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The multi-level perspective and micromobility services

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ABSTRACT

The reduced environmental impact of different forms of transport will contribute to achieving more sustainable cities as a result of more responsible consumption. As a result, this study's main purpose is to clarify the way in which the system, regime and niche dynamics that make up the MLP are interrelated, when it comes to explaining the day-to-day use, or lack of use, of micromobility services. In order to meet that purpose, a QCA panel data is created for 35 European urban areas using different sources and taking Sociotechnical Transition and the Multi-Level Perspective into account, enabling transformations linked to sustainability and transition processes in the transport sector to be studied. The results show that certain system and regime conditions such as the ease of locating vehicles, parking and the affordability of these services combine to explain the daily use of micromobility. In terms of not using these services, this is determined by the interrelation of certain system conditions such as parking, accessibility, ease and affordability.

Introduction

The mobility of citizens is key for the intelligent development of cities from an economic and social perspective. However, there is increasing concern for the negative externalities that this generates for the environment (traffic congestion, accidents, pollution and energy consumption) (Del Vecchio, Secundo, Maruccia & Passiante, 2019; Kamargianni & Matyas, 2017). Emissions have increased rapidly in the last 20 years and the drivers of private vehicles are responsible for approximately 12% of emissions in the European Union, which implies that more sustainable mobility systems should be pursued. (Aguilera-García, Gomez & Sobrino, 2020; Canitez, 2019a, 2019b; Hamurcu & Eren, 2020; Moradi & Vagnoni, 2018; Oeschger, Carroll & Caufield, 2020). This is why sustainable urban mobility has a strategic and unifying approach, aiming to advance in aspects such as access and well-being of citizens, by integrating public transport systems in collaboration with private agents (Del Vecchio et al., 2019; Hamurcu & Eren, 2020).

The fourth industrial revolution coupled with demographic, cultural and behavioural change within cities has led people to use a combination of transport for their journeys. This means that combining different means of shared transport such as walking, bus, bicycle or motorcycle amongst others is becoming more and more common, due to the change in citizens' mentality towards the use of mobility as a service (MaaS) instead of ownership (Kamargianni & Matyas, 2017, p. 4). MaaS enables individuals to move using different means of transport -multimodality- (Del Vecchio et al., 2019). Interest in micromobility systems has increased as a result of the rise of shared mobility systems and microvehicles, and their integration with MaaS platforms. (O`Hern & Estgfaeller, 2020). In accordance with the International Transportation Forum (ITF), micromobility is the use of "*micro vehicles with a mass of less than 350 kgs and a design speed of 45 km/hour or less*" (2020, p. 10). However, due to their constant evolution, it is recommended that it should not be limited to certain types of vehicles or energy sources (Oeschger et al., 2020), even though this growth is associated with the new generation of shared electric bikes and scooters (O`Hern & Estgfaeller, 2020). The competition that new mobility systems represent for traditional vehicles is increasing. This is due to the complementarity between the different means of transport. Increasingly fast and far-reaching public transport, together with the accessibility of micromobility that provides a door-to-door service, makes this an option chosen by many users (Oeschger et al., 2020). Therefore, micromobility should be considered part of the solution to the challenges that cities face, since its use in conjunction with other means causes a change in citizens' mobility patterns and behaviours, as they become less dependant on the car (ITF, 2020; Oeschger et al., 2020). Therefore, this study contributes to knowledge by applying the Multi-Level

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Perspective (MLP) and showing us the different combinations of conditions (system and regime) that promote the use or non-use of micromobility services. This can make it easier for governments, researchers and stakeholders in the transport sector to promote such services and reduce car use.

The successful widespread use of mobility services requires consumers' personal factors and those linked to the social and physical environment to be considered (Kanger, Geels, Sovacool & Schot, 2019; Wolf & Seebauer, 2014). Therefore, conceptual tools are required to provide an understanding of the existing dynamics following the aforementioned transition process, considering both social and technological factors (Canitez, 2019b). Socio Technical Transition (STT) and the MLP provide a suitable focus for studying the transition towards sustainability in the transport sector (Ruhrort, 2020), incorporating multiple factors and dimensions, whilst including niche innovations as well as sector regimes and social contexts (Geels, 2019). As a result, this study will apply MLP, using STT to explore the conditions which determine the use of micromobility, as any change in the transport sector requires the role played by its different components to be defined (Kamargianni & Matyas, 2017). There is evidence that MLP is helpful for analysing the dynamic of creating and embedding innovations at a niche level, such as the shared use of cars, bicycles and mopeds, in the context of the transition towards sustainability in the transport sector.

This study responds to different research gaps. First, the growing concern for sustainability places mobility at the top of the policy agenda (Hirschhorn, Paulsson, Sørensen & Veeneman, 2019), requiring the development of actions at an urban level if sustainability parameters want to be achieved (Torrens et al., 2021). Therefore, it is necessary to analyse the conditions that explain the use of new mobility formulas in cities. Second, the emergence of new vehicle types has destabilized passenger land mobility (Hensher, Ho & Reck, 2021; Hirschhorn et al., 2019; Lyons, Hammond & Mackay, 2020; Wu, Shao, Su & Zhang, 2021), requiring work in the field of mobility for which the use of qualitative and mixed approaches in mobility research is suggested (Hirschhorn et al., 2019).

Therefore, the first objective of this study is to identify the conditions that determine the daily use or non-use of micromobility services through MLP. The second objective is to establish the way in which the system-level, regime-level and niche-level dynamics that make up the MLP are interrelated, when it comes to explaining the day-to-day use, or lack of use, of micromobility services. In order to perform the analysis a panel of 35 urban areas in different European countries was created, in which data relating to the system-level, regime-level and niche-level dimensions was collected from different secondary sources, in particular the "Moovit" 2020 Global Public Transport Report.

The results of this study demonstrates how the day-to-day use, or lack of use, of micromobility services can be explained by the different combinations of system-level, regime-level and niche-level variables. Thus, a primary contribution, this article shows the explanatory ability of the MLP in terms of the adoption of technological innovations such as micromobility services, as is the capacity of QCA for studying its interactions and explaining the occurrence or non-occurrence of a phenomenon. Therefore, this study could help Governments and "shared mobility" companies, as well as the environments in which they operate, in terms of detecting the factors that influence the use of micromobility. This would support increasing its use, with the aim of contributing to the reduction of emissions, thanks to a boost in the use of these mobility systems.

Section 2 presents the article's theoretical contribution and propositions. Section 3 is dedicated to the Method; presenting the methodology, the research model, data and sample. Section 4 presents the analysis and results, justifying both the Two-Step Protocol and the Enhanced Standard Analysis. Section 5 is dedicated to the discussion and ends with conclusions and contributions.

Theoretical contribution and propositions

The multi-level perspective and the use of micromobility services

The dominant approaches for explaining the emergence and adoption of radical innovations, and the systems associated with these, have limitations given that these processes "depend on the co-evolution and interdependence of different elements" (Gruber, 2020, p. 535). This is especially the case when the management of radical innovations involves taking into account both intra and inter-organizational elements and its success will depend on both the company and the market (Tiberius, Schwarzer & Roig-Dobón, 2021). Furthermore, these models should recognise the complexity of the environment including the culture, technology, behaviour and users' skills, as well as infrastructure and regulations (Geels, Schwanen, Sorrell, Jenkins & Sovacool, 2018; Gruber, 2020; Vagnoni & Moradi, 2018). This dependency on the context appears in the transition pathways, which present the transitions as evolutionary processes, "increasingly used in the understanding of technological innovation processes" (Helgegren, McConville, Landaeta & Rauch, 2021, p. 120,368). In addition, the new models based on the collaborative economy result from the synergy between technology, information and marketing (Dabbous & Tarhini, 2021).

STT is a systematic co-evolutionary process based on the interrelationships between the social, economic and technical fields that arise when changing from one system to another, considering the environment as a dynamic force that applies pressure through the emergence of new technologies (Canitez, 2019b; Geels, 2018; Helgegren et al., 2021; Hess, 2020; Kanger et al., 2019; Vagnoni & Moradi, 2018). The STTs represent changes towards new systems that, in addition to technical innovations, involve changes to several aspects like citizens' behaviour, policies and infrastructure, amongst others (F. W. Geels, 2020). This approach is used to study the change and stability in the Socio Technical Systems (Gruber, 2020), made up of a network of relationships between natural resources, landscapes and ecology; technologies, actors and organisations; and cognitive and normative structures (Canitez, 2019b; Geels, 2018; Hess, 2020; Kanger et al., 2019; Vagnoni & Moradi, 2018). Therefore, the implementation of an innovation requires the establishment of a Socio Technical System, which can involve drastic social (environment) and technological (mainly technology) changes (Gruber, 2020; Kanger et al., 2019).

Innovations in transport systems are relatively slow as they require trust and credibility amongst the agents involved, as well as strong relationships between different organisational contexts (Kamargianni & Matyas, 2017). As a result, the STT perspective "provides a useful formula for interpreting the social and technical dynamics and complexities involved in sustainable transitions" such as mobility systems (Canitez, 2019a, 2019b; Geels et al., 2018, p. 319). This is because (1) it requires large-scale, long-term, capital-intensive infrastructure, which evolve jointly with technology, institutions, skills, knowledge and behaviours to create a broad Socio Technical System; (2) it understands the intricacies of the change processes involved. The MLP as a central theory in the STT field is used to study the transition processes linked to radical systems and innovations (Canitez, 2019b; Ford, Maidment, Vigurs, Fell & Morris, 2021; F. W. Geels, 2020; Gruber, 2020; Helgegren et al., 2021). This perspective "broadens its unit of analysis from technological products towards Socio Technical Systems" (Geels, 2018, p. 225), and "has both a global focus (consisting of three analytical levels and different temporary phases) which describes the course of the STT; as well as a local focus, linked to specific activities and causal mechanisms from multi-level interactions" (Geels, 2019, p. 189).

Within the STT, the MLP is a useful framework for analysing transitions as its concepts adapt both to radical changes (through the concept of niches as places for radical innovations), as well as dynamic stability (through socio-technical concept regimes, representing the institutional structure of these systems), and broader influences and contexts (through the system concept)" (F. W. Geels, 2020, p. 119,894).

The three analytical levels throughout which change processes are created and the MLP bases its analysis on are the *macro*/system *level, meso/regimes level* and *micro/niches level* (Canitez, 2019a, 2019b; Ford et al., 2021; Geels, 2019; Geels et al., 2018; Gruber, 2020; Matschoss & Repo, 2020; Moradi & Vagnoni, 2018; Vagnoni & Moradi, 2018). The *macro*/system-level refers to external factors which makes certain developments more likely. It includes political, economic, technological, social and cultural factors, which form an exogenous context which is expected to change slowly. All of the events that take place at this *level* can exert pressure on the current system or *regime* which can force it to change (Geels, 2019). The *meso/regime level* refers to the rules that condition the response of the existing systems, in which different elements such as technologies, preferences, policies and regulations together create a stable operation. This means that it is complex to carry out radical changes. The *regime* is affected: on one hand by the system-level which can change the *regime's* structures; and on the other hand, as a consequence of the innovations introduced by the *niche* actors (Ruhrort, 2020). The *micro/niche level* is where radical innovations emerge, the users' preferences or experiences and technologies co-evolve, providing spaces for breakthroughs. The *regime* is the structure that is responsible for the stability of the system and determining the direction of the transition processes, as the system-level and *niches*-levels are defined in relation to the regime (Matschoss & Repo, 2020).

The MLP suggests that STTs are produced as a result of the alignment of pathways and processes that are present in and between the three analytical levels: (1) innovations at a niche level create its internal events; (2) "changes at a system-level create pressure on the regime, and (3) the destabilisation of the regime creates windows of opportunity for the implementation of niche innovations" which are aligned to the regime processes, leading to significant transformations and disrupting the current system (Geels, 2019; F. W. 2020, p. 119,894; Ford et al., 2021). As a result, "radical innovations tend to emerge in small niches at the periphery of the existing socio-technical systems", whose interactions are influenced by a much wider macro context (Geels, 2019, p. 189; Matschoss & Repo, 2020). The MLP was introduced to conceptualise and analyse the STT processes on their journey towards sustainability (Canitez, 2019b; Geels et al., 2018; Matschoss & Repo, 2020), and have been applied in transitions towards sustainable urban mobility (SUM) (Becker, Bögel & Upham, 2021; Canitez, 2019a, 2019b; Geels, 2018, 2019; Geels et al., 2018; Moradi & Vagnoni, 2018; Vagnoni & Moradi, 2018).

According to the MLP, passenger land mobility contains multiple regimes – such as traditional vehicles - amongst which the car has a dominant position. However, there are doubts about whether different trends, such as new types of vehicles that act as a new niche, will destabilize this system, threatening the position held by cars (Hensher et al., 2021; Hirschhorn et al., 2019; Lyons et al., 2020; Wu et al., 2021). While niche-level developments may be the beginning of a transition, the inertia and stability of the existing regime –such as the pre-eminence of the car regime- may cause such developments to remain as a niche or even disappear (Hirschhorn et al., 2019; Lyons et al., 2020). Therefore, it is not clear whether micromobility will be sufficient for the transition from a technological regime dominated by traditional private vehicles; recommending innovators to overcome the "niche bubble" to interact intensely in the regime (Hirschhorn et al., 2019; Pangbourne, Mladenović, Stead & Milakis, 2020). Pressures linked to digitisation modify individuals' preferences regarding the way in which they travel (Hirschhorn et al., 2019). When radical innovation faces a current regime, it is unlikely to replace the dominant one in the market, so new and old technologies will coexist (Sun et al., 2021). The incumbent firms could reject the commitment to new technologies, seeking dual strategies to simultaneously preserve and develop the niche (Werner, Flaig, Magnusson & Ottosson, 2022). The development and diffusion of new linked systems is an attempt to incrementally transform personal mobility systems towards an increasing alignment of service regimes (Smith & Hensher, 2020). Therefore, for micromobility services to play a key role in this transition, they must seek synergies with, rather than compete with classic mobility alternatives (Böcker, Anderson, Uteng & Throndsen, 2020).

Propositions

The use of products that are respectful to the environment, such as micromobility systems, represents socially responsible behaviour. In urban environments, traditional vehicles are not a sustainable form of transport. Therefore, there is a move towards more sustainable solutions linked to the use of vehicles or micromobility (shared or individual), thanks to the advantages these options offer (Aguilera-García et al., 2020; Hardt & Bogenberger, 2019; Lin, Wells & Sovacool, 2018; McKenzie, 2019; G. 2020; Moradi & Vagnoni, 2018; Liao & Correia, 2020; Müller, Lerusse, Steen & Van de Walle, 2021; Younes, Zou, Wu & Baiocchi, 2020; Zagorskas & Burinskienė, 2020): solving the issue of first/last mile; flexibility with parking and accessibility; reduction in road congestion, noise and emissions; and improvements in the quality of life. SUM is used particularly for short daily journeys within a city (Aguilera-García et al., 2020; Hardt & Bogenberger, 2019; McKenzie, 2019; G. 2020; Zagorskas & Burinskienė, 2020), meaning they tend to have regular users.

Aguilera-García et al. (2020) establish that personal socioeconomic characteristics and those attributes linked to the journey explain the adoption of shared SUM services. In our case, at the system-level, we talk about four conditions that influence micromobility and these form the first proposition. At a regime level there are another four conditions, and these form the second proposition.

Conditions considered at a system-level

The *level of income (EURO)* influences the type of transport chosen Lin et al. (2018). explain how people with greater purchasing power travel using more expensive forms of transport, such as cars. In contrast, bicycles tend to be associated with lower levels of income, and they are avoided in some areas as they can portray the wrong image (Zhao & Li, 2017). In fact, the use of certain forms of transport can be influenced by a country's culture. As a result, studies carried out in Holland show that those people with higher incomes tend to use a combination of trains and bicycles more frequently (Bachand-Marleau, Larsen & El-Geneidy, 2011). This also occurred in Munich, where the use of public transport in combination with shared mobility transport such as bicycles is common amongst people with high levels of education (Miramontes, Pfertner, Rayaprolu, Schreiner & Wulfhorst, 2017) Fishman (2016). also concludes that the users of shared bicycles tend to be people with higher levels of education and income. Furthermore, owning an e-bike can increase the use of micromobility. As long as these forms of transport remain expensive, purchasing power will remain a key factor (Lin et al., 2018; Miramontes et al., 2017). In contrast, and despite the fact that bike sharing facilitates cheaper forms of transport (Lo, Mintrom, Robinson & Thomas, 2020), access to public and shared bicycle services involves indirect costs. This limits access for certain population groups with lower incomes (Ji et al., 2017; Lazarus, Pourquier, Feng, Hammel & Shaheen, 2020).

The perceived psychological *distance (KM)* is the variable with the greatest influence on both the choice of transport as well as the behaviour during the journey (Qin, Gao, Kluger & Wu, 2018). The use of micromobility services is a competitive form of transport in terms of speed, especially for short distances where it can replace public transport (Campbell, Christopher, Ryerson & Yang, 2016; Faghih-

Imani, Anowar, Miller & Eluru, 2017; Adnan et al. 2018; Guidon, Becker, Dediu & Axhausen, 2019). Sometimes, such relationships are doubted, it being argued that distance negatively impacts the adoption of shared bikes, with the impact not being significant when studying e-bikes and e-scooters (Adnan et al., 2018). However, Carse, Goodman, Mackett, Panter and Ogilvie (2013), show a significant link between using cars and longer journeys.

The *use of cars (CAR)* continues to be one of the main options for many people, especially for cultural reasons. This is because in certain areas not using a car is associated with having a lower social status (Lin et al., 2018; Zhao & Li, 2017). However, in many countries the value of shared mobility systems extends further than cultural aspects and is based on factors such as: reduced pollution, technological benefits, comfort, safety and speed/time saved (Jones, Cherry, Vu & Nguyen, 2013), which has an impact on the intention of using electric vehicles (Fleury, Tom, Jamet & Colas-Maheux, 2017). E-bikes and e-scooters therefore become alternative forms of transport thanks to the existence of public transport networks and extensive shared mobility systems, significantly reducing the use of cars (Miramontes et al., 2017). Similarly, there are studies that indicate that the use of micromobility can be more suitable in cities with traffic jams (G. McKenzie, 2020). Others establish that if the connection between shared bikes and transport stations is less than 1Km, dependency on cars can decrease by approximately 10% (Basu & Ferreira, 2021). However, the car continues to be the preferred mode of transport for longer journeys, which can prevent people from using shared bicycles (Carse et al., 2013).

Journeys by foot (WALK) tend to be the second most common form of transport, being of particular importance for disadvantaged people from a physical, social or economic perspective, and the preferred option for distances less than 1 km (Adnan et al., 2018). However, the forms of transport people tend to substitute when they use micromobility are: walking, public transport or the use of private bikes instead of cars (Fishman, Washington, Haworth & Mazzei, 2014). Therefore, our mobility behaviour aims to close the gap between long distances by improving proximity (Lavadinho, 2017).

Proposition 1. *The conditions considered at the system-level are necessary for the use of micromobility services.*

Conditions considered at a regime level

The concept of MaaS establishes that usage intentions could be he higher by making *access easier (EASY),* more flexible and reliable, and at a reasonable price (Kamargianni & Matyas, 2017). Various studies have shown that the expected effort is a significant factor in terms of the intended use and ongoing use of e-scooters, shared bicycles and e- bikes (Campbell et al., 2016; He, Song, Zhaocai & Sze, 2019). In fact, Miramontes et al. (2017), establish the relevance of certain factors in the use of shared bikes: the ease of locating a bike, places they can be parked and connections with public transport. Similarly, if this access is difficult, their usage will decrease (Fishman et al., 2014).

Whether micromobility is *affordable (AFFORD)* can be a factor in its use. In fact, there are studies that confirm that those factors that at related to price are more relevant than aspects such as comfort (Gilbert & Ribas, 2019). Studies such as Miramontes et al. (2017) and Reck, Haitao, Guidon and Axhausen (2021), establish that an increase in price has a negative effect on choosing these mobility systems. Therefore, financial incentives and price are important resources for promoting micromobility, especially amongst the most frequent users (Bieliński & Ważna, 2020; Oeschger et al., 2020). In fact, “students and other young people are typical users of this service, with saving money and not having to buy a scooter being the main reasons” (Eccarius & Lu, 2020, p. 102,327).

The availability of secure, user-friendly and affordable *parking (PARK),* as well as stations and dockless close to public transport are key aspects in the use of micromobility (Oeschger et al., 2020) Reck et al. (2021)., p. 102,947), also establish that station-based operating models such as shared bikes “can better support regular travel patterns compared to models” without stations. Therefore, Basu and Ferreira (2021) provide evidence that a new shared bike station can reduce vehicle ownership by 2.2%. However, it is important to remember that if the workplace offers free parking for cars, this could represent a barrier for the use of micromobility (Carse et al., 2013).

The *Accessibility (ACC)* condition, linked to the possibility of benefiting from the first and last mile service, seems to be another of the reasons that has a strong impact on the use of micromobility. In fact, the introduction of shared bike services means that many people opt for this method of transport to make first and last mile journeys, especially for distances of between 0.5 km and 2 km (Adnan et al., 2018). Therefore, in places such as Zurich, electric bikes are preferred for these types of journeys (Reck et al., 2021).

Proposition 2. *The conditions considered at the regime level are linked to those considered at a system-level when it comes to explaining the use of micromobility services.*

Method

Section 3 is structured as follows. First, we discuss the methodology used (3.1). Then, in section 3.2 we explain the research model. Finally, in section 3.3 we explain the data and the sample used for this study.

Methodology

Analysing the transition towards new types of mobility requires the use of qualitative approaches (Kanger et al., 2019). In fact, a qualitative methodology is usually used with the application of STT and the MLP (Gruber, 2020; Moradi & Vagnoni, 2018). The explanatory and predictive factors for people’s adoption “can be better understood by studying the events and interactions in the system” in which they are based (Gruber, 2020, p. 537). The use of qualitative methodologies is therefore recommended, in order to capture the phenomena’s complexity rather than reduce it (Gruber, 2020), and has been recently applied in this area (Zhao & Fan, 2021). “Set theory methods such as QCA assume that the influence” that attributes have on a specific result depends on the way in which the “attributes are combined, rather than the levels of the individual attributes per se” (Ordanini, Parasuraman & Rubera, 2014, p. 135; Xu, Zheng, Xu & Wang, 2016, p. 916; Damian & Manea, 2019).

QCA, based on set theory methods, assumes that the influence that attributes have on a specific result depends on the way in which they are combined, rather than the isolated levels of the individual attributes (Wu et al., 2021). QCA is based on causal symmetry, meaning that the occurrence or non-occurrence of a phenomenon requires different and separate analyses and explanations. Equifinality is another differentiating characteristic that is also included in this technique, which is why different combinations of factors can lead to the same result (Medina et al., 2017; Kusa, Duda & Suder, 2021; Olaya-Escobar, Berbegal-Mirabent & Alegre, 2020; Ott, Williams, Saker & Staley, 2019).

This is why this study uses QCA (using R Setmethods), applying the Two-Steps Protocol for two main reasons: it helps to distinguish between contextual and proximate factors (similar to the system and regime dynamics), whilst dealing with a larger number of conditions. In our model, the daily use of micromobility services (niche variable) is the result, and the two levels (system and regime) are the conditions.

Research model

When using QCA, instead of independent and dependant variables, the terms conditions and result are used. Likewise, instead of posing hypotheses, work propositions are established. In this study, a model that explains the use of micromobility services in accordance with the MLP has been developed, considering the system, regime and niche levels. Conditions are linked to the first two levels, and results are linked to the niche level. In order to identify the variables, this study follows the suggestion of certain authors (Moradi & Vagnoni, 2018; Vagnoni & Moradi, 2018), who include political, social and technological elements in the system-level dynamics. In the regime dynamics, they make a distinction between public transport, private transport and motorised transport, when referring to variables linked to accessibility, comfort, parking, etc. Finally, within the niche dynamic, they consider mobility management, technologies and the existence of green vehicles. Furthermore, in previous studies, micromobility had already been considered as part of the regime, as mobility consists of multiple regimes (cars, buses, trains, bicycles, etc.) with contradictory dynamics (Canitez, 2019a; Lin et al., 2018; Moradi & Vagnoni, 2018). As a result, the system-level dynamics include those elements that are more stable and harder for the agents involved in the sector to change. Elements linked to the use of different mobility services are included in the regime dynamics. Finally, the use of micromobility services is considered in the niche dynamic.

Data and sample

For the analysis, data was collected from 38 cities and urban areas in Spain, Portugal, Italy, France, Germany, Turkey and the United Kingdom. Subsequently, the sample was reduced to 35 cities and urban areas because the necessary data was not available for the other cities.

The panel data used for this study were divided taking into account the three multilevel perspectives, system-level, regime-level and niche-level. Thus, as can be seen in Table 1, three conditions were used for the system-level, four conditions at the regime-level and one condition at the niche-level, which is the outcome. In this study, the outcome corresponds to the use or non-use of micromobility (USE). The conditions incorporated within each level, as well as the sources from which they have been extracted are detailed in table 1.

Analysis and results

The first step of the analysis was the calibration of data. The 90th and 10th percentiles were selected as the maximum inclusion and exclusion points (Miranda, Tavares & Queiró, 2018; Olaya-Escobar et al., 2020). The mean was used as the maximum point of uncertainty, as previously used (Berné-Martínez, Arnal-Pastor & Llopis-Amorós, 2021). This is because resorting to the median would mean having to eliminate cases in the analysis. This study uses a large number of conditions so removing cases would have increased the number of logical remainders.

As can be seen in Table 2, none of the variables used in the model present problems related to skewness, with MINUT representing the lowest percentage of cases and ACC the highest, but without being less than 20% or greater than 80%.

Two-step approach. Remote and proximate factors

The Two-Step Approach was developed by Schneider and Wageman (2006, 2013) and reformulated by Schneider (2019). One of the key aspects of the Two-Step Approach is the "distinction between remote and proximate factors" (Schneider, 2019, p. 1112). Remote factors are historical, they are more stable and changes to them affect the actors. Therefore, they are often considered as distant causal conditions, and they "provide the context in which the proximate conditions have their effect on the result". Proximate factors originate closer to the result, they are more volatile and can be manipulated by the actors, although they are not a result of the remote conditions (Schneider, 2019, p. 1111). In this study, the system-level dynamics will be treated as remote factors and regime-level dynamics as proximate factors. In the reformulation of the Two-Step Approach (Schneider, 2019), the two stages are maintained, even though the first stage is established as an analysis of the remote conditions and the second as an analysis of sufficiency.

Step 1. Identification of necessary conditions

In step 1, only the conditions linked to the remote factors are analysed using an analysis of necessity. Firstly, the individual conditions are analysed with the aim of identifying the existence of

Table 2
Anchors and skewness.

Variable	90%	Mean	10%	Skewness check*
EURO	73.39	58.15	37.51	54.29%
MINUT	50.00	39.51	30.60	34.29%
KM	8.46	5.72	2.96	48.57%
CAR	0.54	0.40	0.17	60.00%
WALK	0.29	0.15	0.00	57.14%
EASY	0.25	0.16	0.07	51.43%
AFFORD	0.29	0.19	0.10	42.86%
PARK	0.36	0.24	0.15	54.29%
ACC	0.38	0.31	0.20	71.43%
USE	0.08	0.04	0.00	57.14%

Set Vble-Cases > 0.5 / Total number of cases

Table 1
Levels, conditions and sources.

Level	Conditions	Source
Landscape	Average journey distance (KM), which is the distance that someone travels during an average journey (single or return)	"Moovit" 2020 Global Public Transport Report
	Per capita income (EURO)	http://www.journaldunet.com/management/ville/classement/villes/richesse/2019 https://www.ons.gov.uk/economy/grossdomesticproductgdp/bulletins/regionaleconomicactivitybygrossdomesticproductuk/1998to2018
	Percentage of the population who use cars for their journeys (CAR)	https://es.numbeo.com/
	Percentage of the population who walk on their journeys (WALK)	
Regime	The reason for using micromobility is that "It is easy to find a shared bike or scooter when you need one" (EASY)	"Moovit" 2020 Global Public Transport Report
	The reason for using micromobility is because "It is cheap" (AFFORD)	
	The reason for using micromobility is because "I can park where I like" (PARK)	
	The reason for using micromobility is because "You can reach places that are not accessible via public transport" (ACC)	
niche	Day-to-day use of micromobility options in your city (bikes, electric bikes, scooters, electric mopeds) (USE).	

Table 3
Analysis of necessary conditions.

	Result: Use			Result:∼USE		
	Cons.Nec	Cov.Nec	RoN	Cons.Nec	Cov.Nec	RoN
EURO	0.739	0.730	0.762	0.522	0.457	0.614
MINUT	0.492	0.599	0.764	0.574	0.619	0.773
KM	0.557	0.595	0.715	0.641	0.607	0.721
CAR	0.619	0.581	0.648	0.719	0.598	0.657
WALK	0.630	0.636	0.714	0.648	0.581	0.684
∼EURO	0.450	0.515	0.705	0.692	0.702	0.795
∼MINUT	0.687	0.645	0.685	0.629	0.523	0.618
∼KM	0.632	0.665	0.746	0.573	0.534	0.679
∼CAR	0.571	0.696	0.810	0.496	0.536	0.737
∼WALK	0.585	0.652	0.760	0.594	0.587	0.728

isolated necessary conditions, the results of which are shown in table 3.

As can be seen in table 3, there are no individual conditions with a consistency level higher than 0.9 and a RoN higher than 0.5. The Relevance of Necessity (RoN) is a parameter of special relevance in the analysis of the need for taking into account the two possible sources of triviality (a significant difference between the condition and the result, as well as between the condition and its negation) (Oana, Schneider & Thomann, 2021). Thus, the disjunctions were analysed to establish whether they could be considered a superset of the result. The "EURO+∼KM+∼CAR" disjunction exceeded the required threshold (Cons.Nec=0.913, Cov.Nec=0.652, RoN=0.500) for the use of micromobility services result. If the conditions form a non-trivial consistent superset of the result, they can be considered as attributes that are functionally equivalent to a higher-order concept, and therefore SUIN conditions (Schneider, 2019). In this case, the disjunction between these three conditions can be considered a higher-order concept as it is theoretically significant (Schneider, 2019, 1116), remaining linked to the system-level. The conditions linked to the remote factors that passed the theoretical and empirical criteria in step 1 are included in the analysis of sufficiency in step 2 (Schneider, 2019). Therefore, in step 2, the necessary condition made up of "EURO+∼KM+∼CAR" is included relating to the use of micromobility services under the higher-order concept named "ENT" and there is no necessary condition for the analysis of the non-use of micromobility services.

Step 2. Identifying remote-proximate sufficient terms

Step 2 consists of an analysis of sufficiency in which the conditions associated with proximate factors are included, as well as all the remote conditions identified as being necessary in step 1. Truth tables were created using a minimum level of consistency of 0.8, and a Proportional Reduction of Inconsistency (PRI) of 0.51, starting with an analysis of the cross-over point 0.5, to identify and eliminate the existing ambiguous cases (that were the cities Bursa and Nice). This was initially done for the analysis of the use of micromobility services.

The truth table for the use of micromobility was elaborated, those cases that exceeded the required consistency level (0.8), presented PRI whose minimum was 0.627 (higher than the criterion of 0.5). The PRI is relevant for its ability to determine simultaneous subset relations. Subsequently, a truth table was created for the case of the non-use of micromobility services. In the truth table for the non-use of micromobility it is observed how once again the inclusion consistency criteria (incl) and PRI are exceeded, although in this case some of the conjunctions present a PRI lower than 0.6. As in the case of the use of mobility, the conjunction that represents seven of the cities does not explain the result under study.

Enhanced standard analysis (ESA)

Since the Standard Analysis does not take into account the making of inadvertent untenable assumptions, Enhanced Standard Analysis (ESA) was carried out. Untenable assumptions are those counterfactuals: (1) making statements on the conditions for the opposite outcomes; (2) that contradict the necessary conditions; and (3) contradict basic logic (Oana et al., 2021). Thus, prior to obtaining solutions, logical remainders were eliminated as they are "untenable assumptions". Subsequently, contradictory simplifying assumptions and statements contradicting claims of necessity were avoided. In the case of the use of micromobility services, complying with the "ENT" necessary condition was included as a requirement. As there was no necessary condition present in the case of non-use of micromobility services, this requirement was not imposed. Enhanced Solution Formulas were then obtained. Due to the fact that in the solution analysis any of the available solutions could be selected (conservative, intermediate, parsimonious) (Schneider, 2019), the most parsimonious solution formula was chosen. The parsimonious solution was chosen since only a parsimonious solution effectively eliminates all causally irrelevant (redundant) factors, if it presents high coverage (indicating necessity) it is causally interpretable allowing inferences to be drawn (Oana et al., 2021; Thomann & Maggetti, 2020). In the case of the use of micromobility services, the most parsimonious solution (see table 4) is as follows: ∼EASY*∼PARK*ENT + AFFORD*ASEQ*ENT -> USE

In table 4 we see how, in the case of daily use of micromobility services, this is explained by the presence of the environment "ENT" condition, combined with the fact that it is not easy to locate one of these micromobility vehicles and find parking for micromobility vehicles, or they are easy and affordable to use. In the first case, both the raw coverage (0.564) and the unique coverage (0.339) of the first term stand out. With the presence of "ENT", it should be remembered that it refers to cities with high purchasing power, where commutes are quite short, or where cars are hardly used.

In the case of non-use of micromobility services, the most parsimonious solution (see table 5) is as follows: PARK*∼ACC + ∼EASY*AFFORD*PARK + (PARK*∼ENT) -> ∼USE

The lack of day-to-day use of micromobility services is explained by three configurations, one of which is "considering that parking micromobility vehicles is simple". The first configuration is accompanied by the lack of accessibility. The second is linked to the fact that using them is not considered easy, even though they are affordable. Finally, in the third configuration, despite micromobility vehicles being considered easy to park, their non-use is because they are not in areas with high purchasing power, journeys are longer distance, or cars are used more for these journeys. Although none of the three terms has a high unique coverage (0.080, 0.051 and 0.013), the set of the solution shows optimal parameters, with a coverage of 0.578.

Table 4
Most parsimonious solution for the use of micromobility services.

	inclS	PRI	covS	covU	Cases
∼EASY*∼PARK*ENT	0.805	0.702	0.564	0.339	Glasgow, Barcelona; Yorkshire, Paris, Santa Cruz de Tenerife; Vigo, Porto, London; Montpellier, Valencia, Napoles
EASY*AFFORD*ENT	0.857	0.728	0.353	0.127	Lille, Madrid; Toulouse, Thessaloniki
Model	0.792	0.692	0.691		

Table 5
Most parsimonious solution for the non-use of micromobility services.

	inclS	PRI	covS	covU	Cases
PARK*∼ACC	0.842	0.657	0.333	0.080	Malaga; Turin
∼EASY*AFFORD*PARK	0.823	0.549	0.271	0.051	Palermo
PARK*∼ENT	0.897	0.825	0.408	0.013	Athens; Bologna; Adana-Misin, Ankara, Istanbul
Model	0.861	0.762	0.578		

Table 7
Robustness_Protocol_Report_(∼USE).

Sensitivity_Range	
Parameter	Raw_consistency_Lower:0.8 Threshold:0.8 Upper:0.8 Frequency_Lower:1 threshold:1 Upper:1
Robustness parameter	
Fit_orientated	RF_cov: 0. 760 RF_cons:0.934 RF_SC_minTS: 0.666 RF_SC_maxTS: 0.666
Case_orientated	RCR_typ:0.714 RCR_dev:0 Rank:3
Performing models	
EASY*∼ENV+EASY*∼AFFORD*∼ACC (1) RCC_Rank:3 SC: 0.666	
EASY*∼ENV+EASY*∼AFFORD*∼ACC (2) RCC_Rank:3 SC: 0.666	

This fact shows us the existence of numerous overlaps between the three conjunctions of conditions.

Robustness test

To establish the robustness of the results, the protocol proposed by Oanna and Schneider (2021) was followed, establishing the sensitivity of the parameters (consistency and frequency), the fit-orientated robustness and the case-orientated robustness, both for USE (Table 6) and ∼USE (Table 7).

The sensitivity ranges showed how modifying the consistency of 0.8 and the frequency cut-off of 1 would modify the solution obtained. Since, due to the number of cases, it makes no sense to modify the required frequency, models with a consistency of 0.85 (1) and 0.9 (2) were developed. As can be seen in Table 6, the results obtained for the fit-orientated robustness for the consistency are high showing a high robustness, but not for the Robustness Fit Coverage. As a result, it is confirmed that there is a difference between the coverage of the initial solution and the robust core. The ranking of 3 indicates the existence of shaky cases.

The results obtained for the ∼EI show the same pattern as for the EI. Although with a greater Robustness Fit for coverage for ∼EI, an element that can also be observed in the case-orientated robustness fit. Thus, it can be concluded that the solution obtained for ∼USE shows a high robustness. These results can be seen in Fig. 1 where it is observed that there are few shaky cases.

The upper figure (Fig. 1) shows the plot that represents the initial solution (in this case the enhanced parsimonious solution) and the min/max Test Set, and the existence of shaky cases for both solutions is expanded.

Discussion

This study was carried out to explain the conditions that determine the daily use or non-use of micromobility services, applying fsQCA to MLP. In this sense QCA is an important method for applying the MLP, as suggested by others who opted for qualitative methodologies in their analyses (Gruber, 2020; Moradi & Vagnoni, 2018).

In the two resulting recipes that explain the use of micromobility, the ENT condition appears, that is, the use of micromobility is more frequent in those places where the level of purchasing power is higher, the distances to be travelled are shorter and, as a consequence, the car is used less. This suggests that proposition 1 for the use of mobility services is met. This is in line with several studies showing that higher levels of purchasing power tend to use more micromobility (Ji et al., 2017; Lazarus et al., 2020). Also, when the distances to be travelled are shorter the use of micromobility is more common (Campbell et al., 2016; Faghih-Imani et al., 2017; Guidon et al., 2019), or as a consequence of these shorter distances car use is lower (Carse et al., 2013). In the first recipe, the use of micromobility is determined by the combination of the existence of the ENT, and the lack of parking facilities (∼PARK) and ease of locating these means of transport (∼EASY). This is in line with studies that mention that the level of purchasing power is key in the use of micromobility and that it is those cities with higher purchasing power levels that tend to make use of these means more frequently (Bachand-Marleau et al., 2011; Fishman, 2016; Miramontes et al., 2017). This is coupled with shorter distances to travel, which stimulates less car use and make the use of micromobility more frequent (Carse et al., 2013; Qin et al., 2018). All this despite the fact that it is not easy to locate these means of transport or there is no parking to leave them at, which would go against those who establish that both the ease of parking and the ease of finding bikes for example are key in the use of micromobility (G. McKenzie, 2020; Miramontes et al., 2017). Or those who show that having more places to park could reduce car use and therefore encourage micromobility (Baser & Ferreira, 2021; Oeschger et al., 2020; Reck et al., 2021). This is perhaps due to the fact that those cities in which this recipe for the use of micromobility is produced are cities that already have well-established micromobility networks and that is what makes the ENT condition (within the system-level) prevail over the regime conditions (EASY and PARK). On the other hand, the second recipe states that when the ENT condition occurs coupled with the ease of finding a micromobility (EASY) vehicle and the fact that it is a cheaper means of transport (AFFORD) the use of micromobility increases. This is in line with the authors who show how the fact that these means of transport are cheaper than other means, or encourage savings, can give a boost to the use of micromobility (Gilbert & Ribas, 2019). Likewise, the location of micromobility vehicles is important in their use, something that has already been established previously, i.e., the easier it is to find these micromobility vehicles, the more they will be used (Miramontes et al., 2017). Thus, optimisation of the coordination between different vehicle systems, pedestrian areas and infrastructure, are amongst the reasons that explain the use of micromobility (Fau et al., 2019). Financial incentives also play a role (Eccarius & Lu, 2020; Oeschger et al., 2020). Therefore, in this second recipe, it can be seen that both the existence of the system-level (ENT) and regime (EASY and AFFORD) conditions are necessary for the use of micromobility to occur. Both receipts place us before what could be different transition trajectories. Although in both recipes there is a relevant presence of the environment, in the first recipe there is a misalignment due to the lack of development of the micromobility niche -inferred from the denial of the conditions-, whilst in the

Table 6
Robustness_Protocol_Report_(USE).

Sensitivity Range	
Parameter	Raw_consistency_Lower:0.8 Threshold:0.8 Upper:0.8 Frequency_Lower:1 threshold:1 Upper:1
Robustness parameter	
Fit_orientated	RF_cov:0.525 RF_cons: 0.910 RF_SC_minTS: 0.471 RF_SC_maxTS: 0.639
Case_orientated	RCR_typ:0.333 RCR_dev:0.333 Rank:3
Performing_Models	
AFFORD*∼ACC*ENV (2) RCC_Rank:3 SC: 0.471	
EASY*AFFORD*ENV+AFFORD*∼ACC*ENV (1) RCC_Rank:3 SC: 0.471	

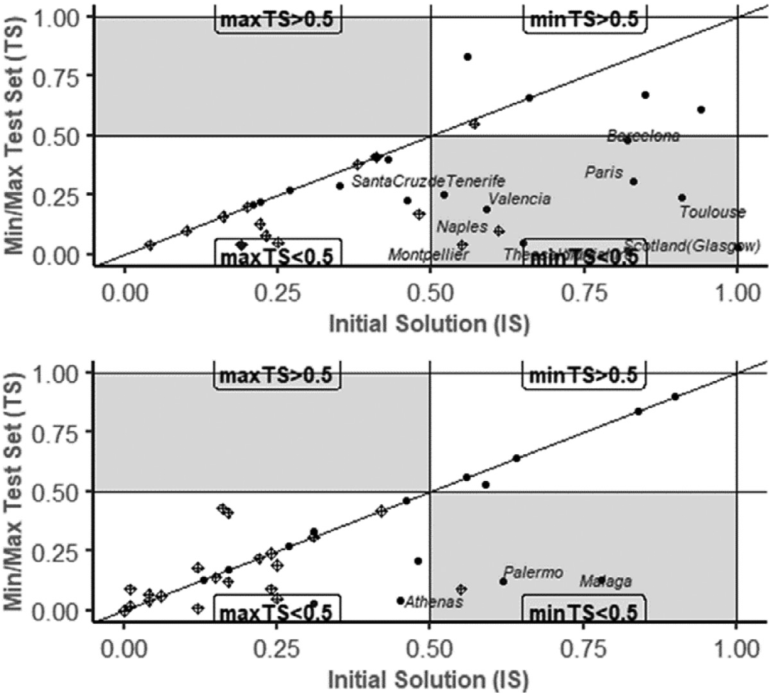

Fig. 1. Robustness plot USE and ∼USE.

second one there is a technological substitution due to the consolidation of the niche. This means that the destabilisation of the regime provides an opportunity for spreading the niche innovation (Ford et al., 2021; Geels, 2019; F. W. 2020), which in our case is micromobility. Regarding the second proposition for the use of micromobility service is accepted as well, as regime level conditions are linked to those consider at a system level.

In terms of explaining the use of micromobility services, the combination of low levels of income, shorter journey times and not using cars are necessary conditions. Furthermore, there are *meso* or regime level variables present such as the ease of locating these types of vehicles, their affordability, how easy they are to park or whether they provide access to areas not served by public transport.

On the other hand, the non-use of micromobility is explained by three conditions. Firstly, in some cities, despite the fact that parking (PARK) is easy, which according to some authors could trigger the use of micromobility (Miramontes et al., 2017; Oeschger et al., 2020), if ∼ACC, i.e., if it does not facilitate access to the first and last mile, the use of micromobility will decrease explaining the non-use of micromobility. This is in line with previous studies that show how this accessibility is one of the main reasons why people decide to make use of micromobility (Fishman et al., 2014). Secondly, non-use would be explained by the fact that although there are conditions that would favour its use such as these means of transport are cheap (AFFOR) (Ji et al., 2017) and easy to park (PARK) (Miramontes et al., 2017), if it is not easy to find these means of transport (∼ EASY) it would cause the non-use of micromobility (Campbell et al., 2016; He et al., 2019; Miramontes et al., 2017; Li & Lai, 2020). As a result, and in line with Fishman et al. (2014), the use of micromobility services is reduced in those areas where accessing them is not easy. Finally, the non-use of micromobility could be explained by the fact that although parking (PARK) may be easier (Miramontes et al., 2017), if the ENT condition does not exist (∼ENT), i.e., high purchasing power level, short distances and less use of the car, the use of micromobility would not occur. That is, although the use of micromobility is not the most expensive means of transport, it is true that the costs associated with its use can be high, which would mean that if the level of purchasing power is not high, its use would be reduced, in line with Ji et al. (2017). Likewise, if distances are long, the use of micromobility will be lower in line with Qui et al. (2018) since this condition is key in the choice of means of transport. Similarly, and linked to the above, if the distance is longer, the use of micromobility will be lower because there will be a greater use of the car as established by Carse et al. (2013) and Basu and Ferreira (2021). Therefore, in the latter case, as stated at the beginning, even though the regime condition occurs if the system-level condition (ENT) does not change, the use of micromobility will not occur. This means that for the case of non-use of micromobility services, propositions 1 and 2 are partially accepted, since they only appear in one of the three prescriptions explaining the non-use of micromobility.

Likewise, the two receipts that explain the use of micromobility show the relevance of the system-level. In any case, improving the regime factors, such as increasing the number of micromobility vehicles or improving access to certain areas by building more suitable infrastructure, could drive a transition towards the use of micromobility, because as previously mentioned, the system-level and niche could be defined in relation to the regime (Krigsholm et al., 2020; Matschoss & Repo, 2020). Furthermore, making cars less convenient to use could be an effective method for increasing the use of micromobility (Fishman et al., 2014). This highlights the need for the niche to overcome its bubble in order to interact with the regime (Hirschhorn et al., 2019; Pangbourne et al., 2020).

Conclusions and contributions

Conclusions

The present study analyses which receipts explain the use and non-use of micromobility using the fsQCA tool and through the use of the MLP. Cities, especially metropolitan ones, continue to grow and need agile and sustainable solutions if they want to achieve an environmental quality that will differentiate them from the rest. Transport is responsible for a high percentage of pollution, which increases the need to make mobility increasingly sustainable. This is why individual or shared micromobility is emerging as a possible solution to the problems that exist in cities (traffic, pollution, noise, etc.). Therefore, analysing the combination of system-level, regime-level and niche-level conditions that explain the use and non-use of micromobility can help organisations to promote appropriate solutions that encourage the use of these services, thus mitigating the negative effects of other forms of transport which produce more greenhouse gas emissions.

In response to the two objectives of this work, firstly, the conditions that determine the use or non-use of micromibility services have been identified. Secondly, this study explains the relationship that exists between the *system-level, regime-level and niche-level* dynamics (MLP), showing the conditions that determine the use (or non-use) of micromobility services. As a result, it can be seen that the use of micromobility in environments with high levels of purchasing power, shorter journey distances or less car usage, increases when micromobility vehicles are easy to find and affordable. Furthermore, the use is explained by the fact that, although it is not easy to find a micromobility vehicle or parking is not easy, the environmental components mean that this form of transport is more attractive. In contrast, the non-use is determined by the combination of regime-level conditions for two of the three receipts, and in the last receipt by the combination of system-level and regime-level conditions. In this sense, the non-use is explained by the difficulty of accessing this means of transport in spite of the ease of finding parking spaces; and also, because, although they are easy to park and affordable, these vehicles are not easy to find. Finally, for those people with low levels of income and who need to travel longer distances, the use of cars is likely to be higher, although the parking of these means of transport might be easier. These results show the key role that system-level and regime-level conditions play in the adoption of micromobility services. Then, the results show that there are several recipes that can explain the use and non-use of micromobility, demonstrating the relevance of QCA epistemological asssumptions (asymmetry, conjunctural causation and equifinality).

Contributions

This study presents both theoretical and practical implications. From a theoretical perspective, the explanatory ability of the MLP has been demonstrated in terms of the adoption of technological innovations such as micromobility services. And, QCA proves to be the most valuable method for applying the MLP as it makes identify the relationships that exist between the system, regime and niche level dynamics. Similarly, this study allows to affirm the effectiveness of the fsQCA methodology in the face of complex outcomes such as the adoption of a micromobility service. This is because it gives different types of solutions that can reach the same result while showing how the use and non-use of micromobility is asymmetric, i.e., it is not usually explained by the opposite positions. Likewise, the application the robustness test makes it possible to verify how the solution that explains the non-use of micro-mobility services is more robust. Finally, the Two-Step Approach has enabled us to work with a greater number of conditions without suffering from the problems that can arise from having logical remainders.

In terms of practical implications, this study demonstrates how micromobility operators should apply criteria linked to the system-level in order to identify new urban areas in which to implement their services, as these seem to determine the use of micromobility services. In fact, a first group of cities is identified in which micromobility vehicles are used daily, despite difficulties parking and locating them. When looking at the areas in which they are implemented, with the aim of increasing usage, it is not enough to increase parking areas, but rather it is better to focus on improving accessibility and making it easier to use micromobility devices. Therefore, improving the regime-level factors, such as increasing the number of micromobility vehicles or improving access to certain areas by building more suitable infrastructure, could drive a transition towards the use of micromobility, because as previously mentioned, the system-level and niche-level are defined in relation to the regime-level. Furthermore, making cars less convenient to use could be an effective method for increasing the use of micromobility. This could be done through the payment of a fee for all those who travel alone or for those living for example in areas well served by other more sustainable means of transport and do not make use of them. From a different perspective, one could also bet that innovations in micromobility seek alignment with the regime as well as the development of synergies with classical micromobility alternatives. One way to do this is through mobile applications that allow users to manage and control the different existing transport modes and their connections from a single application, known as MaaS.

Limitations and future research

The main limitation of this study is having primarily relied on a single source of data. It would be interesting to apply an additional source in order to include more urban areas as well as additional conditions. As demonstrated in the article, culture determines the perception of different micromobility services. Therefore, it would be interesting to carry out this study in cities in other continents, not only in Europe as on this occasion, to see if the results are applicable to other continents. Furthermore, investigating the accessibility of these micromobility services for disabled people would be a challenge in itself. Currently no studies have been found that explore micromobility and the accessibility of these services for disabled people, as established by goal 11 of the SDGs: “to make cities inclusive, safe, resilient and sustainable”.

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