Tackling Un-sustainable Mobility. Smart City Tools to Limit Car Access to the City Center Through MaaS Solutions, the Genoese Experience

Ilaria Delponte[1] and Valentina Costa[2(✉)]

[1] Civil, Chemical and Environmental Engineering Department, University of Genoa, Genoa, Italy

[2] Italian Excellence Centre for Logistics, Transport and Infrastructures, University of Genoa, Genoa, Italy

valentina.costa@edu.unige.it

Abstract. Mobility-as-a-Service (MaaS) solutions usually aim at defining an integrated and multi-modal framework to make sustainable mobility choices easier and seamless. Nevertheless, several scholars highlight that their effectiveness in supporting modal-shift from individual mobility is therefore limited without side-interventions on making more difficult, expensive and non-competitive the use of private cars. Similar goals may be achieved through the increasing of sustainable alternatives' attractiveness (effective and easy multi-modal integration reducing travel times, convenient fare policies…) or the reduction of individual cars privileges (urban tolls, congestion charges, controlled or limited access to green-vehicles to urban cores…). Recently, Genoa Municipality has started to evaluate a smart-gate system to border the city center and limit car access. This measure targets several goals: to control vehicles flow, collect data on city users and support modal shift towards public transport and sharing mobility. Moreover this measure should be able to make sustainable alternatives more appealing together with the adoption of a urban MaaS solution (thanks to "GetUp" project, currently ongoing) integrating urban parking, PT services and sharing mobility options. Data-driven process should improve urban performances concerning sustainable mobility and improve citizens quality of life in terms of reducing polluting emissions and ease individual journeys across the city.

Keywords: Mobility-as-a-Service · Smart City · Sustainable Mobility · Data-driven governance

1 Introduction

Digital and green transition represent key-challenges of the post-Covid era within EU framework and context, as Resilience and Recovery Plan initiative shows undeniably (Pilati, 2021). Evidently, similar goals prove to be particularly pivotal as far as transport sector is concerned (Kakderi *et al.*, 2021), since it plays a relevant role both in terms of

A. Marucci et al. (Eds.): INPUT 2023, LNCE 467, pp. 645–656, 2024.
https://doi.org/10.1007/978-3-031-54118-6_57

ICT applications, as well as in terms of environmental impacts (Reyes-Rubiano et al., 2021). In this direction, multi-modality and transport integration constitutes key elements to support and promote sustainable mobility within urban contexts (Kramarz and Przybylska, 2021). Mobility-as-a-Service (MaaS) represents indeed a strategical tool to implement transport modal integration through the deployment of digital applications (Campisi et al., 2021).

MaaS solutions provide users with a single-sourced, though wide and various range of transport alternatives that may be modularly combined to move from point A to point B through a flexible and custom travel planning and booking (Maas, 2022).

Mobility-as-a-Service concept relies both on infrastructural and digital integration of multi-modal mobility supply. Main aim is to deliver a seamless urban mobility ecosystem that enable users to choose sustainable alternatives, thus tackling their private car usage (Hensher *et al.*, 2021). Similar considerations may also include freight transport options (Le Pira *et al.*, 2021) to improve last-mile component sustainability within urban environment. Despite the innovative and interesting approach, MaaS impact on modal shift still appears quite limited without the implementation of measures supporting sustainable alternatives through disincentives reducing personal cars usage (Alyavina *et al.*, 2020).

Making sustainable transport options more appealing is therefore a key-challenge for policy-makers and local administrations that may be pursued through a double approach (Salihou *et al.*, 2023): the definition of specifical actions and policies enhancing green, collective and shared solutions - MaaS may play its central role in this direction- and the complementary identification of tools and strategies aiming at limiting the attractiveness and the possibility for car-users to move freely across the city (Buehler *et al.*, 2017; Mulalic and Rouwendal, 2020).

Respective integration among these two lines of actions may be provided through data-driven processes thus enabling deep knowledge of local mobility flows and ecosystem, as well as to tailor and monitor targeted initiatives (Valdez *et al.*, 2018). In this direction, the investigation of potential coupling of MaaS solutions with access' regulation policies should be addressed as an interesting mechanism to target sustainable mobility transition on a local level through tailored and place-based initiative. Furthermore, data-driven tools may support the progressive and dynamic implementation of similar push-and-pull measures, thus enabling gradual users mind shift, and enhancing actions' potential overall effectiveness that top-down policies are often not able to achieve (Hrelja and Rye, 2023).

Genoa case-study may represent indeed an interesting reference as local municipal administration is currently working both on the implementation of a MaaS solution (through the regionally funded GetUp Project) and the concurrent assessment of a Smart Gates system to address monitoring and management of private car usage and flows.

Present contribution would focus indeed on the development of an integrated and ICT-based push-and-pull measures framework that may support digital and green transition of urban transport systems, through incentives- and disincentives-driven initiatives (Sect. 2). Particular attention would therefore be paid to the role data collection and management may play in the definition of an integrated and tailored approach to

urban sustainable mobility (Sect. 3). In this direction, Genoa Municipality would represent a significant case-study in terms of ICT-driven measures supporting sustainable modal shift. Final remarks would be provided on potential drivers and barriers to the implementation of similar initiatives (Sect. 5).

2 Double Strategy for Sustainable Mobility Transition

The choice of sustainable alternatives to move across the city and their consequent spreading heavily rely on individual and therefore social perception and sensitivity on a quite large range of environmental, economical, reliability and safety-related issues (Nogueira *et al.*, 2023). Nevertheless, several actions may prove effective in making them more attractive and desirable (Zawieska and Pieriegud, 2018). In this direction, strategies usually focus on implementing local transport supply and general transport cost reduction (Nicolas *et al.*, 2003) as far as sustainable options are concerned, thus enabling them to compete more effectively against individual cars.

Consequently, three main measures incentivizing sustainable mobility alternatives may be identified:

- Multi-modal supply improvement;
- Travel time reduction;
- Convenient fare-policies implementation.

Three main goals that may be jointly faced through MaaS solutions implementation.

Multi-modal alternatives integration and improvement may indeed be targeted through infrastructural interventions (MaaS hubs' design, re-alignment of urban main transport axes…) as well as digital tools and initiatives gathering mobility-providers and respective transport solutions within a single application for planning, booking and payment procedure (Athanasopoulous *et al.,* 2022).

Boosting seamless integration affects directly travel times: physical and digital integration leads indeed to the reduction of inter-modal change and stopovers, thus making sustainable choices more competitive (Durand *et al.*, 2018). Moreover, through MaaS solutions, journey can be planned and booked on a tailored basis, thus providing user-centered options, meeting individual needs and preferences. In this direction, MaaS may enhance inclusiveness and accessibility (Delponte and Costa, 2022), constituting a relevant improvement for users traditionally segregated by one-fits-all solutions (e.g. the elderly, people with disabilities, younger children…).

Competitiveness of similar solutions within MaaS platforms is targeted also through mobility-packages. The re-definition of urban mobility as a service to be provided and therefore used, translates into innovative and different approaches to fare policies, as well (Reck *et al.*, 2020). Pay-per-use options, daily, monthly, yearly bundle subscriptions may be implemented thus reducing transport fares and prices for users.

Similar actions directly affect general transport cost, thus making sustainable mobility alternatives more competitive. Nevertheless, individual cars are usually perceived as more responsive and seamless to move across the city (Kim *et al.*, 2021), to meet individual needs, despite traffic congestion, parking issues and several related sunk costs (Gössling *et al.*, 2022).

In this direction, sustainable alternative promotion and enhancement cannot be developed without the support of measures disincentivizing individual car usage (Graham-Rowe *et al.*, 2011).

Similar actions usually belong to two clusters of actions: limiting the number of accesses to urban center or introducing specifical tolls or charges making accesses more expensive (Saleh, 2007).

First group of actions may lead to complete denying of urban center accesses, with few exceptions only for local residents and several cities across the world have already implemented similar initiatives through the deployment of limited traffic zones.

The second one consists of several actions related to the internalization of transport-related environmental externalities through the introduction of congestion and emissions charges. Similar initiatives aim at making individual cars mobility more costly, thus collecting resources to be invested in sustainable mobility services and infrastructures.

Defining the right mix of incentives and disincentivizing measures to support sustainable mobility transition may constitute indeed a key challenge for policy-makers (Fig. 1).

Final aim should therefore target an integrated form of multi-modal transport management and optimization within a wider urban transport and mobility environment, where MaaS solutions benefit from smart and data-driven traffic advanced control systems (Coconea *et al.*, 2019).

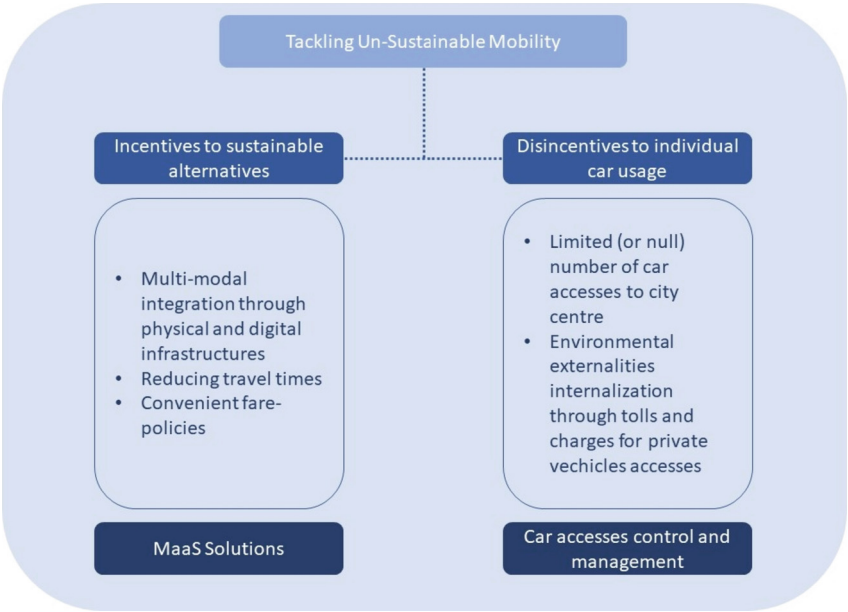

Fig. 1. Incentives and disincentives policies to support sustainable mobility transition.

3 ICT Role Within Urban Mobility Framework

Implementing this double approach towards sustainable mobility requires indeed a strong technological support both referring to incentivizing (Audouin, 2019; Mostofi, 2021) as well as disincentivizing measures.

MaaS solutions rely indeed on a strongly Information and Communication Technology (ICT) asset concerning mainly (Mostofi, 2022):

- Info-mobility services to be provided to users (e.g. through Advanced Traveler Information Systems) in order to tailored custom solutions;
- Planning, booking and buying digital platform integrating mobility providers supply at different levels;
- Fare policies optimization and tailoring.

Digital asset is therefore at the heart of similar solutions, both from the demand side, being users' profiling necessary to shape personalized option able to meet individual needs and preferences; as well as on the supply side to integrate separate booking and ticketing systems (Kamargianni and Matyas, 2017).

Nevertheless, data collection and managements -and respective ICT applications- prove to be even more pivotal ss far as vehicles flows and access regulation are concerned (Oskarbski and Kaszubowski, 2016). The implementation of traffic flows limitations requires indeed a deep prior knowledge of local features and dynamics, in order to evaluate potential impacts, both in terms of cost and benefits of similar measures. This approach is not needed for scientific and technical purposes, but also in terms of social acceptance of a relevant political action that local administration is undertaking (Hysing and Isaksson, 2015; Sugiarto *et al.*, 2017).

In this direction, preliminary surveys of flows and accesses in several spots of the city need to be conducted. Similar initiatives usually require the design of a local camera and sensors network enabling quantitative and qualitative evaluation (Guerrero-Ibáñez *et al.*, 2018).

Present asset confirm its central role in the subsequent implementation step to manage in-coming and out-going flows.

Any form of control and limitation of private accesses is therefore comprehensive of a complex set of "exceptional authorizations" that need to be provided. Specifical exemptions need to be designed for collective and emergency vehicles, as well as tailored measures for local residents and/or shopkeepers.

As far as congestion charge mechanisms are concerned, other specifical issues requiring ICT applications may concern the different fare policies targeting green (e.g. hybrid or full-electric) vehicles in order to shape tolls and charges on the basis of respective environmental externalities and impacts.

Camera and sensors data need indeed to be processed, managed and evaluated by proper control rooms and center, thus orienting local policy-makers decisions, as well as supporting local structures providing sanctions and fines for limitations transgressors.

Similar measures implementation require specifical ICT solutions to manage a large amount of data. Urban Internet-of-Things (IoT) applications, as well as Artificial Intelligence (AI) and Deep Learning (DL) solutions (Patil, 2022) may play a key-role, thus

allowing to gather and network unprecedented quantities of information and enabling respective use for urban policies development (Rathore *et al.*, 2016).

It is therefore necessary to highlight that massive data collection and use imply significant issues in terms of individual privacy and profiling. Local administrations need to be aware that similar initiatives need to be addressed through proportionate and limited actions (Eckhoff and Wagner, 2017).

4 Genoa Case-Study

As far as urban sustainable mobility strategies are concerned, Genoa Municipality may constitute a quite relevant case study.

Genoa urban area, in North Western Italy, counts approximately 560 000 inhabitants, rising up to 840 000 looking at its Metropolitan boundaries.

Motorization rate is one of the lowest among Italian larger cities -48 cars per 100 inhabitants- (Legambiente, 2021) and Public Transport (PT) is a widely chosen alternative for local city users - approximately 32% of Genoese residents use collective transport solutions (Genoa Municipality, 2018). Sharing services are present as well: e-car, bike and scooter-sharing urban services are provided to support sustainable modal shift.

Withing this general framework, Genoa local administration is currently tackling private car usage through a double strategy. Multi-modal transport integration and enlargement has been recently addressed through the implementation of a MaaS initiative, the regionally funded *GetUp Project*, to set the basis for a local pilot thus supporting collective and sharing services. At the same time, the definition of a local system of *Smart Gates* to monitor and manage private cars access to the city historical center is currently under evaluation thus targeting future framing of dedicated fare and control policies.

This joint initiative together with a strong and relevant action in terms of local public transport infrastructures enhancement aims at increasing sustainable mobility appeal, attractiveness and role within local context. ICT in this direction plays pivotal role in terms of innovation as well as management of similar deeply data-driven processes (Fig. 2).

4.1 GetUp Project

Present project -which started in 2021 and is currently taking its conclusive steps- gathering among its partners mobility and technology providers, local administrations and research centres, aims at developing a local MaaS proposal able to support green transitions of city-users attitudes and patterns.

First step has been to implement an integrate travel planner (MaaS platform-Integration Level 1), thus providing users with dedicated information to choose among local mobility alternatives according to travel times, costs and environmental impacts (saved CO_2 emissions).

Subsequently, referring to potential business models, as well as fare-integration policies, a local MaaS ecosystem was shaped according to local features and involved stakeholders.

As far as mobility-bundles packages are concerned, first hypothesis were drawn thus targeting four different users groups: Under25 and Over65 users, tourists and inner areas residents.

Initial step implementation translated also into a digital application -currently available in its beta-version for employees of the partner companies and institutions the project- as well, where registered users authorizing data collection and management (according to GDPR legislation) provide personal and mobility choice-related data, thus enabling future profiling and tailoring of services and fare-policies.

4.2 Smart Gates

Present initiative -which is still in its preliminary feasibility evaluation phase- targets the evaluation of a urban systems of Smart Gates to monitor and manage private vehicles flows in-coming and out-going Genoa historical city centre. In this direction, the definition of a similar network constitutes an essential pre-condition, for consequent assessment of access and fare-policies to limit individual car-usage where sustainable alternatives are present.

It must be noted that evidently, limitations to car-access require as well the implementation of proper park-and-ride facilities to support adequately users modal-shift, as well as the definition of specifical actions targeting different groups of users (e.g. local residents, shopkeepers, people with disabilities…).

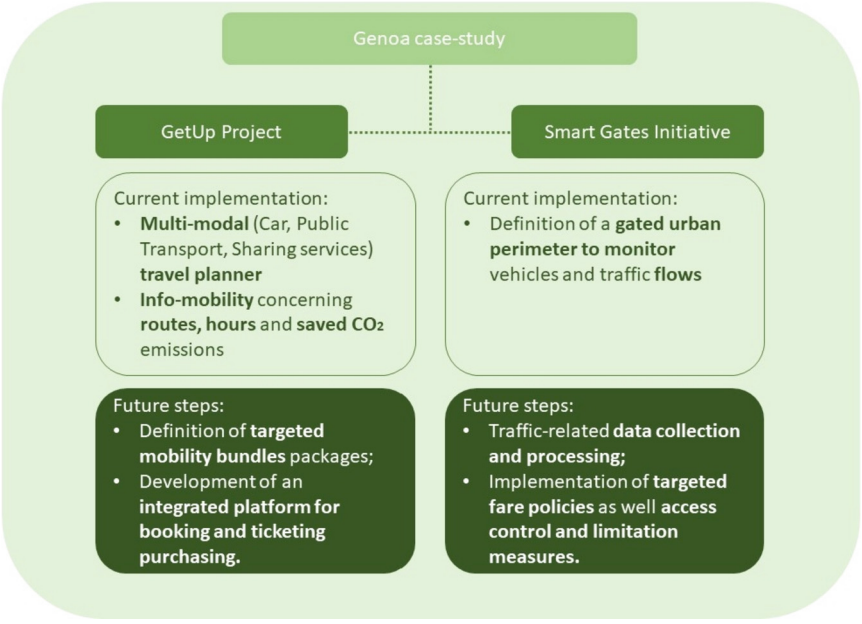

Fig. 2. Genoese sustainable mobility initiatives framework.

Even though similar actions need time to achieve an overall sustainability and acceptance among users, Smart Gates (SG) implementation represent somewhat the preliminary infrastructure building step, thus setting the framework for future evaluation and decision making.

At the same time, even though access limitations may not be implemented, SG may prove indeed extremely supportive in terms of traffic management and monitoring, thus enabling more effective actions to enhance sustainable transition and modal shift on the basis of a deep knowledge of local mobility trends, attitudes and patterns.

5 Discussion

It is therefore evident that green and digital transition need to be implemented jointly. Not surprisingly Next Generation EU supports this double approach to recover from the Covid19-related crisis and to face at the same time an improvement of EU overall resilience.

Being transport sector pivotal in terms of energy consumption and polluting emissions, ICT applications represent indeed an essential tool to promote sustainable mobility within urban contexts.

Their contribution may be extremely relevant both to promote incentivizing measures, as well as in terms of discouraging private mobility component. These two families of actions need to be developed through a coupled approach to foster mutual potential synergies.

Data-driven technologies for traffic management and optimization may contribute building a real-time updated and reliable knowledge of urban flows, thus feeding urban info-mobility systems.

Similar informative systems play key-role within MaaS solutions, thus constituting the essential basis both on the supply and demand side. Real-time information on local traffic flows allows local administration and mobility providers to develop targeted and tailored actions. It may enable initiatives such as dynamic pricing and fare-policies (e.g. depending on urban congestion levels), as well as to manage access to the city centre according to vehicles types and/or polluting emissions city thresholds.

At the same time, MaaS platforms originally descended from info-mobility apps (MaaS Integration level 1), thus basing their added value creation on the opportunity to provide users real-time transport-related information to enable them to choose knowingly modal alternatives, routes and hours more suitable for their needs and preferences. User-centred approach require MaaS providers to give users complete, integrated and real-time information to support their decisions.

In this direction, *GetUp* experience, where traffic-related information concerning the different modal alternatives are coupled with respective environmental data of saved CO_2 emissions, may represent an interesting case study, thus raising users environmental consciousness about their potential footprint, thus taking it into account as a relevant variable for choosing their mobility options.

Evidently, urban *Smart Gate* implementation could support this knowledge process, through the continuous collection of geo-referenced data on traffic and vehicles flows,

constituting a strategical tool both for users and local policy-makers, developing control, regulation and fare-policies that can shape around real-time data.

Following initiatives to tackle private car usage, being them oriented towards sustainable alternatives modal choice or towards monitoring and limitations to individual vehicles accesses and mobility, would evidently benefit from this data-based approach and structure.

Moreover:

- Relevant infrastructural intervention currently under implementation within Genoese context (e.g. railway network improvement, urban bike-lanes system enlargement, bus-dedicated infrastructures, etc.)
- Progressive enlargement of the local mobility-providers eco-system through the inclusion of new service operators, but also of other transport-related stakeholders (e.g. infrastructural license holders, traffic management operators, etc.)

represent a pro-active and favourable *milieu* to enhance the existing propension of local community towards green, viable and inclusive mobility solutions.

It must be remembered as well that similar data collection and processing would require significant efforts, resources and structures to deal with privacy issues, to balance adequately public and common needs with individual rights through a proportionate and minimized use of personal information.

In this direction, competencies and responsibilities allocation will be represent a quite critical factor. Public stakeholders' engagement would indeed play a relevant role in guaranteeing citizens a minimized and protected use of personal data, while private mobility/technology providers and operators may constitute key actors in terms of efficiency and efficacy of the overall business model and proposal.

Chosen interactions and relation schemes among the numerous stakeholders involved would finally define the prevailing roles and instances.

6 Final Remarks

Similar approach towards sustainable mobility may represent the most suitable strategy to speed-up transport sector green transition. Nevertheless, it is evident that present work relies its structure on two projects that have been implemented separately, thus having been at the moment developed unevenly, so that potential synergies are investigated only at research level, and not addressed yet by targeted public polices due both to acceptance and technical issues.

Moreover, referring to Genoa case-study as well as to other territorial contexts, some potential barriers and criticalities need to be underlined:

- Massive limitations to private vehicles access and mobility within urban centres are usually difficult to be implemented on the political level, being extremely critical in terms of social acceptance;
- The potential related to ICT applications is not self-sufficient to support long-term changes towards sustainable attitudes and mobility patterns. In this direction, deep variations in individual (and therefore social) mindset and perceptions are needed and

simple restrictions without the adequate support of culture- and communication-based initiatives risk to prove quite limited in their impacts;
– The implementation of highly innovative and disruptive technologies require to integrate to previous data-collection and monitoring systems, thus enabling past information mainstreaming. Nevertheless, their compatibility and compliance may prove critical in terms of standards and coding, so that particular attention needs to be paid to nullify precedent investments and resources, thus using them as the basis for updates and improvements;
– Despite being implemented on a local level, similar initiatives should be standardized in terms of technological and management schemes and models. Locally-tailored actions risk indeed to produce limited impacts, without targeting the adequate requirements of transferability and replicability. As far as MaaS solutions are concerned, similar standards are currently under implementation on a national level, and smart gates networks should be provided as well of similar standard design guide-lines to ensure widespread and effective outcomes.

Facing similar challenges appears pivotal to support a long-term, shared and effective green and digital transition in the way people live and move within their cities, thus targeting sustainability in each of its dimensions and potential contribution.

References

Pilati, M.: National recovery and resilience plans: empowering the green and digital transitions? EPC Discussion Paper, April 2021

Kakderi, C., Oikonomaki, E., Papadaki, I.: Smart and resilient urban futures for sustainability in the post COVID-19 era: a review of policy responses on urban mobility. Sustainability **13**(11), 6486 (2021)

Reyes-Rubiano, L., Serrano-Hernandez, A., Montoya-Torres, J.R., Faulin, J.: The sustainability dimensions in intelligent urban transportation: a paradigm for smart cities. Sustainability **13**(19), 10653 (2021)

Kramarz, M., Przybylska, E.: Multimodal transport in the context of sustainable development of a city. Sustainability **13**(4), 2239 (2021)

Campisi, T., Garau, C., Acampa, G., Maltinti, F., Canale, A., Coni, M.: Developing flexible mobility on-demand in the era of mobility as a service: an overview of the Italian context before and after pandemic. In: Gervasi, O., et al. (eds.) ICCSA 2021. LNCS, vol. 12954, pp. 323–338. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-86979-3_24

Le Pira, M., Tavasszy, L.A., de Almeida Correia, G.H., Ignaccolo, M., Inturri, G.: Opportunities for integration between Mobility as a Service (MaaS) and freight transport: a conceptual model. Sustain. Cities Soc. **74**, 103212 (2021)

Maas, B.: Literature review of mobility as a service. Sustainability **14**(14), 8962 (2022)

Hensher, D.A., Ho, C.Q., Reck, D.J.: Mobility as a service and private car use: Evidence from the Sydney MaaS trial. Transport. Res. Part A: Policy Pract. **145**, 17–33 (2021)

Alyavina, E., Nikitas, A., Njoya, E.T.: Mobility as a service and sustainable travel behaviour: a thematic analysis study. Transport. Res. F: Traffic Psychol. Behav. **73**, 362–381 (2020)

Salihou, F., Le Boennec, R., Bulteau, J., Da Costa, P.: Incentives for modal shift towards sustainable mobility solutions: a review. Revue d'économie industrielle, 199–246 (2023)

Buehler, R., Pucher, J., Gerike, R., Götschi, T.: Reducing car dependence in the heart of Europe: lessons from Germany, Austria, and Switzerland. Transp. Rev. **37**(1), 4–28 (2017)

Mulalic, I., Rouwendal, J.: Does improving public transport decrease car ownership? Evidence from a residential sorting model for the Copenhagen metropolitan area. Reg. Sci. Urban Econ. **83**, 103543 (2020)

Valdez, A.M., Cook, M., Langendahl, P.A., Roby, H., Potter, S.: Prototyping sustainable mobility practices: user-generated data in the smart city. Technol. Anal. Strateg. Manag. **30**(2), 144–157 (2018)

Hrelja, R., Rye, T.: Decreasing the share of travel by car. Strategies for implementing 'push' or 'pull' measures in a traditionally car-centric transport and land use planning. Int. J. Sustain. Transport. **17**(5), 446–458 (2023)

Nogueira, M., Dias, F., Santos, V.: Sustainable mobility choices: exploring the impact of consumers' values, attitudes, perceived behavioural control and subjective norms on the likelihood to choose sustainable mobility options. J. Consum. Behav. **22**(2), 511–528 (2023)

Zawieska, J., Pieriegud, J.: Smart city as a tool for sustainable mobility and transport decarbonisation. Transp. Policy **63**, 39–50 (2018)

Nicolas, J.P., Pochet, P., Poimboeuf, H.: Towards sustainable mobility indicators: application to the Lyons conurbation. Transp. Policy **10**(3), 197–208 (2003)

Athanasopoulou, A., Deijkers, T., Ozkan, B., Turetken, O.: MaaS platform features: an exploration of their relationship and importance from supply and demand perspective. J. Urban Mob. **2**, 100028 (2022)

Durand, A., Harms, L., Hoogendoorn-Lanser, S., Zijlstra, T.: Mobility-as-a-Service and changes in travel preferences and travel behaviour: a literature review (2018)

Delponte, I., Costa, V.: Metropolitan MaaS and DRT Schemes: are they paving the way towards a more inclusive and resilient urban environment? In: Da Sixth International Conference on Universal Design Transforming our World through Universal Design for Human Development, Brescia, 7–9 Settembre 2022 (2022). ISBN 978-1-64368-305-8

Reck, D.J., Hensher, D.A., Ho, C.Q.: MaaS bundle design. Transport. Res. Part A: Policy Pract. **141**, 485–501 (2020)

Kim, Y., Kim, E.J., Jang, S., Kim, D.K.: A comparative analysis of the users of private cars and public transportation for intermodal options under Mobility-as-a-Service in Seoul. Travel Behav. Soc. **24**, 68–80 (2021)

Gössling, S., Kees, J., Litman, T.: The lifetime cost of driving a car. Ecol. Econ. **194**, 107335 (2022)

Graham-Rowe, E., Skippon, S., Gardner, B., Abraham, C.: Can we reduce car use and if so, how? A review of available evidence. Transport. Res. Part A: Policy Pract. **45**(5), 401–418 (2011)

Saleh, W.: Success and failure of travel demand management: is congestion charging the way forward? Special Issue of J. Transport. Res. Part A. (Guest Editor) **41**(7), 611–614 (2007)

Coconea, L., Mizaras, V., Türetken, O., Dovinola, G., Grefen, P.: Insights on traffic management in the MaaS value chain. In: 13th ITS European Congress: fulfilling its promises, June 2019

Audouin, M.U.J.: Towards Mobility-as-a-Service: a cross-case analysis of public authorities' roles in the development of ICT-supported integrated mobility schemes. Thesis 9098, EPFL (2019)

Mostofi, H.: The association between ICT-based mobility services and sustainable mobility behaviors of New Yorkers. Energies **14**(11), 3064 (2021)

Mostofi, H.: The frequency use and the modal shift to ICT-based mobility services. Resourc. Environ. Sustain. **9**, 100076 (2022)

Kamargianni, M., Matyas, M.: The Business Ecosystem of Mobility-as-a-Service, vol. 96. Transportation Research Board (2017)

Oskarbski, J., Kaszubowski, D.: Potential for ITS/ICT solutions in urban freight management. Transport. Res. Procedia **16**, 433–448 (2016)

Hysing, E., Isaksson, K.: Building acceptance for congestion charges–the Swedish experiences compared. J. Transp. Geogr. **49**, 52–60 (2015)

Sugiarto, S., Miwa, T., Sato, H., Morikawa, T.: Explaining differences in acceptance determinants toward congestion charging policies in Indonesia and Japan. J. Urban Plann. Dev. **143**(2), 04016033 (2017)

Guerrero-Ibáñez, J., Zeadally, S., Contreras-Castillo, J.: Sensor technologies for intelligent transportation systems. Sensors **18**(4), 1212 (2018)

Patil, P.: Applications of deep learning in traffic management: a review. Int. J. Bus. Intell. Big Data Anal. **5**(1), 16–23 (2022)

Rathore, M.M., Ahmad, A., Paul, A., Rho, S.: Urban planning and building smart cities based on the internet of things using big data analytics. Comput. Netw. **101**, 63–80 (2016)

Eckhoff, D., Wagner, I.: Privacy in the smart city—applications, technologies, challenges, and solutions. IEEE Commun. Surv. Tutor. **20**(1), 489–516 (2017)

Legambiente: CleanCities. Genova 2023 (2021). https://www.legambiente.it/wp-content/uploads/2021/11/CC2023_GENOVA2030.pdf

Genoa Municipality: Sustainable Urban Mobility Plan-Strategic Framework (2018)