Factors of the built and social environments associated with the allocation of mobility hubs: A systematic literature review

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ABSTRACT: *Mobility hubs offer a chance to enhance future levels of mobility and simultaneously reduce greenhouse gas emissions in the transport sector. Thereby, the identification of spatial factors, that influence ridership and thus the optimal allocation of mobility hubs, is essential for policymakers and transport planners. However, there is a lack of scientific research, especially regarding factors of the built and social environments. This paper presents a systematic literature review for five key elements: bike sharing, scooter sharing, car sharing, ride and taxi hailing, and charging stations to identify and rank historical factors. Crucial factors of a theoretical mobility hub are further found through a nominalization and merging process. A comprehensive literature search of Web of Science, Google Scholar, and Francis & Taylor databases was conducted. The final analysis included 119 records assessed for eligibility. Overall, 39 factors of the social environment and built environment were found. The factor most associated with the usage of a mobility hub is population density. It is followed by the factors employment density, overall public transport, overall recreation POIs, and household income in declining order. An overall negative association was found for the factor slope. Geographical boundaries of the identified factors were prevented through the variety of different locations in the included articles. The findings provide policymakers and transportation planners worldwide with an unbiased first-hand solution that offers an overview to locate mobility hubs.*

Keywords: Mobility hub, Mobility hub allocation, Factors of the built and social environments, Micromobility sharing systems (MSS), charging stations, Transportation network companies (TNCs), Systematic literature review

1. Introduction

Greenhouse gas emissions, as the main cause of anthropogenic global warming, have continued to rise from around 30 billion in 1990 to almost 50 billion tonnes today (Hannah Ritchie & Max Roser, 2020a). The significant rise in greenhouse gas emissions is closely linked to the continual increase in global mobility demand combined with generally misaligned developments in the transport sector in recent decades. Currently, passenger transportation is the cause of approximately 15% of the total emitted greenhouse gases worldwide. (Hannah Ritchie & Max Roser, 2020b; Kromp-Kolb et al., 2014; Shiying & Mengpin, 2019; US EPA, 2015)

To enhance future levels of mobility and simultaneously reduce greenhouse gas emissions in the transport sector, a shift from mainly privately-used combustion cars towards low-emission public (particularly electric) modes of transport is needed (Clewlow, 2018; Machado et al., 2018; Murphy, Sharon Feigon and Colin, 2016). Shared mobility services such as micromobility systems (bike sharing and e-scooter sharing), ride and taxi hailing, or car sharing as well as the extension of electric charging stations have witnessed significant growth over the last decade, both as individual modes of transport or in combination with existing public transport services as first- and last- mile alternatives (NACTO, 2018; D. Roberts, 2017; Shahraki et al., 2015; Younes et al., 2020).

In this context, mobility hubs (MHs) cater to and provide these more sustainable mobility modes in a multi- or intermodal approach (A. Roberts, 2019; Schemel et al., 2020). Mobility hubs have increasingly appeared in major cities around the world and receive growing attention from current mobility planners (Aono, 2019; City of Columbus, 2022; ERA-Learn, 2021; Huber, 2021; Miramontes et al., 2017). Mobility hubs are predicted to contribute to the sustainable transport transition of the future. The main feature of MHs is to provide multi-modal trips with convenient connections between different modes of transport, adjusted to different necessities of the spatial structure of an analysed area. A more detailed description of MHs is provided in Chapter 2. (Geurs et al., 2021; A. Roberts, 2019; Schemel et al., 2020)

The success of MHs in future mobility planning relies on understanding how the system characteristics affect the use in the surrounding built and social environments. Thereby, the allocation of MHs, with their offered elements, in the right location in evaluated areas is particularly essential. To uncover these locations, it is necessary to analyse factors of the MH´s built and social environments associated with ridership (travel patterns and trip data), namely, the factor-based ridership of the MH´s offered transport modes. (Aono, 2019; Mattson & Godavarthy, 2017; Médard de Chardon et al., 2017; A. Roberts, 2019; Schemel et al., 2020)

By studying the current literature, however, scientific studies and literature for determining optimal locations of MHs are limited. This is likely due to its relatively new role in mobility planning and the fact that MHs combine - as a connection interface - various new mobility modes which are yet to be researched in detail.

On that note, this paper intends to perform a systematic literature review *(SLR)* as a descriptive metasummary for a theoretical MH with chosen elements and transport modes (hereinafter referred to as “key elements”), to provide transportation planners with a factor-based location analysis. Through a systematic literature approach, this report analyses which common factors of the built and social environments are associated with ridership and thus the optimal allocation for each MH key element. The factors are retrieved from statistical models as well as recommendations from reflected studies and guidelines. The identified factors are classified through a normalized scoring system to represent a theoretical MH and its respective main factors for its allocation. Furthermore, geographical boundaries of the identified factors are prevented through the variety of different locations in the included articles (location-neutral findings). The steps are further detailed in 4. Methodology.

The rest of the paper is organized as follows. Chapter 2 provides a compact literature review of the definition and function of MHs in the scope of this paper. Chapter 3 provides a comprehensive literature review of the state of the art follows. Chapter 4 presents the methodology of the paper and the review process. Chapter 5 presents the results, which are divided into two sections. First, the chosen elements of the defined MH themselves are shown. Second an overall summary list for the defined MH is presented. Chapter 6 discusses the results and shows the limitations of the work. Finally, Chapter 7 concludes the paper and gives recommendations for future research.

2. Definition and function of mobility hubs

To analyse respective factors of the built and social environments for the allocation of MHs, it is first necessary to define the term mobility hub and its function in the scope of this paper. By reviewing the following literature about MHs (Ambroz et al., 2016; Aono, 2019; City of Columbus, 2022; Geurs et al., 2021; Monzón & Di Ciommo, 2016; A. Roberts, 2019; Schelling, 2021; Schemel et al., 2020), it is found that there is no single definition for MHs or consensus on the specific functions they need to provide. Moreover, several different terms varying from “Smart Hubs”, “Smart Mobility Hubs”, “Mobility Stations”, or “Public Transportation Hubs” are commonly used in the terminology of mobility planners, therefore expressing similar utilities in the core of its meaning. In the scope of this paper, several definitions and functions are considered to identify a description for an MH that supports the research of essential factors of the built and social environments to locate MHs by including multiple modes of transport and elements.

As previously mentioned, there is no universal definition of MHs in terms of their physical appearance. Mobility hubs are instead characterised by their contribution to the sustainable transport transition of the present and the future as well as by individual adjustments to different necessities of locations. However, as commonly identified in the literature, all MHs include the opportunity for multi-modal trips with the concept of strong connections between different modes of transport. (Geurs et al., 2021; A. Roberts, 2019; Schemel et al., 2020)

They “can be seen as an [optimally organised and designed] interface between the transport network and spatial structure of an area” (A. Roberts, 2019, p. 8), complemented by additional services in the form of different facilities and information features to both attract and benefit the traveller. Therefore, one main aspect in defining MHs is the proximity to major public transport stations or corridors since these stations build the core element for supplying mobility by working as high frequented transition places for citizens. The proximity or availability of public transport modes can therefore be seen as a universal element in defining and locating MHs. Another main characteristic of an MH and how it is equipped as well as located is the dependence on the areal conditions regarding social, economic or mobility aspects. In general, the positioning of MHs needs to be well adapted to the necessities of a considered area. There are no overall standards for MHs and which elements they need to provide - rather tailor-made solutions are created for each situation. (Ambroz et al., 2016; Aono, 2019; Geurs et al., 2021; A. Roberts, 2019; Schemel et al., 2020)

MHs can be constructed in a broad range from city centres to rural areas (Frank et al., 2021; A. Roberts, 2019; Schemel et al., 2020). However, considering the reviewed literature for this paper, mainly urban regions and sub-urban regions with their respective characteristics have been studied (see records Appendix C). Like the range, the size of MHs can also vary significantly as a result of different project extents and the inclusion of various modes of transport (A. Roberts, 2019; Schemel et al., 2020). These differences in the extent of MHs are neglected since the functions provided by the key elements as seen in the following list are assumed to be the same for the entire factor research. According to the framework from the registered charity “CoMoUK” and the collaborative framework from the Research Institutes of Sweden (A. Roberts, 2019; Schemel et al., 2020), elements of an MH can be organised as follows:

A) Main mobility elements in the form of public transport or ride hailing services;
B) Secondary mobility elements in the form of shared mobility options such as bike, scooter and car sharing, cargo bikes, or other future mobility options;
C) Mobility related elements such as mainly E-Car charging stations, bike racks plus additional repair or bike pumps, digital pillars for a clear indication as mobility hubs, and transport-related information and ticket systems;
D) Non-mobility services related to the urban realm improvement. The most essential ones are the following: safe, simple, and barrier-free accessibility, package delivery lockers, activity (green) areas, kiosks, and co-working spaces or (seated and sheltered) waiting areas.

As previously mentioned, category A (transport modes) provides, in the form of public transport, a key aspect in locating MHs. To validate this strong interconnection, public transport is perceived in this paper as a factor of the built environment for further research (see “overall public transport” entity in the result-factor tables in 5. Results). In addition, the mobility components of ride hailing, car sharing, bike and car charging and parking, micromobility options (bike sharing and e- scooter sharing), information pillars, and sheltered waiting areas may be seen as other fundamental key elements of each MH. However, to further narrow down the research by evaluating the key components of MHs in a likely real-world scenario while also focusing on demand related mobility modes in this paper, the following elements were selected as the key elements for a theoretical MH:

- **Bike sharing**
- **Standing e-scooter sharing**
- **Car sharing**
- **Ride hailing and taxi services**
- **E-Charging stations for cars**

All other elements are rather considered as additional elements and services, which are neglected in the scope of this review to focus on the essential factors for the key elements. (Ambroz et al., 2016; A. Roberts, 2019; Schemel et al., 2020)

3. Literature review

Having determined the definition and function of MHs in the scope of this paper, this chapter delivers a literature review on the state of the art of MHs. It is conducted in a chronic sequence starting with research on overall literature regarding the allocation of MHs based on strategic models, frameworks, or factor analyses. This part is understood as the central component of this literature review. Secondly, systematic literature review approaches considering MHs themselves, or combinations of at least two of the key elements of the previously defined MH (hereinafter referred to as "combination hubs") are highlighted. As the last step, the literature gap is identified and based on that the general aim and strategy of this paper further depicted.

3.1. Locating mobility hubs

As previously mentioned, scientific studies on the allocation of MHs are generally relatively limited as also stated by other authors (Frank et al., 2021; Miramontes, 2018; M. Tran & Draeger, 2021). The research that has been carried out can be divided into a) literature examining mobility hubs as one mobility system, and b) literature studying a minimum of two of the shared mobility modes in a combined system, which comes close to the core idea of an MH. In both research groups, the location process, namely the allocation of the mobility systems, was of major importance. Considering mobility hubs as systems, multiple established location frameworks can be found in the literature. Anderson et al. (2017) presented a multicriteria analytic hierarchy process framework, with predetermined service goals, for the optimal siting and equipping of mobility hubs for policymakers and transportation planners. This framework was applied as a case study in the city of Oakland (USA) and the authors found that, for the evaluated study area, built environment factors such as transit- and commercial- activity; city-centre-, airport terminal-, and ferry terminal- proximity; and residential areas are most important to locate mobility hubs.

Petrović et al. (2019) developed a three-phased locating framework for multimodal terminal hubs along a public railway route in two steps. First, a GIS-based pre-processing approach was introduced to define a set of possible locations regarding the population in the catchment zone. Second, they suggested an optimization algorithm to provide assessments of the possible final locations. M. Tran and Draeger (2021) developed a methodological framework, based on geographical siting plus multicriteria evaluation through data science and complex network theory, to plan mobility hubs. They concentrated on social and economic aspects by focusing mainly on different income groups and their accessibility to the hubs and employed the framework in a case study in Vancouver (Canada). Another important contribution to the research on MHs was carried out by Frank et al. (2021). They established a mixed-integer optimisation model for locating and equipping mobility hubs in rural areas to increase the intermodal connection to points of interests (POIs) of private needs and workplaces to the centre. The model was applied in a real-world case study in Germany and the outcome provided an evaluation of the improvement of the connection ratio for the single elements of the mobility hub.

The research of Miramontes (2018), Da Silva and Uhlmann (2021), and (Mouw, 2020) employed empirical investigations combined with findings from already installed mobility stations. Some of the identified success factors, particularly those related to underutilization, were found in mobility hub design and location aspects, policy-making requirements, and contextual factors for the implementation, operation, and user acceptance of mobility hubs. A similar approach was carried out by Miramontes et al. (2017) to evaluate the user acceptance of the currently installed mobility station in Munich by performing an online survey. The findings pointed out that users are mostly young, male, and highly educated individuals and that public transport plays a vital role in the surrounding. Another empirical approach that combined citizen survey results with interview findings from experts in the city administration and the private sector was recently conducted by Klanke (2022). Klanke analysed the needs and expectations of the different stakeholders towards a smart mobility hub (SMH) in the city of Munich. Like Miramontes et al. (2017), the survey results discovered that perceived needs vary significantly by gender and age. For the location process of an SMH, the survey findings showed that proximity to home, work, educational institutions, and public transportation are of major importance. The interview findings aligned with the survey findings additionally highlighted a "concentration of diverse uses", "available space", and "street proximity" are essential for an SMH. Similar to Klanke (2022), Fernanda Navarro-Avalos (not published) and Ben Hassine (not published) used expert surveys to select suitable locations for MHs. Thereby, Fernanda Navarro-Avalos (not published) found that points of interest and population density are of most significance followed by low car ownership, focusing on the integration of sustainable criteria using an analytic hierarchy process-GIS

(AHP-GIS) approach. Similar results were found by Ben Hassine (not published)[1] when applying an AHP method for prioritizing railway stations regarding a best-allocation strategy of MHs in and around the city of Munich. Finally, Coenegrachts et al. (2021) adopted a business model innovation approach designed through expert meetings of public and private stakeholders for different mobility hub designs to ensure the most efficient and sustainable urban development.

With regards to the second category shared mobility modes in a combined system, the paper of Nair and Miller-Hooks (2014) is relevant. They introduced a bi-level network design model to determine optimal configuration - location decision, vehicle inventories, and station capacities - by minimizing total travel times as well as costs of a vehicle (bicycle and car) sharing program. Similarly, a strategic network planning optimization model was presented by Steiner and Irnich (2020). The model makes decisions on the use of existing bus line segments (real-life case study in Germany) connected to on-demand mobility modes (ODMs) by reducing the total cost of ownership. The decision and location processes are built on intermodal travel itineraries with ODMs used for the first or last mile of a trip. Finally, Ko et al. (2021) offer another approach to investigate factors for the location of shared mobility modes in a combined way for transportation planners. They used logistic regression analysis of the usage intention of users for these modes based on potential users´ survey data. The findings and thus the factors of importance for the allocation of the combined modes were found in gender, car ownership, education level, service experience related factors, and long distances to the next bus station from home (Ko et al., 2021).

1 Results from Ben Hassine aligned closely with those of Navarro-Avalos, however, Ben Hassine did not highlight the importance of low car ownership.

After showing the current state of the literature regarding the allocation of MHs and similar combined shared mode approaches, in the next literature group, systematic literature approaches regarding MHs or combined hubs are discussed. However, as a result of the limited literature about locating MHs itself, it comes as no surprise that there is no specific systematic literature review about locating MHs existent to the best knowledge of the author. Nevertheless, two systematic literature reviews and one extended literature review within the field of mobility hubs and combined hubs were identified in this research. Firstly, concerning factors influencing the user behaviour towards micromobility sharing systems (MSS), the recently published systematic review paper from Elmashhara et al. (2022) can be seen as a foundation for future research. Based on 203 studies included in the final review process, a detailed analysis of the literature led to 25 factors influencing MSS user behaviour which were organised into three main groups (1) temporal, spatial and weather-related factors, (2) system-related factors and (3) user-related factors. Another study employing a systematic literature review relevant to mention for this paper was found about shared mobility in China by Hu and Creutzig (2021). The review provides an overview of shared mobility in China regarding the development of the market and the main factors, the reshaping of travel patterns, and the contribution to environmental goals. Lastly, Dimitris Efthymiou et al. (2020) did not conduct a systematic review specifically, however, since they considered car sharing and bike sharing in combination in an extended literature review, it seems important to mention this study in the context of this chapter. They studied exogenous factors from different literature to find deployment locations of both systems. However, after examining the given tables with the collected factors, several flaws regarding the factor-based citing of the literature are encountered which led to an exclusion of this paper in the review process. Other existing systematic literature reviews were conducted for single mobility modes as in Eren and Uz (2020) or in Si et al. (2019) and used for the literature research in this paper, however, for the literature review about MHs or combined hubs, they were not of importance.

3.2. Identification of literature gap

Concluding from the analysis above, it is shown that there is still an overall gap in scientific studies and literature for determining optimal locations of MHs. In particular, considering spatial factors of the surrounding built and social environments of MHs and their impact on ridership, there is a significant gap compared to papers for the allocation of single mobility modes. For many MH studies specific socio-demographic, economic, or stakeholder factors were often of more interest (Ko et al., 2021; Miramontes, 2018; M. Tran & Draeger, 2021). However, both mobility hubs as a whole and combined hub strategies are increasingly topics of recent research. As identified, there are already a few studies focusing precisely on the locating process of mobility hubs (Anderson et al., 2017; Frank et al., 2021; Petrović et al., 2019). However, these studies employ usually more complex models or frameworks with predetermined entities or factors which may make it difficult for policymakers to adopt them, especially in a first basic mobility hub allocation draft. Furthermore, it is also common that studies focus on a precise location as a study area which constricts the findings to a certain urban setting and makes it inaccurate to transfer the findings to other mobility projects in other cities or countries. These limitations were also indicated in previous studies by Huo et al. (2021), Gehrke (2020), and Duran-Rodas et al. (2019). By considering the current research of systematic literature reviews, the gaps can be pointed out as the following to the best knowledge of the author. There is no systematic literature review found on MHs. Moreover, the literature is still missing systematic literature reviews for the single shared mobility modes in a combined way. However, in this context, Elmashhara et al. (2022) provided the first fundamental approach with regards to micromobility modes. Finally, current systematic reviews for MHs, combined hubs or the single elements provide detailed and well-organised information about the current research. However, they do not provide future planners with a ranking system of factors to adopt the found literature directly for location processes of transportation projects.

Due to the reasons mentioned, the general idea of this paper is to provide policymakers and transportation planners in the initiation of a project with a simple first-hand solution that offers a quick overview of crucial boundary conditions in the form of spatial factors of the built and social environments to locate MHs or the researched single elements. Thereby, geographical boundaries of the identified factors are averted through the variety of different locations in the included articles. As mentioned in the introduction, this goal is realized:

a) by performing a systematic literature review in a descriptive metasummary as a ranking system for each of the key elements and;

b) by a merging process of the received literature results and scores to develop ranks for the theoretical MH of this study.

To do so, for each of the defined elements (bike, scooter, car sharing, ride and taxi hailing, and e-charging stations), statistical models and recommendations from a large number of spatial and user-based studies, as well as official guidelines were employed. The precise process, as well as the referenced literature, is further described in the following chapter.

4. Methodology

4.1. Overview of the overall paper structure

To provide a fundamental understanding of the structure and the aim of this paper, the following flowchart (Figure 1) summarizes and outlines the conducted steps. More detailed, it provides an overview of all the assigned steps - including a brief repetition of the research aims, key elements and the anticipated results. The illustrated steps are described in greater detail in the following chapters.

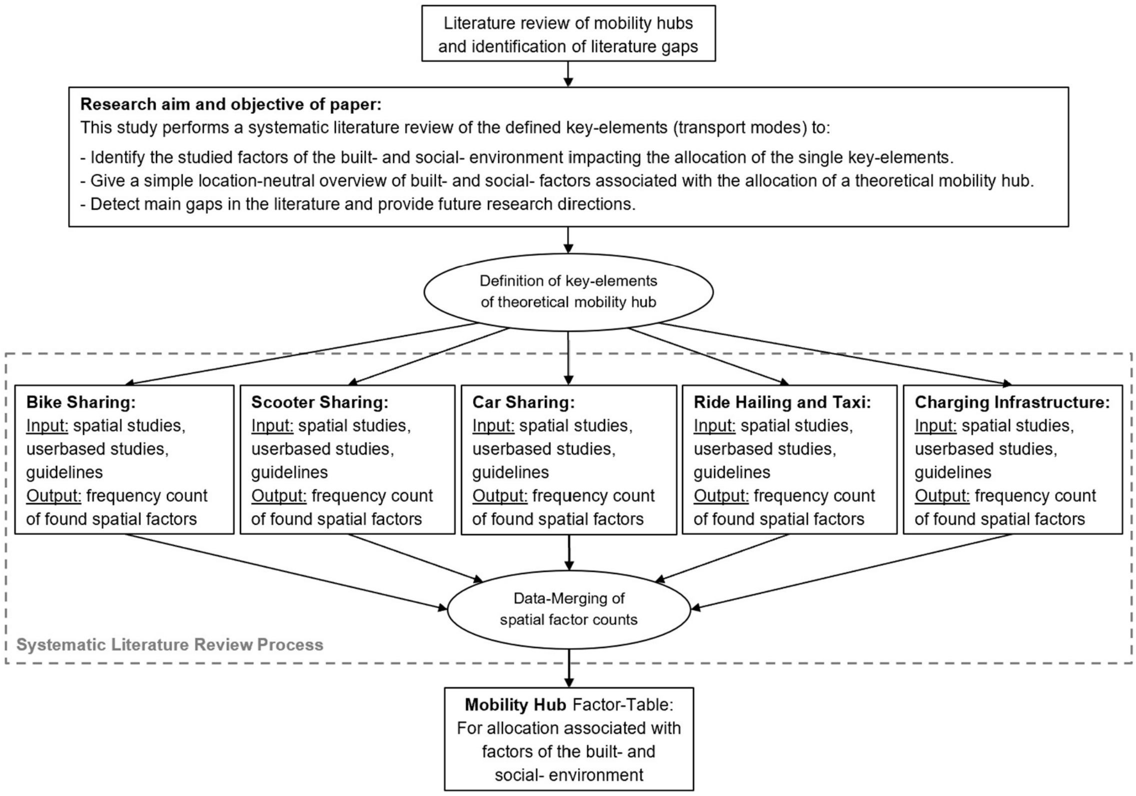


Figure 1: Overview of the overall structure and procedure of this study

4.2. Systematic literature review

The systematic literature review in this paper is conducted as a descriptive metasummary approach by employing both a systematic literature review process and a summarization of the findings as a quantitative element. It follows the common strategy for systematic literature reviews, well recognised in the areas of management, transportation, and educational research (Elmashhara et al., 2022; Khalaj et al., 2020; Limkakeng et al., 2014; Xiao & Watson, 2019). A systematic review goes beyond traditional narrative reviews by applying unbiased strategies. Therefore, the systematic literature process itself is carried out as a transparent and reproducible assessment of the existing literature with clearly defined standards for the inclusion and exclusion of found studies. The metasummary part of the review is applied by introducing a frequency count of the historical factors for each element from the included records. (Stevenson et al., 2017; Tranfield et al., 2003; Xiao & Watson, 2019)

As previously mentioned, the final metasummary table (factor-table) with its established factor ranks aims to provide location-neutral suggestions for the allocation of MHs. Lastly, gaps of knowledge for future research are identified in the SLR.

4.3. Systematic literature process

To find the main factors for the allocation of MHs from the existing literature, a well-structured collection, organisation, and review process is essential. Considering best practices (Elmashhara et al., 2022; Limkakeng et al., 2014; Pickering et al., 2015), in the scope of this paper, this fundamental process incorporates, firstly, a fundamental and comprehensive explanation of the considered factors of the built and social environments of the defined key elements (see 2. Definition and function of mobility hubs), to give the reader the necessary understanding of the focused study data for the metasummary result tables. Second, the overall types of employed papers for the research are briefly described. In the third and fourth steps, the screening process is further explained, through an identification of the databases, keywords and the inclusion and exclusion criteria of the literature. Finally, the data extraction and analysis from the relevant articles are explained. Thereby, the evaluation and ranking procedures for the result factor-tables for each of the elements and the MH are analysed and depicted in detail.

4.4. Considered factors of the built and social environments

As previously mentioned, to plan and locate an MH successfully, it is necessary to analyse travel patterns and trip data of the offered transport modes contained by an MH associated with the spatial factors of the built and social environments. The assigned factors and their extraction from the literature are considered as main research data for the following metasummary approach of the SLR. Therefore, the assigned uniform factors for each element and namely the MH were established through a dynamic feedback analysis of the found literature over the entire period of the literature and writing process of this paper. In Table 1, the section of the considered factors classified in “Groups”, “Sub-Groups”, and “Factors” can be seen. In the scope of this paper, the included factors needed to be associated with the usage of one’s element as well as offer the opportunity to assign a theoretical spatial value. This led to an exclusion of factors regarding the element design and network. However, since this information was already accessible through the applied SLR, the additionally found and counted factors can be seen in Appendix B - Additional found factors for the Factor Group *Element design* from the SLR. Besides the given overview of the considered factors for this paper, this chapter shall be used to explain and define certain factors where logical reasons require it. One factor to be further defined was found in *institutional land use*. It defines areas with high rates of governmental offices and governmental facilities. Another factor needed to be further described is observed in *active-mode infrastructure*. This refers to bicycle and walking infrastructure, such as zones, lanes, or paths (measured in length or density) for cyclists and pedestrians. Also, adequate parking, and pavement surfaces, as well as sufficient buffer and safety infrastructure that increase the walkability around active-mode elements are included in this factor. The other factors are well studied in transport literature (see Appendix C) and are not further examined in this paper.

Table 1: Considered factors of the built and social environments as main research entities of the SLR

Groups	Sub-Groups	Factors
Social Environment	Population	City Population
		Population Density
		Employment Density
	Socio-Demography	High Household Income (Affluence Neighbourhood)
		Household Size
		Household Car Ownership (No or Low)
		Household/Personal Education Level
Built Environment	Topography	Slope (Hilly Terrain)
	Urban Structure	Short Distance to or within City Center (Central Business Districts)
		Commercial/Retail activity
		Mixed Land use
		Industrial Land use
		Single Land use
		Residential Land use
		Institutional Land use
	Transport Infrastructure (Availability)	Overall Public Transport
		Metro (Subway)
		Railway Station
		Tram Station
		Bus Stop
		Taxi Stop
		Micro Mobility or Car Sharing Stop
		Major Roads
		Minor Roads
		Intersection Proximity & Frequency
		Embankment Road
		Active-Mode Infrastructure (Cycle-, Walking zones, Pedestrian Safety)
		Airport Proximity
		Ferry Terminal Proximity
		Parking Lot Availability
	POIs Recreation (Origins, Destinations)	Overall Recreation POIs
		Cinema
		Worship POIs
		Hotel
		Restaurant (Food Businesses)
		Tourist Attractions
		Parks
		Public Squares
		Sports Centers
	POIs Business (Origins, Destinations)	Financial Institutions
		Universities or Educational Facilitis (Also Schools & Student Housing)
		Medical Instituitions (e.g. Hospitals)

4.5. Employed studies in the systematic literature review

To provide an overview of the literature used for the SLR, this chapter briefly describes the overall type of studies that were employed. Moreover, a fundamental overview of all the studies reviewed in the SLR process is provided. The types of studies included in this paper are spatial studies, user-based studies, and guidelines. For these types of studies, a sizeable amount of literature has been published with a focus on locating mobility modes by employing factors of the built and social environments (also see factor-tables in Chapter 5). One reason for this availability is most likely found in the newly experienced data availability and accessibility for the different transport modes. Trip data can meanwhile be obtained real-time through interconnected sensors and mobile devices, then stored in large databases, and finally accessed by researchers to gain a better understanding of the demand and its impacting factors. (Bryan & Blythe, 2007; Reades et al., 2007) (also see records in Appendix C)

This data availability, combined with empirical user-based research, creates the foundation for the reviewed spatial and user-based studies, and guidelines. As background information for the research process in this paper, guidelines refer to spatial factors that were recommended by design guidance for the allocation of the considered key element. User-based Studies are empirical studies that have detected factors of the built and social environments linked to demand by conducting surveys or interviews without a spatial level. Spatial studies are based on a spatial analysis of the previously described trip data for a distinct area. Examples for each type of study can be found in the factor-tables for each element in Chapter 5.

For the evaluation of the employed survey, interview, or trip data, the authors used several statistical, geographical, or mathematical models in single or combined approaches. These applied models vary from study to study for each key element and are already clearly described in several articles (see records in Appendix C). Therefore, in the scope of this paper, the different models are not further explained. Nevertheless, the different models for each assigned study are included for comparison reasons and can be seen in Appendix A - Information Collection of the Factor-tables for each key element in line with the methodology of the SLR. In general, statistic modelling in the form of diverse types of regression analyses for collected trip data or survey data is the commonly applied approach to establish potential demand models and identify the most associated factors for each of the elements in the literature. Examples for each element can be seen in the factor-tables in Chapter 5 or in Daddio (2012), Caspi et al. (2020), Dimitrios Efthymiou et al. (2013), K. Kim (2018), Frade et al. (2011). All employed studies (assessed for eligibility) for each element of the SLR can be found in Appendix C. The final studies included in the SLR are presented in the factor-tables in Chapter 5. The next chapter further describes the screening process of the SLR.

4.6. Search databases and keywords

To obtain a sufficient number of studies aligned with high-quality findings, the selection process of the SLR was based on journals indexed in Web of Science (WoS), Google Scholar (GS), and Taylor & Francis Online (TF). By consolidating these three common bibliographic databases, a mixture of assumed high-quality journals was gathered without experiencing coverage limitations.

With regards to the included keywords for the research, it is of importance to note that for each of the defined key elements, different keywords and combinations for the research were applied to ensure the most adequate findings. In addition, filters were assigned to focus the search on transport sciences. The following tables in this chapter display the multiple keywords - considering varying writing styles and different wording combinations - employed for each element of this boolean-based research.

Table 2: Bike Sharing: Main keywords used in literature search

(("bike shar*") OR ("bicycle shar*") OR ("bikeshar*") OR ("bicycle system") OR (“shared bike*”) OR (“shared cycl*”) OR (“Two-wheeler”) OR (“micromobilit* shar*”) OR (“shared micromobilit*”) OR (“public bicycle”) OR (“public bik*”)) AND ((locati*) OR (allocati*) OR (position*) OR (distribut*) OR (allotment) OR (assign*) OR (dispension))

Table 3: Scooter Sharing: Main keywords used in literature search

(("scooter shar*") OR ("scootershar*") OR ("scooter system") OR ("shared scooter") OR ("Two-wheeler") OR ("micromobilit* shar*") OR ("shared micromobilit*") OR ("public scooter") OR ("shared electric scooter") OR ("shared e-scooter")) AND ((locati*) OR (allocati*) OR (position*) OR (distribut*) OR (allotment) OR (assign*) OR (dispension))

Table 4: Car Sharing: Main keywords used in literature search

(("car shar*") OR ("carshar*") OR ("car system") OR ("shared car*") OR ("public car") OR ("shared electric car") OR ("shared e-car") OR ("vehicle shar*) OR ("shar* vehicle")) AND ((locati*) OR (allocati*) OR (position*) OR (distribut*) OR (allotment) OR (assign*) OR (dispension))

Table 5:Ride hailing and taxi service: Main keywords used in literature search

(("ride hail*") OR ("ridehail*") OR ("ride system") OR (ridesourc*) OR ("ride sourc*") OR ("shared rid*") OR ("taxi") OR ("taxi servic*) OR (uber) OR (lyft) OR ("transport* network company") OR (TNC) OR ("ride pool*") OR (ridepool*)) AND ((locati*) OR (allocati*) OR (position*) OR (distribut*) OR (allotment) OR (assign*) OR (dispension))

Table 6: Charging stations: Main keywords used in literature search

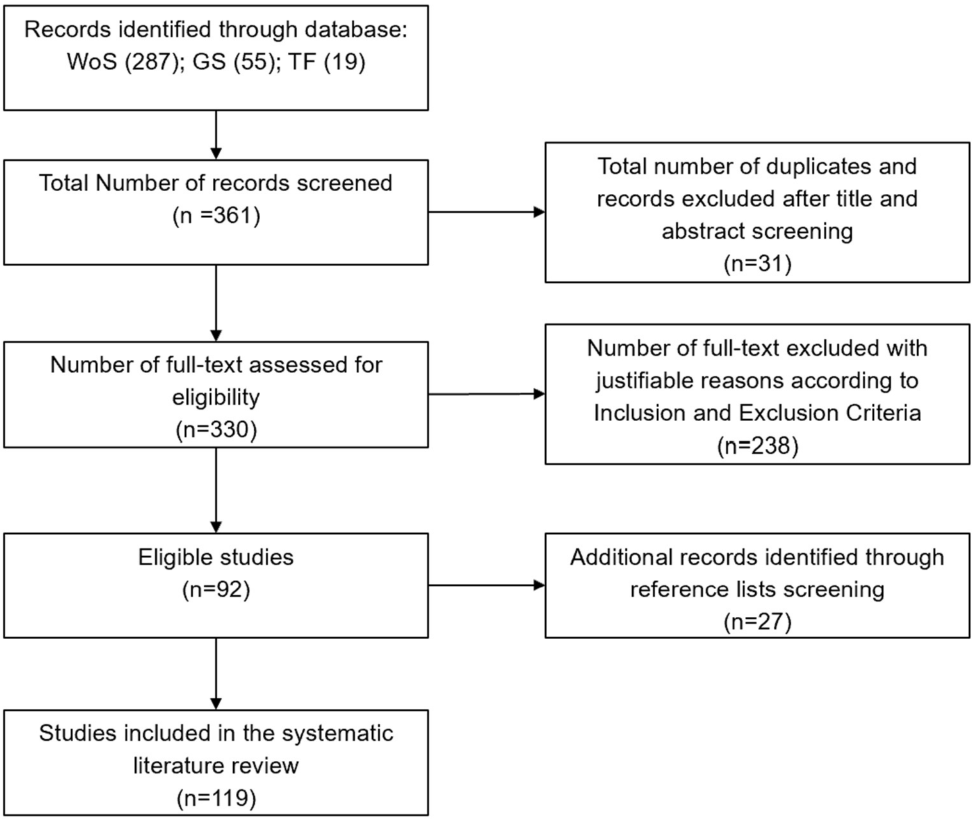
(("charg* station") OR (chargingstation) OR ("e-charg* station") OR (electric vehicle charg*) OR ("electric public charg*") OR ("charg* infrastructure")) AND ((locati*) OR (allocati*) OR (position*) OR (distribut*) OR (allotment) OR (assign*) OR (dispension))

4.7. Screening process - Inclusion and exclusion criteria

Figure 2 shows the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) flowchart, adapted for this paper from recognized literature (Liberati et al., 2009; Stevenson et al., 2017). As depicted, 361 articles were identified in the literature research. A total of 31 records were removed since these records were either duplicates or labelled unrelated after examining the titles and abstracts. This exclusion resulted in a total of 330 full-text articles assessed for eligibility (see Appendix C for key element distribution). In the next step, 238 records were excluded according to the inclusion and exclusion criteria outlined in the following paragraph. An additional 27 records were added to the remaining 92 eligible studies after scanning the reference lists of the identified eligible articles. In total, a database with 119 eligible studies was obtained and included in the SLR. The database contains each document's bibliographic information and full text.

Regarding inclusion and exclusion criteria of the literature, all studies that did not explicitly refer to spatial factors of the built and social environments associated with ridership of each element were excluded. This approach suggests that the analysed studies are sufficiently homogenous in their methodological strategy, which ensures meaningful and applicable results and the ability to draw reasonable conclusions. Moreover, only peer-reviewed articles, written in English were included in the SLR. Therefore, books, book reviews and book chapters, magazines, editorial notes, conference papers or abstracts, conference reviews, reports, and general articles written in other languages were excluded. This exclusion of non-peer-review articles is commonly applied for systematic reviews as seen in Elmashhara et al. (2022), Khalaj et al. (2020), Liberati et al. (2009). For the small number of guidelines employed in the SLR, a scientific, practical, or governmental background of the publishers needed to be existent.

Another overall main criterion was to obtain a variety of records with its models referring to different locations and countries to prevent geographical boundaries or location-dependencies of the results. Therefore, if in the included articles the same locations (cities) were evaluated more often for one type of study, these articles and their found factors were combined into one overall column (entity) in the counting process in the factor-table. This combination of articles is indicated by more literature markers, separated by commas, at the top of a column (e.g., *b, q* in Table 7). This method was necessary to avoid on the one hand a dilution of the factor counts by adding up the same found factors in the literature for the same evaluated cities and on the other hand not to exclude different factors found from studies for the same locations. Additionally, for the MH, the location information was used to build three brief country analysis models to transparently depict in which locations spatial and user-based studies and guidelines were conducted (see Tables 13 and 14). Furthermore, the screening process covers articles published until the end of March 2022. The initial date for the study´s period was set for ten years with the beginning of the work in 2021. Since many publications have been done in the last ten years, building on previous knowledge and literature, this period covered a sufficient up-to-date number of articles and seemed to be adequate.



Note: WoS: Web of Science / GS: Google Scholar / TF: Taylor & Francise Online

Figure 2: Flowchart for the systematic literature review process for all elements combined

(Adapted from: (Stevenson et al., 2017)

4.8. Data extraction and analysis

After obtaining the relevant studies through the literature screening process, the spatial factors associated with the built and social environments examined in each record were extracted. Additional useful information, such as the applied statistical or geographical models used for the factor analysis in the studies, the country data an article referred to, the number of citations in *Web of Science* and *Google Scholar*, and the publication date of each document was extracted. Moreover, information about the type of system for each element (e.g., a dockless or station-based bike sharing system) was obtained from the database for comparison reasons. The extracted data is tabulated for each element, which can be seen in Appendix A. In this paragraph the evaluation and ranking procedures for the creation of the factor-tables for each of the elements and the MH are further detailed. At first, the found spatial factors from the included records were under examination regarding their correlation with the records´ trip data. In other words, it was examined if one factor was associated positively, negatively, or neutrally to the reviewed trip or survey data. This correlation was found by analysing the model results combined with the interpretation of the authors for each record. Every factor that was found to have positive feedback on the trip demand in an article was positively correlated and received a plus value *(+)* in the factor-table; factors with negative feedback on trip demand a minus value *(-)*; and factors with neutral feedback a neutral value *(o)*. An empty cell indicates that a factor was not reflected with any impact or not considered in the article.

In the next step, the tabulated values of each included study were summed up (see *sum* column in factor-tables) to a factor-summation-value. This value provides direct information about the importance of one factor and can be understood as a rank for the considered key element (see Tables 7 - 11). To proceed further the identified factors of the single elements were merged together to obtain a factor-table of the defined mobility hub. To do so, the factor-summation-values of each element were added to make up one overall value. However, by employing the factor-summation-values directly, the results for the MH were slightly distorted by the different number of included records for each element in the screening process. To prevent the influence of the varying number of papers, data nominalization of the factor-summation-values was conducted. Data nominalization is commonly applied in scientific research (Robinson & Oshlack, 2010; Changshan Wu, 2004) and was chosen to be adequate for this problem. To nominalize the factor-summation-values into a score, *Rescaling,* also known as *Min-Max Nominalization* on a scale from zero to one, was applied. The employed mathematical formula for this method can be seen below (Akanbi et al., 2014; Han et al., 2012):

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)}$$

Thereby, x´ represents the nominalized value, x the original value (here: factor-summation-value), min(x) the minimum value in the considered dataset, and max(x) the maximum value in the dataset. The scores of each element were then added up to one overall score for the mobility hub. According to the calculated scores for each factor, a rank was manually assigned to sort the factors from most impactful to least impactful in the last step of the data extraction. The findings can be seen in the MH factor-table (Table 12). On the left the calculated scores for each element are arranged next to the factor-summation-values of the single elements to show their correlation. On the right, the total score with its assigned rank is placed.

5. Results

5.1. Spatial factors of the key elements

As described in the methodology, in this chapter the findings for each of the key elements are presented. For this purpose, each element is first briefly described as well as defined with regards to the scope of the paper. Second, the results of the factor analysis are presented in the form of an overview in a factor-table and accompanying written descriptions for each element. Building on the single elements, Chapter 5.2 presents the results of the factor-merging for the mobility hub.

5.1.1. Bike sharing

Bike sharing has developed as one of the fastest-growing transportation systems in several cities. It is an active micromobility mode based on the usage of bicycles in a defined network with an installed (digital) renting platform. Users can rent a bike at a certain station or position, use it in a classified area, and return it to another station or position. Preferably, short point to point trips or roundtrips are performed by bike sharing models. Bike sharing systems can comprise several forms of bicycles, such as conventional, cargo, tandem, or electric bikes. These forms exist in three types of systems: 1) station based or docked; 2) free-floating or dockless; and 3) hybrid (mix of docked and dockless). More information about bike sharing can be found in the already abundant literature. (Ambroz et al., 2016; Aono, 2019; Christensen & Shaheen, 2014; Duran-Rodas et al., 2021; S. Shaheen et al., 2020)

Considering the scope of this paper and the factor analysis of the most essential factors for locating bike sharing systems, only the conventional and electric bicycles are considered. In line with the previously described extraction process, the following factor overview in Table 7 presents the findings of the SLR highlighted in a colour code related to the importance of each factor. In addition, in Appendix A, the information in line with the methodology of the selected literature is broken down by country of the study area, date of publishment, type of the bike sharing system, the model used for the study, and the citation counts.

Table 7: Factors of the built and social environments for the element bike sharing (factor-table)

Bike Sharing - Factor Table			Spatial Studies																		User-based Studies (Survey)									Guidelines				SUM
			a	b , q	c , j	d	e	f , g	h	i	k	l	m	n	o	p	r	s	t	u	I	II	III	IV , V	VI	VII	VIII	IX	X	A	B	C	D	(n=35)
								(+) Positive Correlation								(-) Negative Correlation								(o) Neutral Correlation										
Groups	Sub-Groups	Factors																																
Social Environment	Population	City Population				+		+						+																		+		4
		Population Density	+	+	+		+	+					+	+	+			+													+		+	11
		Employment Density	+	+	+	+		+	+		+		+					+		+								+	+	+			+	14
	Socio-Demography	High Household Income (Affluence Neighbourhood)					+	+													+	+	+		+		-		+					6
		Household Size			+																+			+										3
		Household Car Ownership (No or Low)						+																										1
		Household/Personal Education Level					+														+			+			+							4
Built Environment	Topography	Slope (Hilly Terrain)			-											-	-																-	-4
	Urban Structure	Short Distance to or within City Center (Central Business Districts)	+					+	+					+					+			+		+				+						8
		Commercial/Retail Activity	+	+	+		+	+			+									+			+		+						+		+	11
		Mixed Land use		+				+											+											+	+			5
		Industrial Land use																	+															1
		Residential Land use		+										+			+		+	+										+				6
	Transport Infrastructure (Availability)	Overall Public Transport		+	+					+		+	+	+				+	+	+					+	+				+	+	+	+	15
		Metro (Subway)	+	+				+			+		+						o	+				+										7
		Railway Station				+		+																+	+									4
		Bus Stop						+									+																	2
		Taxi Stop												+																				1
		Micro Mobility or Car Sharing Stop												+																				1
		Major Roads	-																-															-2
		Minor Roads												+																				1
		Intersection Proximity & Frequency		-															-															-2
		Embankment road				+																												1
		Active-Mode Infrastructure (Cycle-, Walking zones, Pedestrian Safety)	+	+			+	+	+		+	+	+	+	+	+		+	+					+					+		+	+	+	18
	POIs Recreation (Origins, Destinations)	Overall Recreation POIs		-	+									+		+		+							+									4
		Cinema				+								+											+									3
		Worship POIs			-																													-1
		Hotel			+															-														0
		Restaurant (Food Businesses)	+	+	+	+			+				+	+											+									8
		Tourist Attractions																		-													+	0
		Parks						+					+	+					+						+								+	6
		Public Squares																	+	-														0
		Sports Centers																							+									1
	POIs Business (Origins, Destinations)	Financial Institutions																		-														-1
		Universities or Educational Facilitis (Also Schools & Student Housing)	+			+			+								+	+		+														6
		Medical Instituitions (e.g. Hospitals)																		-														-1
Factors not mentioned in Literature		Industrial Land use, Single Land use, Tram station, Airport Proximity, Ferry Terminal Proximity, Parking Lot Availability																																

Literature markers:

a: Faghih-Imani et al. (2014), b: Noland et al. (2016), c: Faghih-Imani et al. (2017), d: T. D. Tran et al. (2015), e: Rixey (2012), f: Daddio (2012), g: Buck and Buehler (2012), h: Wang et al. (2016), i: Nair et al. (2013), j: Hampshire and Marla (2011), F. González et al. (2016), l: Lin and Yang (2011), m: Faghih-Imani and Eluru (2015), n: Duran-Rodas et al. (2019), o: Médard de Chardon et al. (2017), p: Mateo-Babiano et al. (2016), q: Bao et al. (2017), r: Sun et al. (2018), s: El-Assi et al. (2017), t: Yuanyuan Guo and He (2020), u: H. Li et al. (2021) / I: Dimitrios Efthymiou et al. (2013), II: Bachand-Marleau et al. (2012), III: Buck et al. (2013), IV: Fuller et al. (2011), V: Bachand-Marleau et al. (2011), VI: Murphy and Usher (2015), VII: Susan A. Shaheen et al. (2011), VIII: Du and Cheng (2018), IX: Campbell et al. (2016), X: Fishman et al. (2015) / A: Ambroz et al. (2016), B: Gauthier et al. (2014), C: Büttner et al. (2011), D: McCormack et al. (2011)

As highlighted by the colour code and the factor-summation-values in Table 7, the factor most associated with ridership of bike sharing is *active-mode infrastructure,* which was highlighted 18 times (see factor-summation-values on the right) in the literature. It is followed by the factors *overall public transport, employment density, population density, and commercial/retail activity.*

The sub-groups most referenced in literature are *population* for the *social environment,* as well as *transport infrastructure* and *urban structure* for the *built environment*. Negative correlations, and thus a negative association with ridership, were found for the factors *slope, major roads, intersection proximity & frequency, financial Institutions, and medical institutions* in declining order. The factors depicted at the bottom of each element factor-table were not studied in the included literature.

Regarding the employed type of studies, socio-demographics were evenly included in all types of studies with a slight surplus in user-based studies. In contrast, factors of the built environment were marginally more prevalent in spatial studies. Factors in the guidelines were not predominate in either of the groups.

5.1.2. Standing e-scooter sharing

The micromobility mode of standing e-scooter sharing is one of the newest transportation systems and has been growing significantly over the last five to ten years. Meanwhile, in many cities, the usage of e-scooter systems exceeded that of shared bikes significantly. The reasons for this development may be manyfold, however, travel behaviour differences, as well as user attitudes towards overall physical effort and system-based convenience, are likely to play a major role. (Caspi et al., 2020; Noland, 2019)

Considering the usage system of e-scooter, two main sharing systems exist in the form of standing e-scooter and moped-style scooters. This study included records of standing e-scooters as more common systems studied and applied for MHs. The system is in general a free-floating or hybrid system and works by the following: users can rent a scooter from a certain position close by via a digital renting map application, use it in a defined area or network, and return it to another position in the network. Preferably, first and last mile trips are performed by scooter sharing models. More information about scooter sharing can be seen in the already abundant literature. (Caspi et al., 2020; McKenzie, 2019; Noland, 2019; Schemel et al., 2020; S. Shaheen et al., 2020)

As stated in the previous section on bike sharing, the following Tables 9 and 10 provide the results from the systematic literature review.

Table 8: Factors of the Built and social environments for the element E-Scooter Sharing (factor-table)

E-Scooter Sharing - Factor Table			Spatial Studies								User-based Studies (Survey)						Guidelines					SUM
			a , h	b	c	d , e , l	f , k	g	i	j	I	II	III	IV	V	VI	A	B	C	D	E	(n = 23)
					(+) Positive Correlation						(-) Negative Correlation						(o) Neutral Correlation					
Groups	**Sub-Groups**	**Factors**																				
Social Environment	Population	Population Density	+		+	+									+							**4**
		Employment Density			+	+									+		+	+	+		+	**7**
	Socio-Demography	High Household Income (Affluence Neighbourhood)	+		+	+		**o**	+		**o**		+	+				+		+	+	**9**
		Household Car Ownership (No or Low)			-						+			+								**1**
		Household/Personal Education Level				+								**o**	+			+		+		**4**
Built Environment	Topography	Slope (Hilly Terrain)					+															**1**
	Urban Structure	Short Distance to or within City Center (Central Business Districts)			+	+		+		+				+					+	+	+	**8**
		Commercial/Retail activity	+	+		+	+	+					+						+		+	**8**
		Mixed Land use			+	+	+	+		+									+			**6**
		Industrial Land use				+	-	-														**-1**
		Residential Land use	+	+		+		+	+													**5**
		Institutional Land use				+		+														**2**
	Transport Infrastructure (Availability)	Overall Public Transport		+		+		+	+				+				+	+				**7**
		Metro (Subway)		+																		**1**
		Bus Stop			+	+																**2**
		Major Roads	+		+														-			**1**
		Minor Roads	+		+														+			**3**
		Intersection Proximity & Frequency			+	+	**o**															**2**
		Embankment Road													+							**1**
		Active-Mode Infrastructure (Cycle-, Walking zones, Pedestrian Safety)	+			+	+			+		+			+			+	+	+	+	**10**
	POIs Recreation (Origins, Destinations)	Overall Recreation POIs	+	+		+	+					+	+	+		+	+	+	+		+	**12**
		Restaurant (Food Businesses)			+													+	+		+	**4**
		Tourist Attractions	+	+																	+	**3**
		Parks					+	-											+			**1**
	POIs Business (Origins, Destinations)	Universities or Educational Facilitis (Also Schools & Student Housing)		+	+	+		+					+					+				**6**
Factors not mentioned in Literature		City Population, Household Size, Single Land use, Railway Staion, Tram Station, Taxi Stop, Micro Mobility or Car Sharing Stop, Airport Proximity, Ferry Terminal Proximity, Parking Lot Availability, Cinema-, Worship-, Hotel-, Public Squares-, Sport Centers-, Finacial Institution-, Medical Institution- POIs																				

Literature markers:

a. McKenzie (2019), b: Zhu et al. (2020), c: Huo et al. (2021), d: Bai and Jiao (2021), e: Caspi et al. (2020), f: Hosseinzadeh et al. (2021b), g: Bai and Jiao (2020), h: Zou et al. (2020), i: Nawaro (2021), j: Nikiforiadis et al. (2021), k: Hosseinzadeh et al. (2021a), l: Jiao and Bai (2020) / I: Eccarius and Lu (2020), II: Bieliński and Ważna (2020), III: Lee et al. (2021), IV: Yujie Guo and Zhang (2021), V: Laa and Leth (2020), VI: Kopplin et al. (2021) / A: NACTO (2018), B: Orr et al. (2019), C: Sedor and Oriold (2020), D: S. Shaheen and Cohen (2019), E: City of Santa Monica (2019)

As highlighted with the green colour code and the factor-summation-values in Table 8, the factor most associated with ridership of e-scooter sharing is *overall recreation POIs*. It is followed by the factors *active-mode infrastructure, high household income (affluence neighbourhood), short distance to or within city centre, and commercial/retail activity*. The sub-groups most considered in the included records are both *population* and *socio-demography* for the social environment, as well as the sub-groups *POIs recreation* and *urban structure* for the built environment. A negative correlation was found for the factor *industrial land use*.

Considering the employed type of studies, socio-demographics were evenly included in all types of studies. The factors of the built environment were considerably more included in spatial studies. Factors in the guidelines were not prevalent in either of the groups.

5.1.3. Car sharing

Car sharing as a mobility mode has developed over the last forty years, increasing in popularity in the 1990s. Nowadays, car sharing services operate in most major cities worldwide. The main concept of commercial car sharing is to provide users with vehicles without the requirement to own a private car. Users commonly pay a combination of registration fees, fixed fees per use and variable fees related to the duration of a conducted trip. (Ambroz et al., 2016; Schmöller et al., 2015; S. Shaheen et al., 2020)

The different systems of car sharing offered in various cities can generally be broken down into three main models of operation: First, station-based models, which can be round-trip (where trips must start and end at the same station or one-way) or one-way (where the vehicles can be brought back to any designated station of a provider) station-based. Second, free-floating car sharing, where cars can be taken and left at any available parking lot in a defined delimited service area defined by the provider. Third, peer-to-peer (P2P) car sharing. In this model, private customers provide private vehicles for renting which is organized by a provider who matches the different offer and supply requests. The third model type is relatively new on the market and not as established or studied as the previous two. However, the idea is similar to a station-based system, since the start and end location of a trip is the same. (Schmöller et al., 2015; S. Shaheen et al., 2020; S. A. Shaheen & Cohen, 2020)

In the scope of this paper, station-based and free-floating systems for passenger transport are considered. The following Tables 11 and 12 provide the findings from the systematic literature review.

Table 9: Factors of the Built and social environments for the element Car Sharing (factor-table)

Car Sharing - Factor Table			Spatial Studies										User-based Studies (Survey)											Guidelines				SUM
			a	b	c	d	e	f	g	h	i	j	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	A	B	C	D	(n = 25)
					(+) Positive Correlation								(-) Negative Correlation								(o) Neutral Correlation							
Groups	**Sub-Groups**	**Factors**																										
Social Environment	Population	City Population																	+		+			+			+	**4**
		Population Density		+	+			+	+		+	+							+		+			+	+			**10**
		Employment Density		+				+	+	+							+		+									**6**
	Socio-Demography	High Household Income (Affluence Neighbourhood)							+				**o**			+	+	+		+	+			+			+	**8**
		Household Size		+	+			-						+	-		+	**o**	-			+		-			-	**0**
		Household Car Ownership (No or Low)			+								+		+	-	**o**	+			+						+	**5**
		Household/Personal Education Level							+				+					+	+		+	+	-	+			+	**7**
Built Environment	Urban Structure	Short Distance to or within City Center (Central Business Districts)															+							+	+			**3**
		Commercial/Retail activity		+						+	+	+				+				+								**6**
		Mixed Land use									+													+		+		**3**
		Residential Land use										+													+			**2**
		Institutional Land use	-																									**-1**
	Transport Infrastructure (Availability)	Overall Public Transport	+		+	+	+	+				+												+	+	+		**9**
		Metro (Subway)					+																					**1**
		Railway Station	+																									**1**
		Bus Stop	+		+																							**2**
		Micro Mobility or Car Sharing Stop																				+						**1**
		Active-Mode Infrastructure (Cycle-, Walking zones, Pedestrian Safety)																							+	+		**2**
		Airport Proximity	+																									**1**
		Parking Lot Availability	+														+											**2**
	POIs Recreation (Origins, Destinations)	Overall Recreation POIs	+							+		+				+		+							+			**6**
		Hotel									+																	**1**
		Restaurant (Food Businesses)	+			+					+																	**3**
		Parks																									-	**-1**
	POIs Business (Origins, Destinations)	Universities or Educational Facilitis (Also Schools & Student Housing)								+	+	+				+	+											**5**
		Medical Institutions (e.g. Hospitals)										+																**1**
Factors not mentioned in Literature		Slope (Hilly Terrain), Industrial Land use, Single Land use, Tram Station, Taxi Stop, Minor Roads, Major Roads, Intersection Proximity & Frequency, Embankment Road, Ferry Terminal Proximity, Cinema-, Worship-, Tourist Attractions, Public Squares-, Sport Centers-, Finacial Institution- POIs																										

Literature markers:

a: Cheng et al. (2019), b: Schmöller et al. (2015), c: Kang et al. (2016), d: Willing et al. (2017), e: Lorimier and El-Geneidy (2013), f: Kortum and Machemehl (2012), g: Tyndall (2017), h: C. Qian et al. (2017), i: Lage et al. (2019), j: Y. Li and Fan (2017) / I: D. Kim et al. (2015), II: Dimitrios Efthymiou et al. (2013), III: Sioui et al. (2013), IV: Chenyang Wu et al. (2020), V: Seo and Lee (2021), VI: Becker et al. (2017), VII: Prieto et al. (2017), VIII: Yoon-Young et al. (2019), IX: Dias et al. (2017), X: Tao et al. (2021), XI: Acheampong and Alhassan (2019) / A: ITS Australia (2021), B: Stars EU-Horizon (2020), C: Casier et al. (2021), D: Le Vine and Zolfaghari (2014)

Similar to the previously analysed elements, Table 9 depicts the factor-table for car sharing. Thereby, the factor most associated with ridership of car sharing is *population density*. It is followed by the factors *overall public transport, high household income, and household/personal education level.* The factors *employment density, commercial/ retail activity, and overall recreation POIs* share the fifth rank with the same factor-summation-values.

Both sub-groups *population* and *socio-demography* for the social environment, as well as relatively balanced all sub-groups for the built environment were highlighted in the literature. Negative correlations and thus a negative association with ridership were found for the factors *institutional land use* and the *POI parks*.

Concerning the employed type of studies, socio-demographics were contained in all types of studies with a surplus in user-based studies. In contrast, factors of the built environment were marginally more included in spatial studies. Factors in the guidelines were not prevalent in either of the groups.

5.1.4. Ride hailing and taxi service

Ride hailing and taxi services can be described as on-demand ride services, which received a notable growth in recent years through the introduction and improvements of applications (apps) on mobile devices. More accurately, ride hailing (also ride sourcing), and taxi services belong to the group of *Transportation Network Companies (TNCs)*. Ride pooling (also known as ride splitting) and ridesharing services which are generally not considered TNCs, are not considered in the scope of the paper. For ride hailing services, the general aim is to connect commercial drivers with private passengers through smartphone apps; the driver then picks up the passenger(s) and drives them to a predefined destination chosen by the passenger(s). Taxis often offer similar services (e-hailing) in addition to the conventional in person encounters with passengers on the road. Ride hailing and taxi services are an essential element of the transit network since both services cover substantial amounts of trips as well as trips for wide geographic areas. The two services are similar in their operation strategy and were therefore reviewed as one key element in this paper. (Dias et al., 2017; X. Qian & Ukkusuri, 2015; S. Shaheen et al., 2020)

The following Tables 13 and 14 provide the findings from the systematic literature review for ride hailing and taxi services.

Table 10: Factors of the Built and social environments for the element Ride Hailing & Taxi (factor-table)

Ride Hailing & Taxi - Factor Table			Spatial Studies										User-based Studies (Survey)							Guide	SUM
			a	b	c	d / l / m	e	f / h	g	i	j	k	I	II	III	IV	V	VI	VII	A	(n = 21)
					(+) Positive Correlation					(-) Negative Correlation					(o) Neutral Correlation						
Groups	**Sub-Groups**	**Factors**																			
Social Environment	Population	City Population											+								1
		Population Density	+	+	+	-	+	+	+		+		+		+		+	+		+	11
		Employment Density		+	+	+	+	+	+	+	+	+		+				+		+	12
	Socio-Demography	High Household Income (Affluence Neighbourhood)	+		+	+		+			+		+		+		+	+	+		10
		Household Size															-				-1
		Household Car Ownership (No or Low)			+	o		+			+		+		+			+			6
		Household/Personal Education Level			+	+		+				+	+		+	+		+	+		9
Built Environment	Urban Structure	Short Distance to or within City Center (Central Business Districts)				-									+				-		-1
		Commercial/Retail activity	+	+		+						+									4
		Mixed Land use	-				+	+								+					2
		Residential Land use	-	+					+												1
	Transport Infrastructure (Availability)	Overall Public Transport	+		+		+	+	+	+					+				o	+	8
		Metro (Subway)		+		o												+			2
		Railway Station													+						1
		Bus Stop	+	+		-		-										-			-1
		Major Roads	+	+	+	+		+													5
		Minor Roads	+	+	+	+		+													5
		Intersection Proximity & Frequency	+	+	+	+	-	+													4
		Active-Mode Infrastructure (Cycle-, Walking zones, Pedestrian Safety)						+			+									+	3
		Airport Proximity				-		+						+							1
		Parking Lot Availability	+			+	+														3
	POIs Recreation (Origins, Destinations)	Overall Recreation POIs	+	+						+				+			+	+	+	+	8
		Worship POIs	+																		1
		Hotel										+		+						+	3
		Restaurant (Food Businesses)										+									1
		Parks	+																	+	2
		Public Squares	+																		1
		Sports Centers																		+	1
	POIs Business (Origins, Destinations)	Financial Institutions							+											+	2
		Universities or Educational Facilitis (Also Schools & Student Housing)	+	+				+	+					+				+		+	7
		Medical Instituitions (e.g. Hospitals)	+	+																+	3
Factors not mentioned in Literature		Slope (Hilly Terrain), Single Land use, Industrial Land use, Institutional Land use, Tram Station, Taxi Stop, Micro Mobility or Car Sharing Stop, Embankment Road, Ferry Terminal Proximity, Cinema-, Tourist Attractions- POIs																			

Literature markers:

a: Liu et al. (2020), b: Tang et al. (2019), c: Gehrke (2020), d: X. Qian and Ukkusuri (2015), e: Sabouri et al. (2020), f: Yu and Peng (2019), g: B. Li et al. (2019), h: Lavieri et al. (2018), i: Demissie et al. (2021), j: Marquet (2020), k: K. Kim (2018), l: W. Zhang et al. (2020), m: Yang et al. (2019) / I: Dias et al. (2017), II: Henao (2017), III: Grahn et al. (2020), IV: Alemi et al. (2018), V: Lavieri and Bhat (2019), VI: Etminani-Ghasrodashti and Hamidi (2019), VII: Acheampong et al. (2020) / A: City of Perth (2016)

For ride hailing and taxi services (see Table 10), the factor most associated with ridership is *employment density*. The factors p*opulation density, high household income, household/personal education level*, as well as overall *public transport* together with *overall recreation POIs* follow in declining order.

The sub-groups most referenced are again both sub-groups for the social environment, and *transport infrastructure* and *POIs recreation/business* for the built environment. Negative relationships with ridership were explored equally for the factors *household size, short distance to or within city centre,* and *bus stops*.

Considering the employed study types, socio-demographics were included in all types of studies. Built environment factors were more contained in spatial studies. For the guidelines, only one record was found which factors did not show a tendency for either of the groups.

5.1.5. E-Charging station for cars

E-Charging stations play a significant role in the transition to a sustainable mobility in the future. It enables the integration of electric and hybrid vehicles in the transport system by charging a different array of vehicles, such as cars, buses, bikes, or scooters. This paper includes records of charging stations for cars and taxis as key vehicles when considering mobility hubs and the reviewed literature. E-Charging stations for cars can be separated into public, private, and taxi systems. They experience different utilization through different usage behaviours of the related system. Therefore, the diverse types of charging stations employ different charging technologies in the form of battery replacement, slow (standard) charging, and fast charging. Each technology offers a different amount of flexibility when it comes to charging duration, as well as the perceived operating range of a car. (Frade et al., 2011; Gavranović et al., 2014; Jung et al., 2014; Metais et al., 2022) Thus, the allocation process of E-Charging stations is highly dependent on the installed type of station. With regards to the inclusion of records for the factor analysis, in the scope of this paper, all types and technologies were considered. The following Tables 15 and 16 provide the findings from the systematic literature review for E-charging stations.

Table 11: Factors of the Built and social environments for the element E-Charging Station (factor-table)

Charging Station - Factor Table			Spatial Studies							User-based Studies				Guidelines				SUM
			a	b	c	d	e	f	g	I	II	III	IV	A	B	C	D	(n = 15)
			(+) Positive Correlation							(-) Negative Correlation				(o) Neutral Correlation				
Groups	Sub-Groups	Factors																
Social Environment	Population	City Population		+	+					+			-					2
		Population Density		+	+	+	+		+					+	+			7
		Employment Density	+			+		+	+					+	+			6
	Socio-Demography	High Household Income (Affluence Neighbourhood)								+	+	+	+					4
		Household Size								+	+		+					3
		Household Car Ownership (No or Low)								+	+	+	+					4
		Household/Personal Education Level	+						+	+	+	+						5
Built Environment	Urban Structure	Short Distance to or within City Center (Central Business Districts)		+						+								2
		Commercial/Retail activity							+							+	+	3
		Mixed Land use	+															1
		Residential Land use	+			+												2
	Transport Infrastructure (Availability)	Overall Public Transport						+	+					+	+	+		5
		Bus Stop						+										1
		Major Roads												+	+		+	3
		Minor Roads												+	+			2
		Parking Lot Availability													+			1
	POIs Recreation (Origins, Destinations)	Overall Recreation POIs				+		+	+					+	+	+		6
	POIs Business (Origins, Destinations)	Universities or Educational Facilitis (Also Schools & Student Housing)						+							+			2
Factors not mentioned in Literature		Slope (Hilly Terrain), Single Land use, Industrial Land use, Institutional Land use, Metro (Subway), Railway Station, Tram Station, Taxi Stop, Micro Mobility or Car Sharing Stop, Intersection Proximity & Frequency, Embankment Road, Active-Mode Infrastructure, Airport Proximity, Ferry Terminal Proximity, Worship-, Cinema-, Hotel-, Restaurant (Food Businesses)-, Tourist Attractions-, Parks-, Public Squares-, Sports Centers-, Financial Institution-, Medical Institution- POIs																

Literature markers:

a: Frade et al. (2011), b: Shahraki et al. (2015), c: Gavranović et al. (2014), d: J. González et al. (2014), e: Jung et al. (2014), f: Chen et al. (2013), g: Dong et al. (2019) / I: He et al. (2016), II: Y. Zhang et al. (2011), III: Erdem et al. (2011), IV: Plötz et al. (2014) / A: Niti et al. (2021), B: Vermont Energy Investment Corporation (2014), C: National Renewable Energy Laboratory (2012), D: Ministry of Power Government of India (2018)

For the element charging station (Table 11), p*opulation density* is the factor most associated with charging station usage. The factors *employment density*, *overall recreation POIs, household/personal education level, and overall public transport* are on the ranks below. Both sub-groups for the social environment and all the sub-groups for the built environment were emphasised in the records. However, due to the generally small number of suitable records found, several factors were not mentioned and therefore not included in the factor-table. There were no factors indicating a negative correlation with ridership.

Regarding the employed type of studies, socio-demographics were included in all spatial and user-based studies. Built environment factors were more included in the spatial studies and the guidelines.

5.2. Spatial factors of mobility hub and country analysis

This section presents the mobility hub findings. The description and definition of the theoretical mobility hub was shown in 2. Definition and function of mobility hubs. The results of the factor analysis associated with the built and social environments are presented in the form of an overview factor-table (Table 12) and the accompanying written descriptions. In addition, Table 13 highlights the 15 most crucial factors for the allocation of an MH, according to their rank. The Tables 14, 15, and 16 show the country analysis models comprising information on the statistical distribution of countries in the included records.

Table 12: Factors of the Built and social environments for the Mobility Hub (factor-table)

Spatial Factors - Mobility Hub			**Bike Sharing (n=35)**		**Scooter Sharing (n=23)**		**Car Sharing (n=25)**		**Ridehail./Taxi (n=21)**		**Charging Station (n=15)**		**Mobility Hub Overall Counting (n=119)**	
Groups	**Sub-Groups**	**Factors**	Sum	**Score**	Sum	**Score**	Sum	**Score**	Sum	**Score**	Sum	**Score**	**Total Score**	**Rank**
Social Environment	Population	City Population	4	**0,36**	0	**0,08**	4	**0,45**	2	**0,23**	2	**0,29**	**1,41**	**14**
		Population Density	11	**0,68**	4	**0,38**	10	**1,00**	11	**0,92**	7	**1,00**	**3,99**	**1**
		Employment Density	14	**0,82**	7	**0,62**	6	**0,64**	12	**1,00**	6	**0,86**	**3,93**	**2**
	Socio-Demography	Household Income (Affluence Neighbourhood)	6	**0,45**	9	**0,77**	8	**0,82**	10	**0,85**	4	**0,57**	**3,46**	**5**
		Household Size	3	**0,32**	0	**0,08**	0	**0,09**	-1	**0,00**	3	**0,43**	**0,91**	**21**
		Household Car Ownership (No or Low)	1	**0,23**	1	**0,15**	5	**0,55**	6	**0,54**	4	**0,57**	**2,04**	**10**
		Household/Personal Education Level	4	**0,36**	4	**0,38**	7	**0,73**	9	**0,77**	5	**0,71**	**2,96**	**6**
Built Environment	Topography	Slope (Hilly Terrain)	-4	**0,00**	1	**0,15**	0	**0,09**	0	**0,08**	0	**0,00**	**0,32**	**-**
	Urban Structure	Short Distance City Center (Central Business Districts)	8	**0,55**	8	**0,69**	3	**0,36**	-1	**0,00**	2	**0,29**	**1,89**	**11**
		Commercial/Retail activity	11	**0,68**	8	**0,69**	6	**0,64**	4	**0,38**	3	**0,43**	**2,82**	**7**
		Mixed Land use	5	**0,41**	6	**0,54**	3	**0,36**	2	**0,23**	1	**0,14**	**1,68**	**12**
		Industrial Land use	1	**0,23**	-1	**0,00**	0	**0,09**	0	**0,08**	0	**0,00**	**0,40**	**-**
		Residential Land use	6	**0,45**	5	**0,46**	2	**0,27**	1	**0,15**	2	**0,29**	**1,63**	**13**
		Institutional Land use	0	**0,18**	2	**0,23**	-1	**0,00**	0	**0,08**	0	**0,00**	**0,49**	**33**
	Transport Infrastructure (Availability)	Overall Public Transport	15	**0,86**	7	**0,62**	9	**0,91**	8	**0,69**	5	**0,71**	**3,79**	**3**
		Metro (Subway)	7	**0,50**	1	**0,15**	1	**0,18**	2	**0,23**	0	**0,00**	**1,07**	**18**
		Railway Station	4	**0,36**	0	**0,08**	1	**0,18**	1	**0,15**	0	**0,00**	**0,78**	**24**
		Bus Stop	2	**0,27**	2	**0,23**	2	**0,27**	-1	**0,00**	1	**0,14**	**0,92**	**20**
		Taxi Stop	1	**0,23**	0	**0,08**	0	**0,09**	0	**0,08**	0	**0,00**	**0,47**	**34**
		Micro Mobility or Car Sharing Stop	1	**0,23**	0	**0,08**	1	**0,18**	0	**0,08**	0	**0,00**	**0,56**	**29**
		Major Roads	-2	**0,09**	1	**0,15**	0	**0,09**	5	**0,46**	3	**0,43**	**1,23**	**17**
		Minor Roads	1	**0,23**	3	**0,31**	0	**0,09**	5	**0,46**	2	**0,29**	**1,37**	**15**
		Intersection Density	-2	**0,09**	2	**0,23**	0	**0,09**	4	**0,38**	0	**0,00**	**0,80**	**23**
		Embankment Road	1	**0,23**	1	**0,15**	0	**0,09**	0	**0,08**	0	**0,00**	**0,55**	**30**
		Active-Mode Infrastructure (Cycle-, Walking zones, Pedestrian Safety)	18	**1,00**	10	**0,85**	2	**0,27**	3	**0,31**	0	**0,00**	**2,43**	**9**
		Airport Proximity	0	**0,18**	0	**0,08**	1	**0,18**	1	**0,15**	0	**0,00**	**0,59**	**28**
		Parking Lots	0	**0,18**	0	**0,08**	2	**0,27**	3	**0,31**	1	**0,14**	**0,98**	**19**
	POIs Recreation (Origins, Destinations)	Overall Recreation POIs	4	**0,36**	12	**1,00**	6	**0,64**	8	**0,69**	6	**0,86**	**3,55**	**4**
		Cinema	3	**0,32**	0	**0,08**	0	**0,09**	0	**0,08**	0	**0,00**	**0,56**	**29**
		Worship POIs	-1	**0,14**	0	**0,08**	0	**0,09**	1	**0,15**	0	**0,00**	**0,46**	**-**
		Hotel	0	**0,18**	0	**0,08**	1	**0,18**	3	**0,31**	0	**0,00**	**0,75**	**25**
		Restaurant (Food Businesses)	8	**0,55**	4	**0,38**	2	**0,27**	1	**0,15**	0	**0,00**	**1,36**	**16**
		Tourist Attractions	0	**0,18**	3	**0,31**	0	**0,09**	0	**0,08**	0	**0,00**	**0,66**	**27**
		Parks	6	**0,45**	1	**0,15**	-1	**0,00**	2	**0,23**	0	**0,00**	**0,84**	**22**
		Public Squares	0	**0,18**	0	**0,08**	0	**0,09**	1	**0,15**	0	**0,00**	**0,50**	**32**
		Sports Centres	1	**0,23**	0	**0,08**	0	**0,09**	1	**0,15**	0	**0,00**	**0,55**	**30**
	POIs Business (Origins, Destinations)	Financial Institutions	-1	**0,14**	0	**0,08**	0	**0,09**	2	**0,23**	0	**0,00**	**0,53**	**31**
		Universities or Educational Facilitis (Also Schools & Student Housing)	6	**0,45**	6	**0,54**	5	**0,55**	7	**0,62**	2	**0,29**	**2,44**	**8**
		Medical Instituitions (e.g. Hospitals)	-1	**0,14**	0	**0,08**	1	**0,18**	3	**0,31**	0	**0,00**	**0,70**	**26**
Factors not mentioned in Literature:			Single Land use, Tram Station, Ferry Terminal Proximity											

5.2.1. Mobility hub - Data merging element factors

As shown in Figure 1, this chapter provides the findings for the mobility hub obtained through the described classification process of the key elements´ factors. In the following a brief explanation of the mobility hub result factor-table (see Table 12) and the result rank table (see Table 13) is provided. The final number of included factors is 39 with three factors overall not mentioned in the literature. As depicted, with the purple colour code for the total score and the assigned rank in Table 12, the factor most associated with the usage of a mobility hub is *population density*. It is followed by the factors *employment density, overall public transport, overall recreation POIs, and household income*.

As result of the applied min-max nominalization with a scale from zero to one, no negative scores were generated in the merging process. However, by reviewing the sum-columns of each element, an overall negative correlation and thus a negative association with the usage of MHs, was found for the factor *slope.* A neutral correlation could be identified for *industrial land use* and *worship POIs*. Overall, not studied in the literature and therefore excluded in the final factor-table are the factors *single land use, tram station*, and *ferry terminal*.

In addition, the two overall factors with *overall public transport* and *overall recreation POIs* were more highlighted in the records as their related single factors. Therefore, the results for the factors *restaurant*, as most influencing recreation POI, and *metro*, as most referenced public transport mode, are underlined within these two superordinate factors. Furthermore, within all the considered single POIs the factor *universities or educational facilities* received the highest association from the literature with the corresponding rank eight.

Table 13: Ranking of factor-table for the allocation of a Mobility Hub

Sub-Factors	Rank
Population Density	1
Employment Density	2
Overall Public Transport	3
Overall Recreation POIs	4
Household Income (Affluence Neighbourhood)	5
Household/Personal Education Level	6
Commercial/Retail activity	7
Universities or Educational Facilitis (Also Schools & Student Housing)	8
Active-Mode Infrastructure (Cycle-, Walking zones, Pedestrian Safety)	9
Household Car Ownership (No or Low)	10
Short Distance City Center (Central Business Districts)	11
Mixed Land use	12
Residential Land use	13
City Population	14
Minor Roads	15

5.2.2. Key country analysis

The geographical analysis of the included records refers to the location of the data collection in the form of either trip data or survey data. In that context two country tables with their statistical findings were established segregating between spatial studies and user-based studies. Table 14 (spatial studies) shows that the relating 60 articles were carried out in 18 countries over five continents (excluding the category *worldwide*). Thereby, USA received the most concentration of the research community with a share of approximately 47%, followed by the European Countries (20%), and China (15%). The articles conducted in Europe were well distributed over nine countries. Despite the major share of the US, overall, a mix of countries in the articles can be seen.

Considering user-based studies (Table 15), 38 articles were conducted in 17 countries over six continents (excluding the category *worldwide*). Thereby, the European Countries, which included nine different countries, were mostly considered in the included records with a share of around 24%. USA (ca. 21%), China (ca. 16%), Canada (ca. 11%), and Korea (ca. 8%) were the next bigger shares following. Combined they amount to almost 80% of the article country distribution. Together with the additional records a mix of countries in the records can be observed. Regarding the guidelines (Table 16), 18 records are found with the major share in the categories Worldwide (16%), USA (16%), and Europe (8%). In Appendix A the detailed information of the analysed countries and their respective cities can be seen for each included record.

Table 14: Article distribution by country for spatial studies of combined key elements

Country***	Number of Articles					Total Number Articles	Percentage to Total
	Bike Sharing	Scooter Sharing	Car Sharing	Ride hailing & Taxi	Charging Station	Mobility Hub	(n=63)
USA	8	9	2	8	1	28	46,7%
European Countries**	4	2	2	1	3	12	20,0%
China	2	0	3	3	1	9	15,0%
Worldwide*	3	0	0	0	1	4	6,7%
Canada	2	0	1	0	0	3	5,0%
Korea	0	0	1	1	0	2	3,3%
Chile	1	0	0	0	0	1	1,7%
Australia	1	0	0	0	0	1	1,7%
Singapore	0	1	0	0	0	1	1,7%
Brazil	0	0	1	0	0	1	1,7%
Turkey	0	0	0	0	1	1	1,7%
*	Studies considering more than one continent						
**	Greece (1), Germany (1), Poland (1), England (1), Belgium (1), Spain (2), France (2), Netherlands (1), Portugal (2)						
***	The country refers to the place where spatial study of trip data was conducted						

Table 15: Article distribution by country for user-based studies of combined key elements

Country***	Number of Articles					Total Number Articles	Percentage to Total
	Bike Sharing	Scooter Sharing	Car Sharing	Ride hailing & Taxi	Charging Station	Combined	(n=38)
European Countries**	2	3	3	0	1	9	23,7%
USA	1	1	1	5	0	8	21,1%
China	3	0	1	0	2	6	15,8%
Canada	3	0	1	0	0	4	10,5%
Korea	0	1	2	0	0	3	7,9%
Ghana	0	0	1	1	0	2	5,3%
Worldwide*	0	0	1	0	0	1	2,6%
Australia	1	0	0	0	0	1	2,6%
Turkey	0	0	0	0	1	1	2,6%
Taiwan	0	1	0	0	0	1	2,6%
Indonesia	0	0	1	0	0	1	2,6%
Iran	0	0	0	1	0	1	2,6%
*	Studies considering more than one continent						
**	Greece (2), Germany (2), Poland (1), Austria (1), Switzerland (1), England (1), Ireland (1)						
***	The country refer to the place where empirical study was conducted						

Table 16: Article distribution by country for Guidelines of combined key elements

Country**	Number of Articles					Total Number Articles	Percentage to Total
	Bike Sharing	Scooter Sharing	Car Sharing	Ride hailing & Taxi	Charging Station	Combined	(n=18)
Worldwide*	2	0	2	0	2	6	15,8%
USA	1	4	0	0	1	6	15,8%
European Countries	1	0	2	0	0	3	7,9%
India	0	0	0	0	1	1	2,6%
Canada	0	1	0	0	0	1	2,6%
Australia	0	0	0	1	0	1	2,6%
*	Guidelines considering more than one continent						
**	The country refer to the place for which guideline was conducted						

6. Discussion and Limitations

After presenting the findings of the SLR, this chapter discusses the results and later shows the limitations of the paper.

6.1. Discussion of results

As seen in the results, the factor *population density* was overall the most associated factor with the usage of an MH. It was included in 43 articles of the total of 119 records (36.1%). This outcome is in line with many studies in the transport sector (e.g., Faghih-Imani et al. (2014), Lavieri and Bhat (2019)) and in particular matches with the recent findings from Ben Hassine and Fernanda Navarro-Avalos (both not published) from the conducted expert surveys about mobility hubs. It approves the overall important standing of population density as a socio-demographic factor for the allocation of mobility modes. The simplest explanation for this outcome is possibly found in the direct interrelation between a high number of residents and possible users/customers for the offered service. Corresponding to the socio-demographic factor *population density*, the built environment factor *residential land use* is also significant for the allocation process of MHs with a position in the list of the 15 most associated factors. It was highlighted 16 times (13.4%) in the literature. This outcome is consistent with the results from Anderson et al. (2017), which underlined residential land use as an urban structure setting most associated with the optimal siting of mobility hubs.

On the second rank overall and for the social environment, the factor *employment density* follows. It was mentioned 45 times (37.8%) in the records, however, due to the nominalization process and its lower association with car sharing usage, it received a slightly lower score as the factor population density. Like population density also employment density directly leads to higher demand through a high number of workers and thus possible users in the proximity of an MH. The high ranking in this study is also indirectly following the outcomes of the citizen´s survey and expert interviews for MHs in Munich from Klanke (2022), which indicated the proximity to the workplace as a crucial factor.

As assumed in the MH definition chapter and found in several studies and guidelines, *public transport* is one key factor associated with the usage of MHs and thus their allocation. It is placed on rank three overall, on rank one for the built environment, and was emphasized 44 times (37%) in the included records. It approves the recent findings of mobility hubs from Anderson et al. (2017), Miramontes et al. (2017), and Klanke (2022), which indicated the importance of public transport for the location process of MHs. As previously mentioned, major public transport stations work as high frequented transition places for citizens and often provide the core of public mobility in cities. In that context, also the factor *metro* (approx. 10%) of all other public transport modes obtained the highest rank for the association with ridership in this study.

As also indicated in the results from the expert surveys in Ben Hassine (not published) and Fernanda Navarro-Avalos (not published), POIs in general are of major importance when it comes to the location of MHs. This importance was also found in this study with the factor *overall recreation POIs* on rank four with a count of 36 (30.3%) in the factor analysis. As an additional outcome for recreation POIs from this study, the factor *restaurant* (12.6%) can be highlighted. Comparing the two sub-groups *recreation POIs* and *business POIs,* a slightly higher association for the usage of an MH and their respective elements is assumed for recreational/leisure trips since business/work trips were mainly found for *university and educational facilities* (21.8%). That university and educational institutions are of major importance for the allocation of MHs, was also found by Klanke (2022). However, considering the high rank of the social environment factor *employment density* which interacts with workplace proximity, business POIs related trips can be assumed to be similar to or more important than recreational trips for the allocation of MHs.

The social factor *household income (affluence neighbourhood),* on rank five overall and ranked three for the social environment, was considered 37 times (31.1%). It indicates the high dependence between MHs usage as well as generally offered mobility opportunities and the wealth condition of a household or neighbourhood. This inequality of favouring wealthier households and neighbourhoods, based on demand maximising allocation processes, was already indicated amongst others by Duran-Rodas et al. (2021) for bike sharing systems. Furthermore, the dependence of the factor *household income* was also topic in previous studies of mobility hubs and combined mobility modes as in T. D. Tran et al. (2015), or Nair et al. (2013).

The following two ranks overall, depicted with *household/personal education level* (24.3%) and *commercial/retail activity* (26,9%; rank three built environment), approve the findings from Ko et al. (2021) and Miramontes et al. (2017) for a high association with usage due to high education levels, and approve Anderson et al. (2017) results related to commercial and retail activities.

The factor *active-mode infrastructure* (27.7%) was highly associated with ridership of the micromobility modes bike and e-scooter sharing and less important for the other key elements based on cars. However, considering the combined strategy of MHs as the findings indicate, it is still one of the essential built environment factors for allocation processes. The factor *household car ownership (no or low)* on rank ten, was included to 13,8% in the records and received the high ranking especially because of its high shares in the car-dependent elements. It was also considered influential in the studies by Anderson et al. (2017), and Fernanda Navarro-Avalos (not published).

6.2. Limitations

To conduct this study, some limitations were encountered, which are discussed in this chapter. Despite, applying broad inclusion criteria, the author cannot be certain if all essential articles of the literature in the SLR and for the developed factor-tables for each element and the MH were included. Since the inclusion period in the scope of this paper was decided to be ten years to obtain recent research findings, earlier conducted studies with potentially other findings were excluded. Moreover, by focusing on the databases of Google Scholar, Web of Science, and Taylor & Francis, records published in none of the mentioned databases were left out. However, by consolidating three common and large bibliographic databases in general and for transportation planning under the application of standardized methods for identifying records, coverage limitations are assumed to be low.

Another limitation in the validation of the findings of this paper can be experienced in the found factors from the included records. Since this paper conducted a SLR of previously published literature about historical factors, it is limited by its reliance on them. Therefore, it cannot be assured that all possible factors of the built and social environments were included or evaluated sufficiently in the literature. One example of this limitation could be seen in the factor *ferry terminal*, which was found to be of high importance for the allocation of an MH by Anderson et al. (2017), however, was not mentioned in the included records of the SLR. Besides the factor *ferry terminal* also the factors *single land use* and *tram station* were not examined once in the included literature. In line with the factor validation limitation and the possible exclusion of some factors, it is crucial to mention that every urban or suburban area contains special settings. Therefore, location-adjusted analyses are always crucial for each mobility hub which can also explain single outcomes as found with the importance of *terry terminals* for the city of Oakland (USA) in Anderson et al. (2017). The findings in the scope of this paper, however, provide a much-needed simple location-neutral solution with suggestions in the initiation of a project and shall not replace location-adjusted analyses. Moreover, with 119 included records in the SLR, a large sample of articles with evaluated factors was analysed in this paper which statistically balances the found factors and possible coincidences through accidental exclusions of records.

Further limitations of this study can be found for the key elements of the theoretical mobility hub. Firstly, the so-called "substitution relationship" between the different included key elements (transport modes) was neglected in this study. This means that possible interdependencies and user substitution events between the different elements were not considered in the found factors and their association with ridership. Moreover, both the location and the assigned elements of a mobility hub interact dynamically with each other. Therefore, the pre-assignment of five key elements in this paper can be perceived as a limitation. However, this paper focused on the five demand-related key-components of mobility hubs in a likely real-world scenario with the additional opportunity that transport planners may adjust and use the factor-table accordingly to their project assigned MH key elements.

Another limitation refers to the type of papers included in SLR. As previously mentioned in the results, user-based studies somewhat tend to focus more on socio-demographic factors and spatial studies slightly tend to emphasize built environment factors. This fact combined with the broad and transparent inclusion criteria for the found articles might lead to the circumstance that found factors have a certain tendency to either one of these factor groups. In other words, more included user-based studies can lead to more focus on social environment factors and vice versa for spatial studies which could dilute the findings. However, the effect of this limitation is likely to be neglected due to the general low tendency of the factors to one factor group in the included articles. In addition, a distribution key of around 45% spatial studies, 35% user-based studies, and 20% guideline was calculated for the median of all included records which represent a reasonable factor distribution in the scope of this paper. Moreover, since spatial studies received the highest share, the limitation of the factor tendency can be further overruled by the fact that five of the six social environment factors received ranks in the highest positions with the two highest ranks also given to social environment factors.

Some other minor limitation for policymakers and transportation planners can be seen in the neglection of temporal factors such as weather and climate factors for the allocation process of the MH due to the applied methodology for the SLR.

7. Conclusion

The growing trend of implementing mobility hubs around the world - as one response to the challenge of reducing greenhouse gas emissions and high pollution levels worldwide by simultaneously providing further enhanced levels of mobility - signals the need to understand usage data and obstacles regarding these systems. However, there is an overall lack of scientific research regarding the optimal siting and equipping of such mobility hub projects especially when it comes to spatial factors of the surrounding built and social environments and their association with ridership. New studies and strategies to analyse these mobility systems for our future mobility are necessary. Therefore, this paper presents a systematic literature review as a descriptive metasummary (ranking system) for defined key elements (bike, scooter, car sharing, ride hailing & taxi, charging stations) of a theoretical mobility hub to identify common factors of the built and social environments. The findings in the form of factor-tables provide policymakers and transportation planners with a first-hand solution that offers a quick overview to locate MHs beyond geographic boundaries. The systematic review and its developed factor-tables include 119 records published between 2011 and March 2022.

The SLR identified overall 39 factors associated with ridership in the groups of the social environment and built environment. However, some factors in the final factor-table were mentioned only once or a few times. The factor most associated with the usage of a mobility hub was found in *population density*. It is followed by the factors *employment density, overall public transport, overall recreation POIs*, and *household income* in declining rank order. The ranks 6 to 10 in declining order are obtained by *household/personal education level, commercial/retail activity, universities or educational facilities, active-mode infrastructure*, and *household car ownership (no or low)*. An overall negative association with the usage of MHs was found only for the factor *slope*. No association was identified for the factors *industrial land use* and *worship POIs*. Not studied in the literature overall and therefore excluded in the final factor-table were the factors *single land use, tram station*, and *ferry terminal.* An overview of the results can be seen in Tables 12 and 13. The results for each key element can be found in Chapter 5.1. Regarding the geographical aspects of the included records for the combined key elements, an overall sufficient mix of countries was perceived. The researchers are mainly concentred on different cities in the USA, Europe, China, and Canada. However, it was apparent that a major focus relies on American samples for the type of spatial studies. Nevertheless, besides the perceived overall sufficient mix of cities in the included records, the inclusion criterium that each location/city was permitted only once in the factor-tables, further minimized the share of USA articles.

This review contributes to the literature in many ways. At first, it is showing organised the recent research and their attributes regarding mobility hubs and five crucial elements and transport modes (key elements). It further identifies, tabulates, and ranks common factors of the built and social environments associated with ridership for the optimal allocation of each of the considered key elements. Based on those findings and to the author´s best knowledge, it is the first paper that offers a location-neutral first-hand overview of influencing factors to locate mobility hubs efficiently. This catalogue of factors can be directly applied in current practice by supporting mobility hub operators, especially in the initiation sequence of projects to leverage their actions. Additionally, for future studies regarding the single elements or mobility hubs, authors obtain an immediate overview of historical findings through the factor-tables and the related result discussion and can build their studies upon this gathered information. With these contributions, it is hoped to extend the existing literature and enhance the understanding of transportation planners in the private and public sectors. Finally, also gaps in the literature were detected to give future research directions as shown in the following.

Firstly, as an overall recommendation for future research, the extension of the current paper can be stated. For example, this could be done by adjusting the inclusion criteria with non-English papers, extending the considered period of included articles, or adding more factor groups containing more socio-demographic, weather-related, or general temporal factors.

Considering the single elements from this review, for the element e-scooter sharing most of the included articles were found to be conducted in the US or with American databases whose findings would impose a bias on transportation planners. Therefore, future research on e-scooter sharing should focus more on data from other countries and cities or apply multilateral strategies as seen in Duran-Rodas et al. (2019), or Médard de Chardon et al. (2017) for the data evaluation. Concerning the element of bike sharing, the review process revealed a high focus of research on only station-based bike sharing systems. Since free-floating and station-based systems have marginally distinctive features as previously described, this one-sided perspective might influence the results regarding associated ridership data. Therefore, future factor analyses about bike sharing should preferably concentrate on free-floating bike sharing systems for their assessments. Conclusively, factors with low rankings which were not, or very rarely studied in the literature over the last ten years, could be prioritized in future research papers to examine their neutral, positive, or negative association with ridership properly. In this context, examples of factors for further research are *single land use, tram stations, ferry terminals*, and *airports* but also unexpected low ranked factors in this paper such as *railway stations* or *public squares*.

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Appendix A - Information Collection of the Factor-tables for each key element in line with the methodology of the SLR

Bike Sharing - Factor Table	**Spatial Studies**																	
	a	**b , q**	**c , j**	**d**	**e**	**f , g**	**h**	**i**	**k**	**l**	**m**	**n**	**o**	**p**	**r**	**s**	**t**	**u**
Reference Country of Study	Montreal, Canada	New York, USA	Barcelona & Sevilla, Spain	Lyon, France	Three Cities, USA	Washington, USA	Minneapolis & St. Paul, USA	Paris, France	Santiago, Chile	Worldwide	Chicago, USA	Worldwide	Worldwide	Brisbane, Australia	Seattle, USA	Toronto, Canada	Shenzhen, China	Shanghai, China
Type of Bike-Sharing System	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Dockless	Dockless
Model Type - Factor Analysis	MNB	RM	RM	LRM	LRM	MRM	RM	n/a	MNL	RM	MNL	RM	LRM	LRM	GAMM Modell	OLS	NB	NB
Citations in Web of Science	218	91 / 59	105 / n/a	n/a	142	n/a	129	n/a	42	249	n/a	9	95	80	53	183	32	0
Citations in Google Schoolar	402	154 / 78	174 / 78	115	258	72 / 155	231	330	71	523	159	18	159	117	76	332	45	0
Year of Publication	2014	16 / 17	17 / 11	2015	2013	12 / 12	2016	2013	2016	2011	2015	2019	2017	2016	2018	2017	2020	2021

Bike Sharing - Factor Table	**User-based Studies (Survey)**									**Guidelines**			
	I	**II**	**III**	**IV / V**	**VI**	**VII**	**VIII**	**IX**	**X**	**A**	**B**	**C**	**D**
Reference Country of Study	Greece	Quebec, Canada	Washington, USA	Montreal Canada	Dublin, Ireland	Hangzhou, China	Nanjing, China	Beijing, China	Melbourne, Brisbane Australia	Worldwide	Worldwide	Europe	Seattle, USA
Type of Bike-Sharing System	n/a	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Stat. Based	Both	Both	Stat. Based
Model Type - Factor Analysis	OLM	RM	n/a	RM	n/a	n/a	MNL	MNL	LORM	n/a	n/a	n/a	n/a
Citations in Web of Science	n/a	176	122	115 / 62	n/a	160	69	177	158	n/a	n/a	n/a	n/a
Citations in Google Schoolar	299	328	262	221/ 138	175	351	114	282	272	n/a	n/a	n/a	n/a
Year of Publication	2013	2012	2013	11 / 11	2015	2011	2018	2016	2015	2016	2014	2011	2011

Abbreviations:
RM: Regression Model / LM: Linear Regression Model / LRM: Robust Linear Regression Model / PM: P-median Location Model / MM: Multilevel Model / MNB: Multilevel Negative Binomial Model / MRM: Multivariate Regression Model / OLS: OLS Regression Model / GW: Geographically Weighted Regression / NB: Negative Binomial Regression / OLM: Ordered Logit Model / ORM: Ordered Probit Model / MNL: Multinomial Logit Model / BNL: Binomial logit Model / LORM: Logistic Regression Model / LVL: Latent Variable Logit Model / ROPM: Random Parameter Ordered Probit Model / MLM: Mixed Logit Model / GLM: Generalized Linear Model / Com. Analysis: Comparitive Analysis

EScooter Sharing - Factor Table	Spatial Studies								User-based Studies (Survey)						Guidelines				
	a , h	b	c	d , e , l	f , k	g	i	j	I	II	III	IV	V	VI	A	B	C	D	E
Reference Country of Study	Washington, USA	Singapore	5 Cities, USA	Austin, USA	Louisville, USA	Minneapolis, USA	Warsaw, Poland	Thessaloniki, Greece	Taiwan	Tricity, Poland	Seoul, Korea	Tampa, Florida, USA	Vienna, Austria	Germany	USA	Portland, USA	Calgary, Canada	USA	Santa Monica, USA
Type of Scooter-Sharing System	Dockless	Hybrid	Dockless	Dockless	Dockless	Dockless	Hybrid	Dockless	n/a	Dockless	n/a	Dockless	Hybrid	Dockless	Dockless	Dockless	Dockless	Dockless	Dockless
Model Type - Factor Analysis	Trip Data Analysis	Com. Analysis	MNB	RM	RM	NB	n/a	LVL	PLS-SEM	n/a	OLM	ROPM, MLM	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Citations in Web of Science	101 / n/a	31	4	0 / 38 / 3	15 / 18	44	n/a	11	26	20	1	0	14	6	n/a	n/a	n/a	n/a	n/a
Citations in Google Schoolar	171 / 34	57	11	0 / 73 / 12	8 / 46	81	0	21	53	28	6	0	32	11	n/a	n/a	n/a	n/a	n/a
Year of Publication	2019 / 2020	2020	2021	21 / 20 / 20	2021 / 2020	2020	2021	2021	2020	2020	2021	2021	2020	2021	2018	2019	2020	2019	2019

Abbreviations:

RM: Regression Model / LM: Linear Regression Model / LRM: Robust Linear Regression Model / PM: P-median Location Model / MM: Multilevel Model / MNB: Multilevel Negative Binomial Model / MRM: Multivariate Regression Model / OLS: OLS Regression Model / GW: Geographically Weighted Regression / NB: Negative Binomial Regression / OLM: Ordered Logit Model / ORM: Ordered Probit Model / MNL: Multinomial Logit Model / BNL: Binomial logit Model / LORM: Logistic Regression Model / LVL: Latent Variable Logit Model / ROPM: Random Parameter Ordered Probit Model / MLM: Mixed Logit Model / GLM: Generalized Linear Model / Com. Analysis: Comparitive Analysis

Car Sharing - Factor Table	Spatial Studies									
	a	b	c	d	e	f	g	h	i	j
Reference Country of Study	Chengdu, China	Munich, Berlin, Germany	Seoul, Korea	Amsterdam, Netherlands	Montreal, Canada	Austin Texas, USA	Ten cities in USA	Hangzhou, China	Sao Paulo, Brazil	Shanghai, China
Type of Car-Sharing System	Stat. Based	Free-Floating	Stat. Based	Free-Floating	Stat. Based	Free-Floating	Free-Floating	Stat. Based	Stat. Based	Stat. Based
Model Type - Factor Analysis	LORM	LM	MRM	GLM	MRM	BNL	OLS	Clustering Methods	n/a	NB
Number of Citations in Web of Science	12	101	16	27	71	n/a	n/a	10	n/a	-
Number of Citations in Google Schoolar	18	158	35	47	122	42	39	15	4	1
Year of Publication	2019	2014	2016	2017	2012	2012	2017	2016	2019	2021

Car Sharing - Factor Table	User-based Studies (Survey)											Guidelines			
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	A	B	C	D
Reference Country of Study	Seoul, Korea	Greece	Montreal, Canada	London, UK	Incheon City, South	Basel, Switzerland	Worldwide	Java, Indonesia	Seattle, USA	Nanjing, China	Ghana	Worldwide	Europe "Star-Horizon"	Europe	Worldwide
Type of Car-Sharing System	n/a	n/a	Stat. Based	Free-Floating	Stat. Based	Both	Free-Floating	n/a	n/a	n/a	n/a	Free-Floating	All Types	All Types	All Types
Model Type - Factor Analysis	OPM	OLM	Survey Analysis	MRM	MNL	OLM	OPM	OLM	ORM	MLM	RM	n/a	n/a	n/a	n/a
Number of Citations in Web of Science	72	n/a	84	6	n/a	129	91	3	148	3	20	n/a	n/a	n/a	n/a
Number of Citations in Google Schoolar	126	299	152	10	0	252	169	7	264	3	44	n/a	n/a	n/a	n/a
Year of Publication	2015	2013	2012	2020	2021	2017	2017	2019	2017	2021	2019	2020	2020	2021	2014

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Ride Hailing & Taxi - Factor Table	**Spatial Studies**										**User-based Studies (Survey)**							**Guidelines**
	a	**b**	**c**	**d / l / m**	**e**	**f / h**	**g**	**i**	**j**	**k**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**A**
Reference Country of Study	Qingdao, China	Shanghai, China	Three Cities in USA	New York City, USA	24 regions in USA	Austin, USA	6 Districts in China	Lisbon, Portugal	Chicago, USA	Seoul, South Korea	Washington, USA	Colorado, USA	USA	California, USA	Dallas-Fort, USA	Tehran, Iran	Ghana, Africa	Australia
Type of System	Taxi	Taxi	Ride Hailing	Taxi / Both	Ride Hailing	Ride Hailing	Taxi	Taxi	Ride Hailing	Taxi	Ride Hailing	Ride Hailing	Ride Hailing	Ride Hailing	Ride Hailing	Both	Ride Hailing	Taxi
Model Type - Factor Analysis	GW	LORM	MM	RM	MLM	GLM / MRM	RM	MNL	RM	LORM	ORM	Survey Results	GLM	BNL	MM	SEM Model	MRM	n/a
Citations in Web of Science	10	8	8	114 / 2	12	48 / 42	16	2	10	24	148	n/a	21	148	69	10	n/a	n/a
Citations in Google Schoolar	11	13	14	155 / 10	25	71 / 82	19	4	15	28	264	177	50	323	136	15	55	n/a
Year of Publication	2020	2019	2020	2015 / 2020	2020	2019 / 2018	2019	2021	2020	2018	2017	2017	2019	2018	2019	2019	2020	2016

Abbreviations:
RM: Regression Model / LM: Linear Regression Model / LRM: Robust Linear Regression Model / PM: P-median Location Model / MM: Multilevel Model / MNB: Multilevel Negative Binomial Model / MRM: Multivariate Regression Model / OLS: OLS Regression Model / GW: Geographically Weighted Regression / NB: Negative Binomial Regression / OLM: Ordered Logit Model / ORM: Ordered Probit Model / MNL: Multinomial Logit Model / BNL: Binomial logit Model / LORM: Logistic Regression Model / LVL: Latent Variable Logit Model / ROPM: Random Parameter Ordered Probit Model / MLM: Mixed Logit Model / GLM: Generalized Linear Model / Com. Analysis: Comparitive Analysis

Charging Station - Factor Table	Spatial Studies							User-based Studies (Survey)				Guidelines			
	a	b	c	d	e	f	g	I	II	III	IV	A	B	C	D
Reference Country of Study	Lisbon, Portugal	Beijing, China	Istanbul, Turkey	Flanders, Belgium	Worldwide	Washington, USA	London, England	Beijing, China	Nanjing, China	Istanbul, Turkey	Germany	Worldwide	Worldwide	USA	India
Type of Charging System (Private, Public, Taxi)	Public	All	All	Public	Taxi	Public	All	Public	Public	Public; Hybrid	Public	Public	Public	Public	Public
Model Type - Factor Analysis	RM	n/a	PM	RM	SDIRQ Model	OLS	RM	n/a	LORM	ORM	RM	n/a	n/a	n/a	n/a
Number of Citations in Web of Science	197	137	13	32	118	n/a	22	77	131	78	n/a	n/a	n/a	n/a	n/a
Number of Citations in Google Schoolar	348	213	20	59	194	166	40	133	242	154	428	n/a	n/a	n/a	n/a
Year of Publication	2011	2015	2014	2014	2014	2013	2019	2016	2011	2011	2014	2021	2014	2012	2018

Abbreviations:

RM: Regression Model / LM: Linear Regression Model / LRM: Robust Linear Regression Model / PM: P-median Location Model / MM: Multilevel Model / MNB: Multilevel Negative Binomial Model / MRM: Multivariate Regression Model / OLS: OLS Regression Model / GW: Geographically Weighted Regression / NB: Negative Binomial Regression / OLM: Ordered Logit Model / ORM: Ordered Probit Model / MNL: Multinomial Logit Model / BNL: Binomial logit Model / LORM: Logistic Regression Model / LVL: Latent Variable Logit Model / ROPM: Random Parameter Ordered Probit Model / MLM: Mixed Logit Model / GLM: Generalized Linear Model / Com. Analysis: Comparitive Analysis

Appendix B - Additional found factors for the Factor Group *Element design* from the SLR

Bike Sharing - Factor Table			Spatial Studies																		User-based Studies (Survey)									Guidelines				SUM
			a	b , q	c , j	d	e	f , g	h	i	k	l	m	n	o	p	r	s	t	u	I	II	III	IV , V	VI	VII	VIII	IX	X	A	B	C	D	(n=35)
			(+) Positive Correlation												(-) Negative Correlation										(o) Neutral Correlation									
Groups	Sub-Groups	Factors																																
Element Design	Design and Network of Element	Proximity & Indication of Element		+					+		+	+										+		+		+	+	+	+	+		+	+	13
		Density (Number of stations/devices in network)	+		+	+	+		+			+	+		+			+								+		+	+		+			13
		Capacity of station (Number of bike docks and bikes)		+	+	+						+	+		-			+								+					+			7

E-Scooter Sharing - Factor Table			Spatial Studies								User-based Studies (Survey)						Guidelines					SUM
			a , h	b	c	d , e , l	f , k	g	i	j	I	II	III	IV	V	VI	A	B	C	D	E	(n = 23)
			(+) Positive Correlation						(-) Negative Correlation						(o) Neutral Correlation					
Groups	Sub-Groups	Factors																				
Element Design	Design and Network of Element	Proximity & Indication of Element						+		+		+										3
		Density (Number of stations/devices in network)		+								+										2
		Capacity of station (Number of scooter docks and scooters)										+										1

Car Sharing - Factor Table

(+) Positive Correlation (-) Negative Correlation (o) Neutral Correlation

Groups	Sub-Groups	Factors	Spatial Studies										User-based Studies (Survey)											Guidelines				SUM
			a	b	c	d	e	f	g	h	i	j	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	A	B	C	D	(n = 25)
Element Design	Design and Network of Element	Proximity & Indication of Element				+	+			+						+	+								+	+		**7**
		Density (Number of stations/devices in network)					+		+			+				+		o							+			**5**
		Capacity of station (Number of car lots and cars)					+		+			+													+			**4**

Ride Hailing & Taxi - Factor Table

(+) Positive Correlation (-) Negative Correlation (o) Neutral Correlation

Groups	Sub-Groups	Factors	Spatial Studies										User-based Studies (Survey)							Guide	SUM
			a	b	c	d / l / m	e	f / h	g	i	j	k	I	II	III	IV	V	VI	VII	A	(n = 21)
Element Design	Design and Network of Element	Proximity & Indication of Element		+					+											+	**3**
		Density (Number of stations/devices in network)																			**0**
		Capacity of station (Number of parking lots or available vehicle)																			**0**

Charging Station - Factor Table			**Spatial Studies**							**User-based Studies**				**Guidelines**				**SUM**
			a	**b**	**c**	**d**	**e**	**f**	**g**	**I**	**II**	**III**	**IV**	**A**	**B**	**C**	**D**	**(n = 15)**
				(+) Positive Correlation					**(-) Negative Correlation**					**(o) Neutral Correlation**				
Groups	**Sub-Groups**	**Factors**																
Element Design	Design and Network of Element	Proximity & Indication of Element	+				+			+				+		+	+	**6**
		Density (Number of stations/devices in network)	+				+							+			+	**4**
		Capacity of station (Number of charging lots)	+															**1**

Appendix C - Literature assessed for eligibility for the single key elements of a mobility hub (full Reference list is available upon request)

See following page.

Literature Overview Elements of MH (Assessed for eligibility)

Bike Sharing Literature (n=79)
Ambroz et al. 2016; Bachand-Marleau et al. 2011; Bachand-Marleau et al. 2012; Bao et al. 2017; Braun et al. 2016; Büttner et al. 2011; Buck und Buehler 2012; Buck et al. 2013; Caggiani et al. 2020; Campbell et al. 2016; Campbell und Brakewood 2017; Caulfield et al. 2017; Cesbron und Luckhurst 2015; Chen et al. 2020; Choi et al. 2021; Daddio 2012; DellOlio und Ibeas 2011; Du und Cheng 2018; Du et al. 2019; Duran-Rodas et al. 2019; Duran-Rodas et al. 2021; Efthymiou et al. 2013; El-Assi et al. 2017; Eren und Katanalp 2022; Eren und Uz 2020; Esther Anaya Boig und Instituto para la Diversificación y Ahorro de la Energía 2007; Faghih-Imani und Eluru 2015; Faghih-Imani et al. 2014; Faghih-Imani et al. 2017; Fishman 2016; Fishman et al. 2015; Frade und Ribeiro 2015; Fuller et al. 2011; Fuller et al. 2012; Gauthier et al. 2014; Gebhart und Noland 2014; González et al. 2016; Gris Orange Consultant 2009; Gu et al. 2019; Guo und He 2020; Hampshire und Marla 2011; Hosseinzadeh et al. 2021; Hui et al. 2021; IBI Group 2016; Ji et al. 2018; Krykewycz et al. 2010; Lathia et al. 2012; Li et al. 2021; Lin und Yang 2011; Lin et al. 2018; Ma et al. 2015; Mateo-Babiano et al. 2016; Mattson und Godavarthy 2017; McCormack et al. 2011; Médard de Chardon et al. 2017; Mooney et al. 2019; Murphy und Usher 2015; Nair et al. 2013; Noland et al. 2016; O'Brien et al. 2014; Park und Sohn 2017; Raviv et al. 2013; Rixey 2012; Rudloff und Lackner 2014; Shaheen et al. 2013; Si et al. 2019; Stephanie Cesbron und Stephen Luckhurst; Straub et al. 2018; Sun et al. 2018; Susan A. Shaheen et al. 2011; Tian et al. 2018; Tool Design Group 2012; Tran et al. 2015; Wang et al. 2018; Wang et al. 2016; Yang et al. 2018; Yu et al. 2021; Zagster; Zhao und Li 2017

Scooter Sharing Literature (n=52)
Aguilera-García et al., 2020; Almannaa et al., 2021; Bai & Jiao, 2020, 2021; Bieliński & Ważna, 2020; Cao et al., 2021; Carrese et al., 2021; Caspi et al., 2020; Choi et al., 2021; Ciociola et al., 2020; City of Santa Monica, 2019; Degele et al., 2018; Dutta et al., 2011; Eccarius & Lu, 2020; Feng et al., 2020; Field & Jon, 2021; Forest Barnes, 2019; Gössling, 2020; Yujie Guo & Zhang, 2021; Ham et al., 2021; Hardt & Bogenberger, 2019; Hollingsworth et al., 2019; Hosseinzadeh, Algomaiah, et al., 2021a, 2021b; Hosseinzadeh, Karimpour, & Kluger, 2021; Huang, 2021; Huo et al., 2021; Jiao & Bai, 2020; Kopplin et al., 2021; Kostrzewska & Macikowski, 2017; Laa & Leth, 2020; Lee et al., 2021; Leung; Mathew & Bullock, 2019; McKenzie, 2019; NACTO, 2018; Nawaro, 2021; Nikiforiadis et al., 2021; Noland, 2019; Orr et al., 2019; Pham et al., 2019; Phithakkitnukooon et al., 2021; Scott-Smith, 2020; Sedor & Oriold, 2020; S. Shaheen & Cohen, 2019; Shirgaokar, 2016; Ushijima et al.; Y.-W. Wang, 2008; Younes et al., 2020; Zhu et al., 2020; Zou et al., 2020; Zuniga-Garcia & Machemehl, 2020

Car Sharing Literature (n=68)
Calik, 2019; Casier et al., 2021; Celsor & Millard-Ball, 2007; Cervero et al., 2004; Cervero et al., 2007; Cervero & Robert, 2003; D. Chen & Kockelman, 2016; Cheng et al., 2019; Cindy Costain et al., 2013; Clark et al., 2015; Comendador et al., 2014; Correia et al., 2014; Deveci, 2018; Dias et al., 2017; Dong Zhang et al.; Dr. Hatice Calik, Prof. Bernard Fortz, 2017; Efthymiou et al., 2013; Elliot & Stocker, 2016; Goncalo Homem de Almeida Correia & António Pais Antunes, 2011; Hampshire & Gaites, 2011; Hamroun et al., 2020; Hyungjoon Kim & Ihsan Ullah Jan; ITS Australia, 2021; Jörg Firnkorn & Martin Müller, 2012; Joy Chang et al.; Julie Clark & Angela Curl; Kaczor, 2018; Kang et al., 2016; Kim et al., 2015; Kortum & Machemehl, 2012; Lage et al., 2019; D. Lee et al., 2016; Y. Li & Fan, 2017; Li Qing et al.; Lorimier & El-Geneidy, 2013; Marc Prieto et al.; Morency, 2007; Qian et al., 2017; Ransford A. Acheampong & Alhassan Siiba; Riccardo Curtale et al.; Schmöller et al., 2015; Schmöller & Bogenberger, 2014; Scott le Vine & Zolfaghari, 2014; Seo & Lee, 2021; Shaheen et al., 2003; S. Shaheen et al., 2021; S. A. Shaheen & Martin, 2012; Share North, 2021; Simone Formentin, Andrea Giovanni Bianchessi, Sergio Savaresi, 2015; Sioui et al., 2013; Stars EU-Horizon, 2020; Tao et al., 2021; The national academies of Sciences, 2005; Tyndall, 2017; Uesugi; United Nation UNECE, 2020; Weikl & Bogenberger, 2013; Willing et al., 2017; Wu et al., 2020; Xiaolu Zhu et al.; Yikang Hua et al.; Yoon-Young Chun et al.; Y. Yu, 2016

Ride hailing & Taxi Literature (n=64)
Acheampong et al., 2020; Alemi et al., 2018; Bilali et al., 2020; Cynthia Chen et al., 2011; Z. Chen, 2015; Chunmei Chen et al., 2017; City of Perth, 2016; Dean & Kockelman, 2021; Demissie et al., 2021; Dias et al., 2017; Ding et al., 2014; d'Orey et al., 2012; Etminani-Ghasrodashti & Hamidi, 2019; Gehrke, 2020; Gong, 2015; Grahn et al., 2020; Hampshire et al., 2016; Henao, 2017; Hu et al., 2014; Hui et al., 2021; Hwang et al., 2015; Hyun et al., 2021; Kamga et al., 2015; K. Kim, 2018; Lavieri et al., 2018; Lavieri & Bhat, 2019; S. Lee et al., 2021; B. Li et al., 2019; Y. Liu et al., 2012; Xi Liu et al., 2015; Xinmin Liu et al., 2020; Luis Moreira-Matias et al.; Maat & Timmermans, 2009; Malik et al., 2021; Marquet, 2020; G. S. Nair et al., 2020; Nguyen-Phuoc et al., 2020; Peng et al., 2012; X. Qian & Ukkusuri, 2015; Qu et al., 2019; Richly et al., 2020; Sabouri et al., 2020; Secretary-General of the International Transport Forum, 2016; Shuo Ma et al., 2013; Jinjun Tang et al., 2015; Juanyu Tang et al., 2019; B.-J. Tang et al., 2020; C. Tao & Wu, 2008; Tu et al., 2017; Welch et al., 2020; Wong et al., 2001; Hongtai Yang et al., 2017; Y. Yang et al., 2018; Hongtai Yang et al., 2019; Hai Yang & Wong, 1997; Yao & Lin, 2016; W. Yu et al., 2021; H. Yu & Peng, 2019; J. Yuan et al., 2013; N. J. Yuan et al., 2013; Zhan et al., 2013; S. Zhang et al., 2017; W. Zhang et al., 2020; J. Zhang et al., 2021

Charging Stations Literature (n=67)
Asamer et al., 2016; Axsen & Kurani, 2011; Biesinger et al., 2017; Brandstätter et al., 2017; Cai et al., 2014; A. R. Campbell et al., 2012; Cavadas et al., 2015; D. Chen et al., 2013; L. Chen et al., 2016; Cui et al., 2018; J. Dong et al., 2014; G. Dong et al., 2019; Egbue & Long, 2012; Erdem et al., 2010a, 2010b; Inês Frade et al., 2011; Gavranović et al., 2014; Globisch et al., 2019; D. Gong et al., 2019; J. González et al., 2014; Guler & Yomralioglu, 2018; F. He et al., 2015; S. Y. He et al., 2016; B. Hu & López-Ibáñez, 2017; Y. Huang et al., 2015; Jia et al., 2014; Jin-peng Liu et al., 2018; Jung et al., 2014; Kameda & Mukai, 2011; J.-G. Kim & Kuby, 2012; Ko et al., 2017; Liang Feng, Shaoyun Ge and Hong Liu, 2012; Liao & Lu, 2015; J. Liu, 2012; Martin Baresch & Simon Moser; Metais et al., 2022; Ministry of Power Government of India, 2018; Morro-Mello et al., 2019; National Renewable Energy Laboratory [NREL], 2012; Niti Aajoy, Ministry of Power India et al., 2021; Plötz et al., 2014; Prof. Yoshihiko Susuki, Mr. Naoto Mizuta, Dr. Akihiko Kawashima, Prof. Yutaka Ota, Prof. Atsushi Ishigame, Mr. Shinkichi Inagaki, Prof. Tatsuya Suzuki et al., 2017; Reddy & Selvajyothi, 2020; Rick Wolbertus et al.; Roni et al., 2019; Sechilariu et al., 2019; Shahraki et al., 2015; Z. Sun et al., 2020; Thananusak et al., 2021; Tu et al., 2016; Vermont Energy Investment Corporation, 2014; Z. Wang et al., 2013; N. Wang et al., 2021; Y. Wang et al., 2021; Y.-W. Wang & Lin, 2009, 2013; Y.-W. Wang & Wang, 2010; Y. Wu et al., 2016; F. Wu & Sioshansi, 2017; Xi et al., 2013; J. Yang et al., 2017; Ye et al., 2021; You & Hsieh, 2014; Y. Zhang et al., 2011; Shuo Zhang et al., 2019; H. Zhao & Li, 2016

Declaration concerning the study paper:

I hereby declare on my honour that I have done this work independently. The thoughts taken directly and indirectly from other sources are marked as such. The work was neither submitted to another examination authority nor published.

Munich, 09th of May 2022

Michel Geipel