal and intermodal trips, thereby (hopefully) contributing to a reduction of private car use. Investigating the feasibility of e-mobility transformations, together with incentives that could promote e-mobility were also suggested as project aims.

All project aims suggested in the field of environment were scored between +1 ("important") and +2 ("very important"). The reduction of CO_2 emissions attracted higher attention (1.82) than that of air pollution (1.72) despite the global nature of the former. This is no surprising given the increased societal sensitivity of the climate change challenge. Neither the appearance of noise reduction in the third place (1.48) was a surprise. The promotion of environmental education and the need to enhance public awareness of e-mobility solutions were identified as additional aims during the expert interviews.

With a score of 1.65, the role of e-mobility in improving public health was deemed the most important one, followed by improvements in the general livability of the city (1.46) and the access to public transport (1.35). Although still more than "important" (1.12), potential economic growth generated by e-mobility in the transport service sector was the least favored option. In terms of city livability, the experts expressed concerns relating to land use planning with emphasis placed on the need to segregate space for public and active transport to the detriment of motorized traffic.

2.2. Challenges in market penetration

The survey further revealed insights as to the barriers towards implementing e-mobility deemed most challenging by the respondents. The cumulative percentage of respondents across all project cities that mentioned each of the listed challenges appears in Fig. 3. The vast majority of them (66% and 65%, respectively) sees investments in infrastructure and the lack of financial resources as the most significant challenges. More than half of the respondents (52%) also agree that the lack of enabling policies is an important obstacle in the transition to e-mobility. Organizational issues, lack of maintenance services, and low acceptance of EVs among stakeholders/users follow in significance exhibiting frequencies above 30%.

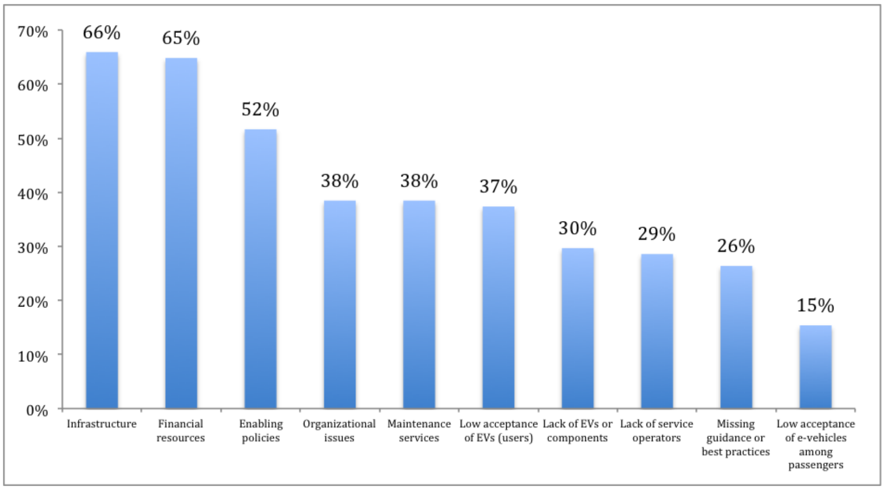


Fig. 3. Main challenges identified across all SOLUTIONSplus cities

From a regional perspective, infrastructure and financial resources remain in the top-3 challenge list for all continents. Enabling policies, however, enters the top-3 only in Asia and Latin America. The third place in Africa is occupied by maintenance services, while in Europe it is shared among organizational issues, lack of service operators and low EV acceptance among passengers, each one with 33%.

Issues of interest that surfaced through interviews include regulatory and governance aspects that hinder e-mobility proliferation (in 3 out of 9 cities), the lack of technical standards (4/9), and the lack of clear/sufficient homologation and registration regulations for EVs (4/9). The capacity of the electricity grid to meet the electrification challenge, lack of technical skills, concerns with regard to urban planning and space requirements for the implementation of e-mobility solutions, as well as diverging objectives of different stakeholder groups were also referred to as problems to be addressed.

2.3. The role of selected external factors

When comparing the results of the online survey across the nine demonstration cities, some notable differences can be observed suggesting that the role of e-mobility is perceived differently depending on the context of the respective city. Although some variation is likely caused by the small sample size, we expect that also external factors affect the different perceptions.

Fig. 4 disaggregates the "mobility patterns" and "quality of life" results of Fig. 2 by city. The descriptive statistics thereby deliver two insights that are particularly striking:

First, for many indicators – mainly travel and mobility related – the City of Pasig received the highest scores. Interestingly, for indicator 6.5 ("To improve precision of estimated travel time") it received a score of 1.69, while all other cities show values of 1.00 or less. This indicator has the lowest average of all indicators, but the highest standard deviation in the sample (AVE 0.88, SD 1.08).

Second, the overall highest score has been found for the city of Kathmandu, with a value of 1.94 for indicator 10.4 ("To improve public health in general, esp. by reducing exposure of citizens to air pollution"). This indicator also received the highest average in the sample (1.65).

We interpret the results in the following way: Indeed, Pasig City is part of one of the most congested regions in the world – Metro Manila, the national capital region of the Philippines – that is notorious for its traffic gridlocks, while Kathmandu, on the other hand, is one of most polluted cities in the world. It appears that where air pollution or traffic congestion is high, e-mobility is seen as a solution to mitigate these types of externalities. In contrast, where air pollution and/or traffic congestion are not perceived as a major issue (e.g., Hamburg), the expected benefits of e-mobility solutions are likely influenced by other challenges the cities face. In the context of Hamburg, this appears to rather be the case for social issues such as providing more equitable and accessible transport services (indicated by the high scores for indicators 10.5, 10.3 and 10.2).

			All Cities (N=90) AVE	SD	Hamburg (N=8)	Hanoi (N=9)	Kathmandu (N=16)	Montevideo (N=14)	Pasig (N=13)	Quito (N=19)
Mobility patterns	6.1	To study impacts of e-vehicle services on the amount of travelling (no. of trips and/or km	1.22	0.82	1.00	1.11	1.50	1.29	1.31	1.47
	6.2	To study impacts of e-vehicle services on choice of travel mode	1.32	0.80	1.13	1.22	1.50	1.21	1.31	1.47
	6.3	To improve quality of travelling	1.41	0.74	1.13	1.00	1.63	1.50	1.77	1.29
	6.4	To support multimodal travel chains	1.43	0.77	1.63	1.33	1.25	1.07	1.77	1.59
	6.5	To improve precision of estimated travel time	0.88	1.08	0.63	0.89	0.81	0.93	1.69	1.00
	6.6	To offer a more stable transport service	1.25	0.87	0.63	1.11	1.38	1.29	1.85	1.25
Quality of life	10.1	To improve livability of the city in general	1.46	0.78	1.13	1.44	1.56	1.21	1.85	1.33
	10.2	To improve possibilities to travel (accessibility)	1.27	0.85	1.25	1.33	1.38	0.93	1.62	1.33
	10.3	To increase equity of citizens regarding their mobility options	1.20	0.91	1.50	0.89	1.13	1.21	1.77	1.22
	10.4	To improve public health in general, esp. by reducing exposure of citizens to air pollution	1.65	0.66	0.75	1.44	1.94	1.50	1.92	1.72
	10.5	To improve access to public transport	1.35	0.94	1.63	1.22	1.44	1.00	1.77	1.29
	10.6	To enhance economic growth of transport service sector	1.24	0.84	0.00	0.78	1.63	0.57	1.62	1.28
	10.7	To enhance job creation and new established businesses	1.24	0.78	0.25	1.00	1.50	1.07	1.54	1.56

Fig. 4. Results of the expert survey for Indicators 6 (Usage and mobility patterns) and 10 (Quality of life in the city) [Note: Only cities with at least 8 valid responses are included in this overview (Dar Es Salaam, Kigali, and Madrid are therefore missing)].

To further investigate the role of external factors, we compare indicators 6.5 and 10.4 with numeric indices of external factors that describe the state of i) the mobility and ii) pollution in the cities. We use the traffic congestion and pollution index from Numbeo.com, and plot them against the experts' answers.

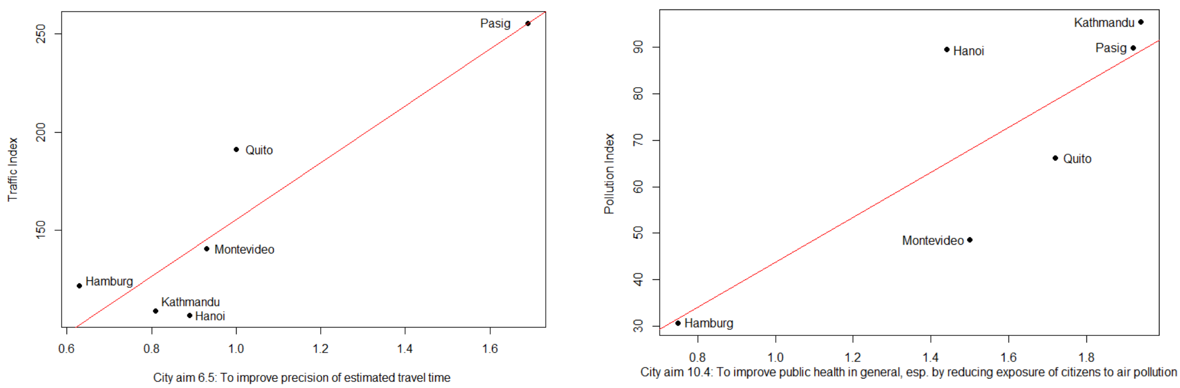


Fig. 5 (a+b). Traffic index vs. city aim 6.5 (left) and pollution index vs. city aim 10.4 (right). [Note: The value of Pasig City for both indices relates to Metro Manila, of which Pasig City is part of]. Source: Numbeo Traffic Index by City 2022 and Pollution Index by City 2022 (values as of May 2022).

The results of the traffic index against city aim 6.5 is shown in Fig. 5a. It shows a positive correlation, where a high value in the traffic index indicates more congestion, and which is likely to result in higher scores of responses to city aim 6.5. In the city of Pasig, accordingly, the need to improve the precision of the estimated travel time is perceived very high, especially in relation to the other cities, where traffic jams seem to be less of a problem. Indeed, travelers in Pasig are often stuck in traffic, and the demand for more reliable services and multimodal travel information is therefore very high (Hasselwander, 2022). The planned demo component of an e-vehicle/services sharing app (see Table 1) therefore appears to be a suitable measure to exactly address these issues.

City aim 10.4 grasped the question whether the cities aim to improve the health of their citizens, in particular by lowering their emissions. The results of the plot of answers to 10.4 against the pollution index is shown in Fig. 5b. Again, a positive relationship can be examined. This indicates that in cities where air pollution is high, especially Kathmandu and Pasig stand out, the associated aims of the cities with the project are higher, while – again in Hamburg – the low pollution index goes along with a least important aim to reduce emissions. We find that also the selection of demo components aligns with this observation. The retrofit of buses to e-buses and redesign of e-3-wheelers in Kathmandu as well as the development of e-quadricycles in Pasig clearly aim at reducing local vehicle emissions. In contrast, while the Hamburg component of integrating e-scooters with public transport has likely no positive impact on reducing emission (Reck et al., 2022), it rather aims at improving access to public transport means.

3. Conclusions

Overall, the preliminary analysis shows that external indicators indeed have an impact on the targeted city aims for e-mobility, especially for extreme values (recall the high values for Pasig/Kathmandu versus the low values for Hamburg in the traffic and pollution index). This is an important finding for public policy and practice. Accordingly, a successful transition towards e-mobility requires the identification of both pressing challenges that need to be addressed as well as suitable e-mobility solutions that can provide a remedy. Following, the expected benefits of these e-mobility solutions to address relevant problems in local context need to be communicated effectively to create awareness and increase the overall acceptance of e-mobility.

Although the correlation between the external factors and answers that we analyzed can also be explained logically, they require a validation by a larger, representative sample. Furthermore, it is recommended to examine and link the other answers of the expert survey to external factors to possibly support our preliminary findings, and whether they also hold in a more comprehensive data analysis.

Acknowledgements

The authors are grateful to our local city team colleagues who identified the relevant stakeholders in each project city and arranged for a series of interviews during the challenging COVID-19 period. The SOLUTIONSplus project is funded through the European Union’s Horizon 2020 research and innovation programme under grant agreement No 875041.

References

Brost, M., Ehrenberger, E., Dasgupta, I., Hahn, R., and Gebhardt, L. (2022). The potential of light electric vehicles for climate protection through substitution for passenger car trips – Germany as a case study. German Aerospace Center (DLR) report, prepared for LEVA-EU.

Hasselwander, M., Bigotte, J. F., Antunes, A. P., & Sigua, R. G., 2022. Towards sustainable transport in developing countries: Preliminary findings on the demand for mobility-as-a-service (MaaS) in Metro Manila. Transportation Research Part A: Policy and Practice, 155, 501-518. https://doi.org/10.1016/j.tra.2021.11.024

International Energy Agency, 2021. Transport – Topics. https://www.iea.org/topics/transport (accessed: 9/11/2021).

Reck, D. J., Martin, H., & Axhausen, K. W., 2022. Mode choice, substitution patterns and environmental impacts of shared and personal micro-mobility. Transportation Research Part D: Transport and Environment, 102, 103134. https://doi.org/10.1016/j.trd.2021.103134

Singh, V., Singh, V., & Vaibhav, S., 2021. Analysis of electric vehicle trends, development and policies in India. Case Studies on Transport Policy, 9(3), 1180–1197.