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Built environment and micro-mobility: A systematic review of international literature

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Abstract: Recent innovations in business models and technology have brought out new mobility systems, including shared and electric micro-mobility. A rapidly expanding strand of literature mirrors the micro-mobility's exponential growth and popularity. While many studies analyze micro-mobility from operations, management and user perspectives, fewer works investigate the micro-mobility and built environment (BE) relationship. This paper systematically reviews the descriptive and empirical studies that investigate this relationship. It analyzes whether, similar to other transportation modes, micro-mobility (e.g., bike-sharing schemes and e-bikes/e-scooters) can potentially influence three BE aspects: urban design, land use, and transportation system. Furthermore, it outlines the recommended changes in the BE to support the micro-mobility and/or enhance the quality of the environment for non-users. This paper investigates the BE and micro-mobility relation at the three levels of node (e.g., the emergence of docking stations and parking stops), link (e.g., the street-level conflicts with walking/cycling/vehicle lanes) and network (e.g., infrastructure network creation and catchment area shifts). In addition, this relation is explored over time, based on the development stage of micro-mobility, the BE aspect (urban design, land use, or transport system), and spatial context (urban or rural). The findings are relevant for urban and transport planners, designers, researchers, policy makers and public authorities. They contribute to a much-needed evidence base for effective design and policy recommendations to accommodate micro-mobility in the BE to achieve a safe and inclusive public space.

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1 Introduction

In recent years, cities have witnessed the widespread introduction of various new personal transport modes, generally referred to as micro-mobility, which are low-powered lightweight utility vehicles used in a communal system. The new micro-mobility market shows a significant increase, and is predicted to grow in the coming years.

The global e-bike market has been growing for the past few years and is expected to keep expand-

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ing at a compound annual growth rate of around 9%, with the Asia Pacific region as the largest market (Ashish, 2019). Meanwhile, the global shared bike and scooter market is also projected to grow at a compound annual growth rate of around 19%. The shared bike segment is expected to take the lead in the market as its influence grows in China (Markets, 2019).

A rapidly expanding strand of literature on micro-mobility mirrors its exponential growth and popularity. Many studies have analyzed micro-mobility from the management and operation perspective (e.g., Bai & Jiao, 2020; Laa & Emberger, 2020), or user perspectives, such as travel behavior, user experience and social impacts (e.g., Bai & Jiao, 2020; Chen et al., 2020; Faghih-Imani & Eluru, 2015). However, fewer studies investigate the relation between micro-mobility and the built environment (Lyons et al., 2019; NACTO, 2019; Zagorskas & Burinskienė, 2019).

The "built environment" (BE), as defined by Handy et al. (2002) encompasses patterns of human activity within the physical environment and includes the following three aspects:

(1) Urban design, which includes the design of the city and its physical elements and is concerned with both the function and appeal of public space;
(2) Land use, which refers to the location, distribution and density of activities (e.g., residential, commercial, office) across the space;
(3) Transportation system, which includes both the physical transport infrastructure (such as roads and bike/pedestrian paths) and the provided level of service that can be determined by e.g., traffic levels, bus frequencies, etc.

New transportation systems are argued to impact the BE and eventually travel behavior (Du, van Wesemael, & Druta, 2021). This relationship is underpinned by the land use-transport feedback cycle (Figure 1) which posits that the introduction of a new or improved transportation system changes the accessibility of locations, by modifying the costs (in terms of money, time or comfort) of reaching them. Accessibility is the extent to which transport systems enable individuals to reach destination (Geurs & van Wee, 2004). The change in accessibility affects land-use patterns which in turn influence how people travel and eventually induce demand for further improvements in the transportation system (Wegener & Fürst, 2004). This cycle happens in phases with different speeds and is furthermore influenced by a host of exogenous factors such as mobility and spatial policies, existing demand and user attitudes.

Whether a transportation system impacts BE, and the impact's type and significance vary based on a host of factors including the type of transportation system, its maturity and the spatio-temporal scale of investigation (Kasraian et al., 2016). Thus, the transportation and BE relation, when existing, can have different extents, be direct/indirect and/or local/regional, as well as short and/or long term (Saxe & Kasraian, 2020). Furthermore, from a spatial perspective, the relations can be distinguished at three scales: the node, the link and the network levels. The node level concerns clustered transport facilities such as stations and parking spots. The link level includes thoroughfares like streets, while the network level is comprised of interconnecting nodes and links.

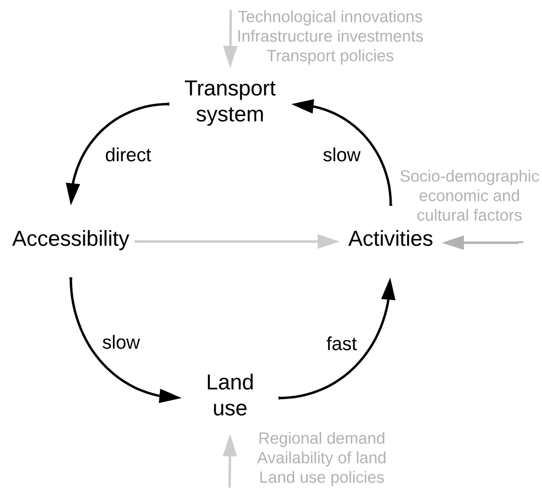

Figure 1. The land use-transport feedback cycle (Wegener & Fürst, 2004; adapted by Bertolini et al., 2012)

Transportation systems can directly change BE at the node and link level as they require demolishing previous infrastructure or land clearing. For instance some first railways were built on the location of city ramparts and many highways initially severed the existing urban fabric. Furthermore, nodes and links of transportation systems can stimulate local land-use changes in their vicinity in the longer term. For example, proximity to highways is shown to encourage (sub)urbanization and an increase in commercial and industrial development (Kasraian et al., 2016). Finally, transportation systems can have network-level influences that go beyond their direct and local vicinity. This indirect impact is known as the "spillover effect" and is due to the network characteristic of transportation systems. Accordingly, changes in a specific part of a transportation system not only modify the accessibility of that link or node and the BE in its direct vicinity, but have consequences for network-level accessibility and could induce BE change in other locations (Giuliano, 2004).

On the other hand, there is also a reverse relation where certain BE characteristics are found to be conducive to the use of certain transportation systems. This relationship has long been investigated in the transportation and land use community and the influential BE characteristics are usually classified as the so-called "D" variables (Density, Diversity, Design, Destination accessibility, Distance to transit) (see e.g., Ewing & cervero, 2010). BE can impact travel behavior, such as travel mode choice, trip frequency, and trip distance, etc. For example, a well-connected and nicely designed sidewalk system may encourage people to choose walking over other travel modes. Finally, changes in the BE are required to integrate the new micro-mobility in a manner that benefits both users and non-users (e.g., pedestrians and car drivers). The introduction or expansion of new micro-mobility should not compromise the travel experience of non-users by causing any inconvenience (e.g., blocking paths, endangering safety). For users, the changes in the BE are required to support the use of micro-mobility.

While the BE-transport relation is thoroughly investigated for mature systems like road and transit, speculations and empirical evidence on this relation in the case of micro-mobility are relatively scarce. Thus, this paper focuses on micro-mobility as the transportation system in the land use-transport feedback cycle. It poses two research questions on the BE-micro-mobility relationship, and answers them by a systematic review of state-of-the-art literature:

(1) How does micro-mobility (potentially) change the BE over time?

(2) How could changes in the BE support micro-mobility and/or enhance the quality of environment for non-users?

The first research question addresses the left side of the land use-transport feedback cycle (Figure 1), while the second research question concerns the right side. The right side of the cycle, i.e, the direct effect of the built environment on micro-mobility systems is less investigated compared to its left side. Some studies investigate the consequences of the relationship for travel behavior, while it is a topic for a literature review in its own right. Furthermore, some work on the subject exists. For example, Guo et al.(2022) have reviewed the studies investigating the effect of BE on shared bike usage. A more comprehensive review including all micro-mobility types is recommended as an avenue for future research. Most of the reviewed studies in this literature review on the second research question provide recommendations on how the BE can support the introduction or expansion of micro-mobility (e.g., parking or sidewalk spaces are suggested to be reutilized into parking spaces for shared micro-mobility to have an equal distribution of parking for different modes in the long term (Crum & Brown, 2019)), or which requirements the BE needs to meet to support this (e.g., more stations are needed to support the shared bike system at Washington (Ahillen et al., 2016)). The studies on how BE impacts travel behavior and the use of micro-mobility are not included in this study.

Investigating the BE and micro-mobility relation is complicated for two main reasons. First, micro-mobility is a recent phenomenon and changes in the BE are slow processes that usually take time to materialize, especially when indirect and regional changes are involved. Second, many decisions on the accommodation of micro-mobility in cities depend on local authorities. So the exogenous factors of spatial/mobility policies play a stronger role than market forces (unlike, for example, the market driven BE changes in the case of the first railways introduced by private companies). Nevertheless, to plan for the integration of micro-mobility in our cities and to address its already emerging BE challenges, we need to understand its (potential) impacts and the needed changes in the BE to best support users and non-users. This understanding is vital for urban and transport planners, urban designers, policy makers and public authorities for introducing effective design and policy recommendations to accommodate micro-mobility in the existing and developing built environment. Many cities have been responding to the expansion of micro-mobility in an improvised and reactive manner (Madapur et al., 2020; Ramboll, 2020). Evidence-based design and policy measures are increasingly needed to guide the integration of micro-mobility in a manner that benefits from its potentials while limiting its disadvantages, to achieve a safe, lively and inclusive built environment in general and public space in specific. The state-of-the-art findings are also of use to the transportation and urban scientific community and industrial operators adopting and adjusting their systems.

1.1 Scope

This paper reviews studies from different parts of the world that have considered the BE and micro-mobility relationship. The micro-mobility type is limited to the two-wheelers that have emerged recently due to technological and business model innovations and have an expanding market. These include shared bikes, (shared) e-bikes, and (shared) e-scooters (Figure 2). A wide variety of micro-mobilities with different designs and appearances can be available. In this paper, e-bikes refer to the bicycle-style e-bikes. The bike-sharing systems could be categorized as the docked and dockless (Ma et al., 2020). In the docked bike-sharing system, users have to rent and return the bikes to designated docking stations, while for dockless bikes, returning to the original location is not necessary. Electrically assisted bicycles (e-bikes) provide motor power and enable the user to maintain cycling speed with less effort, overcoming barriers to traditional cycling (Bourne et al., 2020). E-scooters include both the stand-up and the moped-style e-scooters (Gössling, 2020). The (stand-up) e-scooter has a handlebar and electric powered wheels, while the moped-style e-scooter has a seated design and bigger electric wheels. Most of the reviewed studies on scooters investigate the stand-up e-scooter, which is now available in cities worldwide (Gössling, 2020). Both shared micro-mobility, such as the dockless bikes and docked bikes, and personal micro-mobility, such as personal e-scooters and e-bikes, are included in this study. In this paper, if the terms "deckles," "docked," or "shared" are not explicitly mentioned, the means of micro-mobility under discussion is personal micro-mobility.

The micro-mobility and BE relations are investigated at the node, link, and network levels. The node level concerns clustered transport facilities such as docking stations and parking spots. The link level includes thoroughfares like streets and traveling paths, their layout and the flow of vehicles related to them (micro-mobility's interaction with motorized vehicles or pedestrians is also considered at this level). The network level comprises interconnecting nodes and links and network characteristics like spatial coverage and layout.

This paper reviews international studies from countries that have introduced micro-mobility at different times. This makes it possible to compare micro-mobility in different development stages (maturity), which provides insights into whether the micro-mobility and BE relationship changes over time and spatial context.

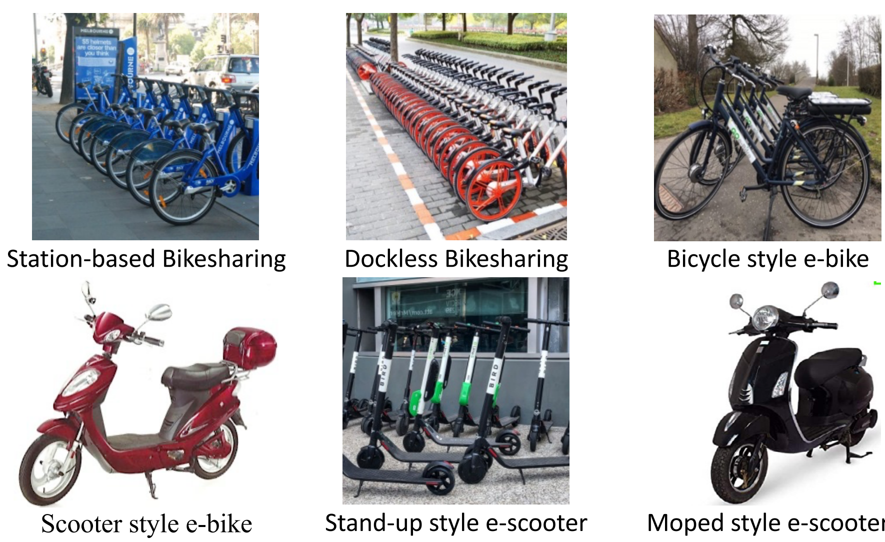

Figure 2. Types of investigated micro-mobility: station-based bike (Cyclehelmets, 2011); dockless bike (Alta, 2017); bicycle style e-bike (Canyon, 2022); stand-up style e-scooter (Hawkins, 2018); scooter style e-bike (Jamerson & Benjamin, 2012); moped style e-scooter (Nandini, 2020)

The paper is structured as follows. Section 2 reviews the basic characteristics of the studies, including the study time, study area, and indicators. Section 3 summarizes the findings. Section 4 provides the conclusion, discusses how the micro-mobility and built environment relation differs over time and space and indicates avenues for future research.

2 Study characteristics

2.1 Search strategy and eligibility criteria

Studies were identified by searching the Web of Science, Scopus, and Google Scholar using combinations of the keywords: "shared micro-mobility," "shared bike," "dockless bike," "shared scooter," "e-scooter," "e-bike," "pedelec," "space," "urban form," "built environment," and "land use." The resulting papers' titles, keywords and abstracts, and eventually full texts were reviewed to exclude the papers that do not answer our two research questions. Thus only literature on the BE impact of micro-mobility or studies on the requirements that the BE needs to fulfill to support micro-mobility are included. Additional papers were added following backward and forward snowball methods by exploring the references and citations of already selected papers. After all steps, 59 literature sources were identified for review.

The reviewed literature comprises three main study types (Table 1). The first group, which is smallest, comprises (I) empirical studies that report actual changes in the BE due to the introduction of micro-mobility (n=24). Most of these studies are based on descriptive observations and interviews rather than statistical analysis. The second and third groups are (II) empirical (n=29) and (III) descriptive (n=13) studies that do not directly measure actual changes in BE. However, they provide recommendations for incorporating micro-mobility in BE that, if carried out, would lead to changes in BE. Some studies mention both actual changes and recommendations. Most reports belong to the last group.

2.2 Study time and development stage

About three-quarters of the studies are published between 2019 and 2022, which corresponds to the rapid expansion of shared micro-mobility in recent years. Few studies are carried out before 2018. Most of these studies are about the bike-sharing systems in the US, including the Smartbike, Capital Bikeshare, and Citi Bike share program which were introduced around 2010 (Ahillen et al., 2016; Buck & Buehler, 2012; NACTO, 2016; Smith et al., 2015).

Although most of the studies are carried out in similar years, they vary in terms of the development stage of the micro-mobility. Some works study micro-mobility's early development phase, e.g., the first 18 months of the bike-sharing system operation in Washington (Ahillen et al., 2016), or 8 months after the introduction of the bike-sharing system in Shanghai (Tu et al., 2019). On the other hand, others have investigated the BE and micro-mobility relation after it is well integrated into the city. For instance, Stowell (2020) investigates the transport equity impact of the shared micro-mobility in the US cities, including shared bikes and e-scooters, after more than a decade of their introduction.

2.3 Study area

This paper reviews studies originating from different parts of the world. Most of the studies (48 out of 59) are about micro-mobility in Europe, North America and Asia. There are more studies about (shared) e-scooters in Europe than studies about shared bikes, while studies in Asia are the opposite. This distribution corresponds with the Europe and Asia having the biggest e-scooter and shared bike markets respectively (Prescient and Strategic Intelligence, 2019).

Most of the studies are at the municipality level, while few are at the regional level. Some studies investigate the shared micro-mobility across different land uses and degrees of urbanity. For instance, Ma et al. (2020) report the differences of shared bikes in five districts of the city of Nanjing while distinguishing between the suburban, entertainment and tourist areas.

3 Results and discussions

Table 1 summarizes the types of reviewed studies, their investigated micro-mobility and BE elements and outcomes formulated as positive/negative relationships (for empirical studies) or optimistic/pessimistic views (for descriptive studies). The findings are elaborated in the next sections under the three BE categories of node, link and network. To address our two research questions, the reviewed studies include i) those investigating how micro-mobility could potentially influence the BE, and ii) studies that suggest requirements for the BE to support micro-mobility. Each section starts with the empirical findings on the potential influence of micro-mobility on BE and proceeds to the requirements and recommendations for changes in the BE to support micro-mobility and/or enhance the quality of the environment for non-users.

Table 1. Overview of the reviewed studies

No.	Author, year	Study area	Introduction time	Methods (data collection, analysis)	Type	BE level	bike	e-scooter
1	Laa & Emberger (2020)	Vienna, Austria	2003	Expert interviews, literature review	I/II	1	–	
2	Butrina et al.(2020)	US	NA	Semi structured interview	II	1,2	–	–
3	Fitt & Curl (2020)	New Zealand	2018	Quantitative survey	II	2		–
4	Gössling (2020)	ten major cities, worldwide	NA	Media report analysis	II	1		–
5	Buck & Buehler (2012)	Washington, DC, US	2010	Usage data, regression analysis	II	1,2	–	
6	Tuncer & Brown (2020)	Paris, France	2018	Travel video recordings	I	2		–
7	Lipovsky (2020)	Paris, France	2018	Media report analysis	I/II	2		–
8	Severengiz et al. (2020)	Bochum, Germany	2019	Scenario analysis	I	1		+
9	Zagorskas & Burinskienė (2019)	Worldwide	NA	Descriptive analysis	III	1,2	+	+
10	Shen et al. (2018)	Singapore	2016	App based travel data, additive mixed model	II	1,2	–	
11	Maas et al. (2020)	Las Palmas de Gran Canaria	2016	Questionnaire, trip data, descriptive analysis	II	1,2	–	
12	Ma et al. (2020)	Nanjing, China	2017	Trip data, regression analysis	II	1	–	
13	James et al.hh (2019)	Rosslyn, Virginia	2017	Survey, observational study	I	1,2		–/+
14	Tu et al. (2019)	Shanghai, China	2016	App based travel data, additive mixed model	II	2	–	
15	Sun (2018)	Beijing, China	2015	Interview and document analysis	I/II	3	+	
16	Crum & Brown (2019)	Eugene, US	2018	Document and trip data, descriptive analysis	III	1,2	–	–
17	Liu et al. (2019)	Hangzhou, China	2008	Correlation analysis and regression analysis	II	1	–	
18	Shaheen & Cohen (2019)	US	2007	Document analysis	III	1	–	–

No.	Author, year	Study area	Introduction time	Methods (data collection, analysis)	Type	BE level	bike	e-scooter
19	Wood et al. (2019)	US	2017	Document analysis	III	1,2		–
20	Zhuang et al. (2019)	Shanghai, China	2016	Data mining, cluster analysis	II	1,2,3	–	
21	Guo & He (2020)	Shenzhen, China	2016	Trip data, negative binomial regressions	II	1,2	–	
22	Turoń & Czech (2019)	Worldwide	NA	Descriptive analysis	III	1		–/+
23	Zhu et al. (2019)	Wuhan, China	2009	GPS data and document analysis	II	1	–	
24	Markvica et al. (2020)	Vienna, Austria	2019	Survey, triangulation research	II	1		–
25	Smit et al. (2015)	US	2012	Spatial regression models	I	1	–	
26	Tuncer et al. (2020)	Paris, France	2018	Video-ethnographic study	I/II	1,2		–
27	Ruhrort (2020)	Berlin, Germany	2019	Descriptive analysis	III	1,2	–	–
28	Ahillen et al. (2016)	Washington, DC and Brisbane, Australia	2010	Usage data, descriptive analysis	II	1	–	
29	NACTO (2016)	US	2010	Trip data, descriptive analysis	II	1,2,3	+	
30	Zou et al. (2020)	Washington, DC	2017	Usage data, exploratory analysis, regression analysis	II	1,2		–
31	Stowell (2020)	Washington, DC	2010	Descriptive analysis	III	1,2	–	–
32	Shaheen et al. (2011)	Hangzhou, China	2008	Intercept survey analysis	II	1	–	
33	Gioldasis &Christoforou (2021)	Paris, France	2018	Street travel survey	II	2		–
34	Fang et al. (2018)	San Jose, US	2017	Descriptive analysis	III	1		–/+
35	Laa & Leth (2020)	Vienna, Austria	2019	Online survey and field survey	II	2		–
36	Norcliffe & Gao (2018)	Beijing, China	2015	Descriptive analysis	III	1,2	–	
37	Yuan et al. (2017)	Beijing, China	2015	Travel survey	II	1,2	–	
38	Tang et al. (2020)	Nanjing, China	2017	Video based travel data analysis	I/II	2	–	–
39	Jin et al. (2015)	Hangzhou, China	2008	Field and video based travel data analysis	I	2	–	
40	Tan & Tamminga (2021)	Washington, DC	2010	Scenario analysis	II	2	–	–
41	Collado et al. (2014)	Gothenburg, Sweden	2010	Travel survey data analysis	II	1,2	–	
42	Glass et al. (2020)	Birmingham, US	2015	Trip data analysis	I	3	+	
43	Bennett et al. (2021)	US	NA	Semi structured interview	I	1	–	
44	Hechemer et al. (2022)	Munich, Germany	2016	Trip data, point clustering method	I	1	–	
45	Bach et al. (2023)	Barcelona, Spain	2016	Semi structured interview	I/II	1,2		–
46	Waitt et al. (2022)	Sydney, Australia	2020	Semi structured interview, sensory analysis	II	2	–	

No.	Author, year	Study area	Introduction time	Methods (data collection, analysis)	Type	BE level	bike	e-scooter
47	Svichynska et al. (2023)	Dnipro, Ukraine	2021	Travel data analysis	I	1		–
48	Ballo (2022)	NA	NA	Expert interview, descriptive analysis	III	2	–	
49	Tao & Zhou (2021)	Shanghai, China	2017	Scenario based analysis	I	1,2	–	
50	Li et al. (2021)	Shanghai, China	2016	Spatial regression models	I	3	+	
51	Beairsto et al. (2022)	Glasgow, UK	2014	Travel data analysis	I	1	–	
52	Zaffagnini et al. (2022)	NA	NA	Descriptive analysis	III	3	–	–
53	Pistelok & Štraub (2022)	Cracow, Poland	2021	Survey, field work	I	1		–
54	Li et al. (2022)	Nanjing, China	NA	Regression analysis	I	3	+	
55	Fearnley (2021)							
NA	NA	Descriptive analysis	III	1,2	–	–		
56	Zhang & Song (2022)	New York, US	2013	Gaussian Mixture Model	I	1	–	
57	Bajolle et al. (2022)	France, Belgium, Switzerland	NA	Qualitative interview	I	2	–	
58	Hurtubia et al. (2021)	Santiago, Chile	2014	Survey, discrete choice model	I	1	–/+	
59	Bai & Jiao (2021)	Austin, US	2018	Population distribution analysis	I	1		–

Notes: Built environment (BE) elements studied: 1 = node; 2 = link; 3 = network
Relationship between BE and micro-mobility: + = positive/optimistic (suggests that the emerging micro-mobility could improve the current BE); - = negative/pessimistic (indicates negative outcomes and a need for changing the BE to adapt to micro-mobility). Positive and negative relationships are shown by empirical studies, optimistic and negative views are expressed by descriptive studies.
Type of study: I = empirical study of micro-mobility BE relation; II = empirical study which suggests implications for BE; III = descriptive study which suggests implications for BE
Bike category includes docked and dockless as well as not shared e-bikes; E-scooter category includes shared and not shared e-scooters
NA: information is not specified in the literature

3.1 Micro-mobility and BE at the node level

3.1.1 Docked bikes and scooters

With the development of the docked bike-sharing system, docking stations are increasingly built in public spaces to support the rising number of docked bikes. Initially limited docking stations are observed to significantly grow following the success of the bike-sharing systems in Washington, DC, (Buck & Buehler, 2012) and Vienna (Laa & Emberger, 2020).

The importance of dedicated infrastructure including shared bike stations for the shared bike system is emphasized by several researchers (Laa & Emberger, 2020; Maas et al., 2020). Furthermore, different locations have different needs for the docking stations and require different planning strategies. Buck and Buehler (2012) suggest additional stations to be built at high population density areas and retail destinations, based on an empirical analysis of trip data. They also conclude that more stations could be built along bike lanes to encourage ridership. Beairsto et al. (2022) report that new sharing bike stations should be placed at high demand areas to maximize accessibility and coverage of the stations and serve the greatest population. Liu et al. (2020) report that the number of docking stations should be increased in the educational land uses in Hangzhou to encourage public bicycle trips, while it is not necessary for residential and industrial land uses.

As the micro-mobility systems mature, studies are emerging that investigate the evolution of these systems and their growth trajectories. Zhang and Song (2022) indicate that the number of docking bike stations have increased in the long run with fluctuating patterns after they began to operate and that a high degree of land-use mix might contribute to the high growth of docking bike stations. Svichynska et al. (2023) introduce an approach to define the number and location of e-scooter sharing stations and the rationality of adding new stations based on the added convenience to recharge e-scooters. Analyzing the location of current stations and the potential new stations guides evidence-based decision making of public space and street design to ensure the safety of pedestrians and road users.

Besides the regular station-based shared bike, there is also a mixed bike-sharing system with no specific stations. In this system, bikes have to be rented and returned at certain designated locations. Several works investigate the methods for accommodating the parking need for mixed sharing bikes at suitable locations. For instance, Laa and Emberger (2020) report that while using racks for mixed sharing bikes is legal in Vienna, it takes away space from private bikes. To solve this, a bike parking rack redistribution system is installed to ensure enough capacity for both shared and private bikes. Guo and He (2020) report that Shenzhen builds designated parking rings for shared bikes around metro stations and bus stops. Shared bikes do not have to be returned at specific stations but need to be returned to one of the parking rings. Here, the location of the parking rings is calculated by a Kernel density approach using the extracted location data of bikes. Pistelok and Štraub (2022) report that shared scooter providers at Poland introduced signs and road markings with pictograms to outline the dedicated area for parking. Zhuang et al. (2019) introduce the electronic bike parking fence concept that uses GPS and other locating techniques to ensure that shared bikes are parked at regulated positions. They conclude that the electronic bike fences could be built in well-selected locations considering the land use and the existence of other cycling infrastructures. Hechemer et al. (2022) report a geofence design which is used to reduce bikes blocking other road users. From the operators' perspective, Ruhrort (2020) concludes that they favor designated parking locations over fixed stations, and they prefer to offer flexible use of space to their users. From user perspective, Hurtubia et al. (2021) report that the presence of shared bike stations has a positive impact on the perception of neighborhood image.

3.1.2 Dockless bikes and e-scooters

The changes brought by dockless bikes and e-scooters are grouped as they are quite similar. Unlike the docked bike, the dockless bikes and e-scooters do not have to be parked at specific stations or racks. Users have a certain amount of freedom to choose where to park the vehicle after use. This saves users walking distance from the bike station to their destination (Cheng, 2018), but could have a negative effect, such as the issue of parked bikes or e-scooters blocking the footpath. Laa and Emberger (2020) report the phenomena of dockless bicycles on narrow sidewalks, which block the footway for pedestrians in Vienna. They also explain the situation of damaged bikes that could not be used anymore and take up public space. Shaheen and Cohen (2019) and Bai and Jiao (2021) report the challenges which shared micro-mobility presents for people with disabilities, such as shared micro-mobility blocked wheelchair ramps. On the other hand, James et al. (2019) have a more positive view and consider a small amount of impeding e-scooters to be a minor nuisance, depending on local conditions.

Increasing numbers of dockless bikes and e-scooters are also taking up the parking space designed for other modes like private bikes, scooters, or cars. Severengiz (2020) uses empirical data to investigate how space could be re-distributed depending on different travel patterns. He concludes that traffic and parking space demand could even increase if the shared e-scooter is perceived as an alternative to other travel modes such as public transport, walking, and cycling. However, the traffic and parking space demand could decrease if shared e-scooter and public transport form an intermodal mobility service. Laa and Emberger (2020) report that Amsterdam city banned all dockless bikes in August 2017 because they took away too much parking space from private bikes. They also note that dockless bikes parked at driving lanes designed for motor vehicles could cause car and motorcycle drivers to resent the shared micro-mobility. Ruhrort (2020) reports that one borough of Berlin has turned some car parking areas into parking spaces for the shared e-scooters, due to the increasing demand. Crum and Brown (2019) recommend the cities of Eugene and Gresham to reutilize current parking or sidewalk spaces into parking spaces for shared micro-mobility and to have an equal distribution of parking for different modes in the long term.

There are also studies about the shared micro-mobility and public space relation from an aesthetic perspective. Laa and Emberger (2020) conclude that the indiscriminate parking and clutter with the striking colorful dockless bicycles has a negative impact on the cleanliness of the public space. Zhu et al. (2019) worked on a project to build a shared bike parking spot on the campus, which could not only protect the shared bikes from sun and rain but also improve the aesthetics of the campus. The canopy and frame are designed with a beautiful appearance and unique shape to be aesthetically pleasing.

To mitigate the improper parking issue of the shared micro-mobility, different policies and management strategies are carried out. Shaheen and Cohen (2019) suggest cities to adopt policies that encourage e-scooters to be parked on private property, such as the bike or car parking spaces provided by the residential developers. Laa and Emberger (2020) contend that cities need to remove the damaged or illegally parked bikes (e.g., Vienna removed 129 shared bikes from September 2017 until June 2018, Melbourne removed 134 bikes from mid-October 2017 to the end of May 2018, and Xiamen removed more than 10,000 bikes in January 2018). Guo and He (2020) report that due to the spatial and temporal variation of the dockless bike use, operators need to relocate them regularly to maintain the short search time for bikes and mitigate the cluttering problem. Shaheen and Cohen (2019) recommend more stringent parking regulations only when micro-mobility blocks the access for pedestrians or people with disabilities.

3.2 Micro-mobility and BE at the link level

3.2.1 Shared bikes

With the increasing number of shared bikes in public space, more cycling facilities including dedicated bike lanes are needed to promote the shared bike system growth. Guo and He (2020) report that there are not sufficient numbers of bike lanes in Shenzhen and many cyclists, including shared bike users, use the footpaths or motorized vehicle lanes, which is dangerous. To solve this issue, the Shenzhen government plans to build 600km bike lanes by the end of 2020 to support the Mobike bike-share program. Maas et al. (2020) conclude that it is essential to have dedicated cycling paths. Some areas have improved/implemented bike networks to serve the bike-sharing system. Shen et al. (2018) report that the rapid growth of the shared bike system is not sustainable due to the limited public space and road resources. Operators and the government could use the bike trip data to calculate the new bike lanes' potential location. These new built bike lanes could also potentially benefit other shared micro vehicles, such as shared e-scooter. Most studies show that more bike lanes are needed to encourage ridership (Maas et al., 2020; Wang & Chen, 2020; Zhang et al., 2017), however, there are studies that find it not necessary (Ding, 2016; Wang et al., 2016). These studies are carried out in European cities where cycling is ubiquitous and shared bike users are less affected by the presence of bike lanes (Martens, 2007).

In several studies, it is recommended to build bike lanes separated from motorized vehicles for shared bikes. Maas et al. (2020) report that shared bike users feel the safest using separated bike paths, contrary to motorized vehicle paths and footpaths and thus it is crucial to have dedicated cycling infrastructure, including separated cycling paths. This response varies by gender. Females feel more unsafe than males on the motorized vehicle path. It is also found that shared bike users without a private bike show a stronger preference for separated cycling paths due to less cycling experience.

A bike-friendly environment is important for the bike-sharing system. Guo and He (2020) suggest that to encourage the bike-sharing system, the Shenzhen government might need to improve the cycling environment, including better road conditions, a better connection of cycle paths, and fewer intersections. Tu et al. (2019) conclude that the density of intersections has a negative impact on the dockless trip density in shanghai. To promote dockless bike use in shanghai, the street connectivity and quality of the intersection need to be upgraded to improve the cycling experience.

3.2.2 E-bikes

Due to the electric assistance, an e-bike could reach a higher speed, leading to higher safety requirements for the traveling path. Some studies investigate how e-bikes interact with other modes using the same space. Norcliffe and Gao (2018) report that the number of e-bikes in Beijing has grown rapidly over the years. However, the spread of e-bikes has triggered the clash between e-bike users and other mobility users, especially motorized vehicle users, over priorities on the road. E-bike users sometimes travel in the motorized vehicle lanes, while motorized vehicles frequently park in and block the lanes reserved for e-bike users. Waitt et al. (2022) report that shared speed and performance of the travel modes play a critical role in asserting a right to the road stabilizing the spatial order of public space.

Van den Steen et al. (2019) report that due to the unfamiliarity with traffic regulations for speed pedelecs (fast e-bikes that could reach 45 km/h), their users are often confused about whether they should use the bike path or the motorized vehicle path. Users perceive it dangerous to share the bike path with slow mode users or to share the motorized vehicle path with cars due to possible conflicts. Bajolle et al. (2022) report that speed e-bikers consider themselves as cyclist and value the opportunity to ride on cycle lanes. Furthermore, this also depends on their actual speed and weather they want to accelerate. Jin et al. (2015) present a more optimistic view. They contend that the size and speed differences between regular bicycles and e-bikes inevitably lead to safety concerns for bicycle and e-bike users and cycleway capacity efficiency optimization issues. However, the result shows that the estimated cycleway capacity increases with an increased proportion of e-bikes because the higher free flow and speed of e-bikes means a larger capacity and a more stable bicycle operation.

There are several studies about the lane design for e-bikes. Based on an analysis of travel behavior data, Tang et al. (2020) recommend urban designers to account for adequate sight distance at e-scooter and e-bikes at intersections. Furthermore, removing horizontal curvature or vertical grade, can improve the safety performance of e-bikes and e-scooters in existing intersections. For e-bikes sharing the lane with other transportation modes, Tan and Tamminga (2021) propose an adaptive lane design with fast and slow functions to fit the mixed streaming, including the increased presence of micro-mobility on urban streets. Ballo (2022) propose a e-bike city concept relocating large part of existing road space from car to cycling and dealing with large flow of various electric micro-mobilities.

3.2.3 Shared e-scooter

A number of studies analyze how the shared e-scooters impact the use of footpaths and walking routes. Fitt and Curl (2020) provide an empirical investigation of the mismatch between user e-scootering practices on the footpath and footpath space availability for shared e-scootering. Their survey shows that most of the shared e-scooter users are using the footpath, while the footpath is considered the least suitable option for e-scooters. They highlight the issue of shared e-scooters using the footpath, especially the concerns from pedestrians and those with disability. This issue might be resolved by changing the perception of using e-scooters on the footpath, or the e-scootering space's materiality. Fearnley (2021) report that e-scooter users may take to the sidewalks for reasons of traffic safety and accessibility rising conflicts between pedestrians and e-scooter users. Tuncer et al. (2020) discuss the conflict between shared e-scooter users and pedestrians as public space users, how the e-scooter users interact with pedestrians and social equity in access to public space. They show that in Paris, shared e-scooters move through routes where walking is the dominant form of mobility, which causes sensitive visual and auditory contact between the e-scooter user and the pedestrian. Lipovsky (2020) carried out a survey about how pedestrians feel about the shared e-scooter trip in Rosslyn, US. It finds that most of the pedestrians feel unsafe around e-scooter riders, especially pedestrians who have never used an e-scooter before. In response to the concerns from shared e-scooters using the footpath, countries have rolled out different actions. France released a national ban on driving e-scooters on sidewalks in September 2019. Madrid city government removes the shared e-scooters from the street, due to the improper areas that scooters are used (Zagorskas & Burinskienė, 2019).

Some studies investigate how shared e-scooters use the bike lanes. Wood et al. (2019) report that in some US cities, there are no designated travel paths for the shared e-scooters, leaving riders to use bike lanes. However, in many parts of the cities, there is not enough place for bike lanes. Cities must therefore find a way to ensure this new travel mode's integration into a broader transportation network. Crum and Brown (2019) report that in the US shared e-scooters mostly use the bike lane, which should be called more appropriately as a micro-mobility lane or mixed-use micro-mobility lane. However, there are still safety risks since the micro-mobility lanes are not always separated from cars. From a long-term perspective, it is recommended to have protected micro-mobility lanes, which unfortunately are not always feasible. Zagorskas and Burinskienė (2019) also suggest separated lanes for bikes and e-scooters. The design of these new lanes must consider the higher speed of e-scooters and if possible, with the provide divisions for different speeds.

The development of the shared e-scooter system could also change the travel space of motorized vehicles. James et al. (2019) report that motorized vehicle drivers are not used to the shared e-scooter, as it is a new mode of transport. Nevertheless, they also present a relatively positive idea that safety might increase with increasing e-scooters. This idea is supported by the 'safety in numbers effect', i.e., the drivers and pedestrians becoming more accustomed to e-scooters on the road as their number increases. Zagorskas and Burinskienė (2019) give insights into the public space sharing problem due to the emerging shared e-scooters. With the increasing number of e-scooters, space that is currently used by cars might be reorganized to serve e-scooters or bicycles. They also highlight a popular measure in dense urban environments to set low-speed zones (30 km/h) where no division of space is needed.

With the development of the shared e-scooter system, the current patterns of public space use might be challenged. Ruhrort (2020) reports that the development of the shared e-scooter system might cause a redistribution of public space, for example, involving the redesign of dangerous junctions and the network of cycling highways. Furthermore, the growing number of shared e-scooters could provide opportunities for re-distributing space away from private cars. Tuncer and Brown (2020) present a positive view that the shared e-scooter system could contribute to ongoing innovations in the planning and design of public space, for example, adapting bike and foot paths more broadly for e-scooters would promote walking, cycling, and the use of light electric vehicles.

3.3 Micro-mobility and BE at the network level

In addition to the node and link levels, the introduction of micro-mobility has implications for the larger network and city scale, however, this is far less investigated.

Sun (2018) concludes that the dockless bike-share system changes urban spatial structure as it increases the metro's catchment area. With the introduction of the shared bike system to the city, this area extended from the station's 900 m buffer to 1650 m, from 2013–2015 to 2016–2017. Li et al. (2022) report that e-bikes can be applied for better accessibility in a metro-based trip. Li et al. (2021) report that dockless bikes expand the service coverage of metro stations and improve the accessibility of metro system. They propose that government should improve the cycling environment and infrastructure around metro station to promote transfer trips between metro and dockless bikes.

Glass et al. (2020) find that bike-sharing plays a significant role in the success of transit-oriented development (TOD), which is used as a strategy for reducing urban sprawl by urban planners. Unlike standard bikes, e-bikes could support travel at longer distance and more complicated landscapes. However, this study does not differentiate between the TOD impacts of standard bikes and e-bikes due to the much smaller quantities of e-bikes.

Some studies emphasize the need for creating and expanding the cycling lanes into a well-integrated transportation infrastructure network. For instance, Zhuang et al. (2019) study the shared bike trips in Shanghai and conclude that the current cycling network lacks integrity with other transportation infrastructures and connectivity with urban land use. To solve this, they propose the construction of a network with cycling control system, electronic parking fence, and integrated land use and transport planning. Maas et al. (2020) report that the Las Palmas de Gran Canaria municipality proposed a plan in 2019 to build a cycling network for the city, to serve the bike-sharing system and accommodate the increasing number of shared bikes. Zaffagnini et al. (2022) report that electric and shared micro-mobilities have the potential to re-write the feature of a city. They propose a network of electric charging stations with a wide range of other urban services and versatile street furniture to support the emerging new micro-mobilities.

3.4 The role of other factors

The relation between micro-mobility and the BE depends significantly on exogenous factors that can influence their supply. Advances in shared micro-mobility technology like the emergence of e-scooter docking stations or electronic fencing could be a major driving force of BE change. Furthermore, mobility policies such as investment in the supply of micro-mobility infrastructure are very influential. Government plays a vital role in the investment for the infrastructures used by micro-mobility (Sun, 2018). Many US cities made significant investments to build protected bike network for the shared bike and e-scooter users (NACTO, 2016). Beijing made an investment in a bike-sharing program by building parking stations and cycle routes (Norcliffe & Gao, 2018).

Finally, spatial measures introduced by the micro-mobility supplier and government policies could influence the BE and micro-mobility relation (Table 2). However, this influence is rarely measured empirically. Crum and Brown (2019) evaluate parking issues after the e-scooter sharing program implementing the incentive measures. Laa and Emberger (2020) and James et al. (2019) evaluate the effectiveness of national and regional government policies mitigating the floating bicycle issues at the node level and the safety of e-scooter user and non-user at the link level.

Table 2. Effects of supplier measures and policies investigated in the reviewed studies

Measure type and level	Measure and result	Figure
Supplier measures		
Node	Program use reward and fee system to encourage scooters parking at proper locations (Crum & Brown, 2019) **Result:** Issue of improper parking is improved	 (Crum & Brown, 2019)
National/regional government policy		
Node	The municipal agency in Tianjin publish “Tianjin Internet Rental Bike Management Interim Measures” to help with the free floating bicycle parking issues (Laa & Emberger, 2020) **Result:** Issues of vandalism of the bicycles and bicycle blocking footways are improved	 (Shan, 2022)
Lin**k**	Arlington County has laws that e-scooters are not allowed to be ridden on the side walk (James et al., 2019) **Result:** No significant impact. Laws not penetrated into the general public yet.	 (Ellis, 2018)

3.5 Discussion

3.5.1 Micro-mobility and BE over time

The relationship between micro-mobility and BE changes over time depending on the development stage (maturity) of micro-mobility, the BE element (node, link or network) and the BE aspect (urban design, land use or transportation system) (Figure 3). Over the first few years of the expansion of the (shared) micro-mobility, the urban design and transportation system aspects of BE are quickly adapted at the node and link levels to incorporate it. The changes at the node level include the emergence of parking spots for micro-vehicles, which happen directly/soon after their introduction and are relatively less resource intensive in terms of time, space and funding needed for realization. At the link level, the appearance of micro-mobility on motorized vehicle lanes and pedestrian/cycle paths can cause clashes with other users and change the use patterns of public space. While the level of service of transport infrastructure can directly change after the introduction of micro-mobility (e.g., the addition of micro-mobility directly changes the congestion at the link level), physical urban design and transportation infrastructure changes at the link level cannot happen immediately. Most studies outline potential changes expected to happen in the future, or those that have not happened yet due to a lack of funding or space. Examples are the addition or division of lanes, and the eventual growth of the micro-mobility infrastructure into a large scale well-integrated network.

Potentially, micro-mobility could influence the land-use aspect at the node and link levels in the long run as well. For instance, certain complementary functions like retail or recreation could emerge or move close to micro-mobility hubs or highly used micro-mobility routes. However, to the best of our knowledge, such (potential) influences have not been demonstrated or speculated by the literature yet.

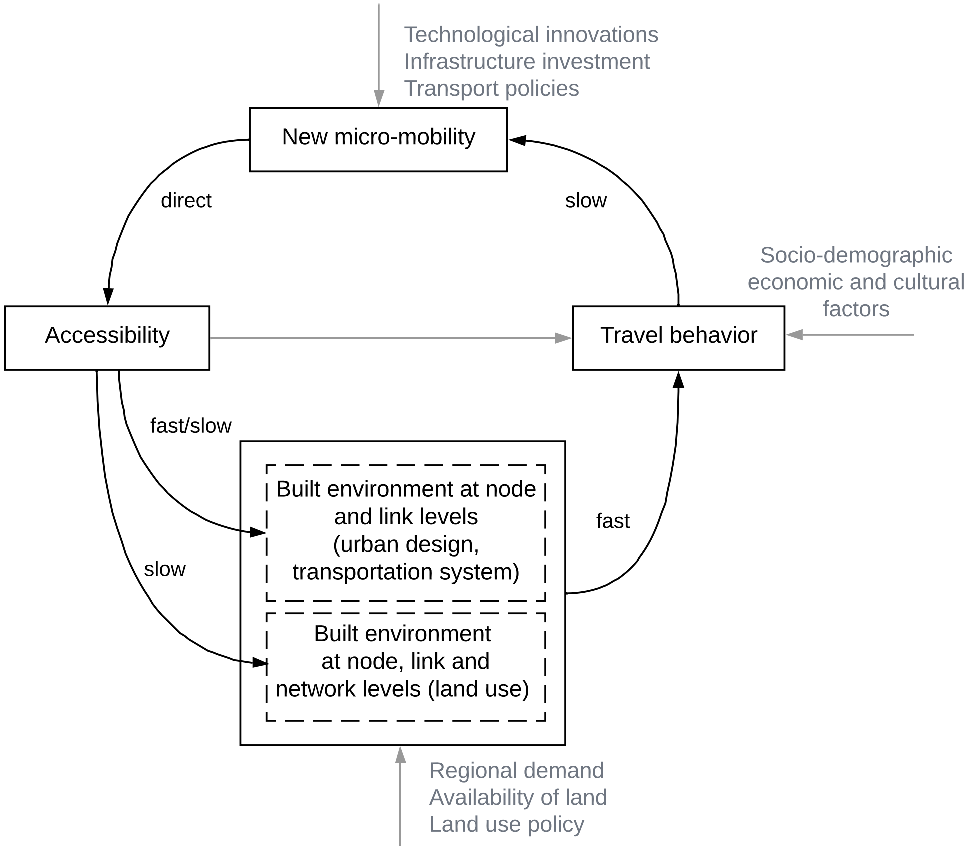

Figure 3. The land use-transport cycle adapted to micro-mobility and built environment relation at the node, link and network levels

There are not many studies about the micro-mobility and BE relation at the network level. The growth of shared micro-mobility services has accelerated in the past few years (Lazarus et al., 2020; Reck et al., 2020). However, existing transportation infrastructures and land-use patterns are persistent BE aspects that take a long time (from a couple of years to decades) to change (Wegener & Fürst, 2004). While initial studies suggest that micro-mobility could stimulate the creation of new/complementary transport infrastructure networks and shift the catchment area of transit nodes (and thus land-use patterns), more time is needed for the evidence of the connection with shared micro-mobility on the network level to becomes observable.

The studies of the Capital Bikeshare system in Washington, DC, give an example of how the requirements for BE change evolve over time corresponding with the development stage of micro-mobility (Table 3). The capital Bikeshare system was introduced in 2010 (Buck, 2012). In the first 5 years, the need for docking stations and bike lanes due to emerging shared bikes is reported. From 2015 till 2019, there are still studies about the placement of docking stations and cycle lanes but also studies encouraging the planning of a network-level system. One study about how the BE is adapted to fit shared micro-mobility at Washington is found (NACTO, 2016). This study explains that shared micro-mobility creates an equitable transportation network for the city, which could be categorized into the relationship at the network scale.

Table 3. Micro-mobility and need for BE change over time, the case of shared bikes in Washington, DC

2010-2015	2015-2019	After 2019
Node: more stations at suburban areas are needed (data collected at 2011) (Ahillen et al., 2016) **Link:** More cycle lanes are needed to encourage ridership (Buck & Buehler, 2012)	**Node:** smart station placement is needed to avoid inequity of bike access (Ursaki & Aultman-Hall, 2015) **Link/network:** protected bike lane network is needed for cities considering bike-share programs (NACTO, 2016)	**Network:** shared micro-mobility industry is creating a more equitable transportation network for all, including equitable station and infrastructure access (Stowell, 2020)

The introduction of the shared micro-mobilities shapes built environment in various ways. Examples are new docking stations on the street (Buck & Buehler, 2012) and the vehicles occupying sidewalk and curb space (Shaheen & Cohen, 2019). As the micro-mobility systems mature, studies are emerging that investigate their long-term growth patterns. Examples are investigations into the growth trajectories of the connections among stations (Zhang & Song, 2022) and the ideal location for future stations (Svichynska et al., 2023).

3.5.2 Micro-mobility and spatial context

Studies about the requirements of shared micro-mobility in the suburban area show considerable divergence from shared micro-mobility in the central urban area. Studies show that docking stations for shared bikes are needed at suburban areas (Ahillen et al., 2016; Ma et al., 2020), but no such need is reported for central urban areas (as the stations are more likely located first in these areas). Shared e-scooters are also recommended to be used in the suburban area instead of the city center, because the density and infrastructure (e.g., cobblestone pavement) at the city center might not be suitable for e-scooter use (Markvica et al., 2020). However, findings are inconsistent regarding dockless bike use. Liu et al., (2018) find more dockless bike usage in central city areas, but Shen et al., (2018) report higher usage in the peripheral area instead of the central business area. A possible reason is the different contextual factors such as availability of other transportation modes, distribution of land uses, cultural norm and weather in Beijing, China, versus Singapore, where these two studies are performed.

There are several studies about shared e-scooters used in residential areas. They mostly agree that residential areas are suitable for the use of shared e-scooter (Fitt, 2020), but not many trips happen here (Mckenzie, 2019). Besides, more improper parking happens at residential areas, compared to commercial areas (James et al., 2019).

Some studies mention the rebalance strategy for shared bikes due to the temporal variation of bike usage. Regular reallocation and visible parking sites are needed for residential areas and commercial areas to improve the accessibility of bikes (Guo & He, 2020; Shen et al., 2018).

4 Conclusions, discussion, and recommendations for future research

4.1 Conclusion on the BE and micro-mobility relation

This paper reviews the built environment (BE) and micro-mobility relation at the node, link, and network levels based on works from different parts of the world – the US, Europe, and Asia. First, it investigates how BE aspects like urban design, land use and transportation systems could change due to the emerging and expanding micro-mobility at the levels of node, link and network, and the potential role of exogenous factors, including policies and new technologies. Second, it reviews the recommended changes to the BE to support micro-mobility and/or enhance the quality of the environment for non-users in its presence. Third, it gathers evidence on how the relation between micro-mobility and BE can differ over time (different development stages of micro mobility) and spatial context (different locations and land uses). The findings of this study contribute to evidence-based design and policy measures, which are needed to guide the integration of the micro-mobility into the BE.

At the node level, shared micro-mobility causes parking space conflicting issues with other travel modes and requires a designed parking facility in public space. The link level relation between BE and shared bikes, e-bikes, and e-scooters differ due to their different sizes and speeds. E-bikes and e-scooters with power assistance and higher speed interact with other traveling modes from motorized vehicles to pedestrians. Moreover, the corresponding traveling rules for e-bikes and e-scooters are not yet clear to the public. As new transport modes, e-bikes and e-scooters could challenge the current pattern of public space use and distribution. Shared bikes, which have a relatively lower speed than other micro vehicles, require safe travel lanes and travel surroundings that can create a pleasant biking experience. There are fewer studies about the network-level of micro-mobility and BE relation. Micro-mobility is shown to increase the catchment area of metro stations and play a role in transit-oriented development (TOD). Furthermore, integrated travelling networks, including facilities like parking and control systems, are being suggested and built for the new micro-mobility.

Various works have outlined optimistic and pessimistic views (studies that speculate the potential effects) or shown positive and negative relations (empirical studies that measure actual changes) between BE and micro-mobility (Table 4). Of the 59 reviewed studies on the relation between micro-mobility and BE most of them indicate negative outcomes and a need for changing the public space to adapt to micro-mobility. At the same time, there are also some studies with positive results suggesting that the emerging of new micro-mobility could improve the current BE. Furthermore, exogenous factors influencing the supply of micro-mobility and the BE characteristics can determine the interaction between micro-mobility and BE. New technologies, infrastructure investments and mobility and spatial policies play essential roles.

The BE and micro-mobility relationship varies over time, spatial context and BE aspect. In the short term, micro-mobility can change the urban design and transportation systems' aspects of the BE at the node and link levels (e.g., the introduction of docking stations and changes in the transport infrastructure use patterns). In the long term, micro-mobility can potentially change the land-use patterns too (e.g., increases in transit nodes' catchment areas or the relocation of complementary land uses to micro-mobility hubs). This network-level relation however takes time to materialize and is investigated by a handful of works so far.

Table 4. Optimistic and pessimistic views and positive and negative evidence about the micro-mobility and BE relation on three levels

Connection	Node	Link	Network
Positive /optimistic	Impediments caused by micro-mobility could be just a minor nuisance	Safety increases as drivers become more accustomed to seeing micro-mobility users on the road.	The size of the catchment area of metro increases
Negative /pessimistic	Parked micro-mobility impedes pedestrian and disabled people's access; Oversupply has led to graveyards of bikes	People feel less safe while walking or driving around micro-mobility; Spread of e-bikes triggers the clash between e-bike and other modes	
Recommended measures	More stations are needed for high-density areas; Damaged and illegally parked bikes need to be removed	Separated cycle paths are needed for safe shared bike trips; More bike lanes are needed	A cycle network with control system, electronic parking fence and integrated planning are needed

4.2 Recommendation for future research

This paper identifies two main avenues for future research based on the state-of-the-art literature and gaps. First, there are many papers about the BE and micro-mobility relation on the node and link levels, but few at the network level. In terms of BE aspects, the focus is mostly placed on changes in urban design and transportation infrastructure and the land use aspect is overlooked. As micro-mobility comes of age, more studies on the micro-mobility and BE relation at the network level and on land-use patterns such as transit's catchment areas, housing price dynamics and urban sprawl are needed.

Second, the temporality of micro-mobility development is often overlooked. Micro-mobility and BE relation will evolve over time (Fitt & Curl, 2020). Longitudinal studies of micro-mobility that investigate its dynamic effects on BE and assess the success of BE changes to accommodate it are needed. These can help the urban and transportation planners and policymakers to introduce effective and proactive mobility and spatial policies to create and maintain urban spaces that are safe, lively and inclusive for all citizens while benefitting from the accessibility gains provided by micro-mobility.

Finally, a number of studies investigate the impact of built environment on the travel behavior of micro-mobility users (Yang et al., 2022; Younes & Baiocchi, 2022) and some reviews on this relationship for specific modes exist (e.g., Guo et al., 2022). While outside the scope of the current work, a review of these studies can help to understand the role of different BE characteristics in the travel behavior of various micro-mobility users.

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