Transport Reviews

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ttrv20

The Smarthubs integration ladder: a conceptual model for the categorisation of shared mobility hubs

Karst Geurs, Anna Grigolon, Karla Münzel, Konstantinos Gkiotsalitis, David Duran-Rodas, Benjamin Büttner, Christoph Kirchberger, Jesse Pappers, Lluis Martinez Ramirez, Antonia Graf, Julia Hansel, Roxani Gkrava & Roman Klementschitz

To cite this article: Karst Geurs, Anna Grigolon, Karla Münzel, Konstantinos Gkiotsalitis, David Duran-Rodas, Benjamin Büttner, Christoph Kirchberger, Jesse Pappers, Lluis Martinez Ramirez, Antonia Graf, Julia Hansel, Roxani Gkrava & Roman Klementschitz (2023): The Smarthubs integration ladder: a conceptual model for the categorisation of shared mobility hubs, Transport Reviews, DOI: 10.1080/01441647.2023.2239499

To link to this article: https://doi.org/10.1080/01441647.2023.2239499

Published online: 26 Jul 2023.

TRANSPORT REVIEWS
https://doi.org/10.1080/01441647.2023.2239499

The Smarthubs integration ladder: a conceptual model for the categorisation of shared mobility hubs

Karst Geurs[a], Anna Grigolon[a], Karla Münzel[a], Konstantinos Gkiotsalitis[a], David Duran-Rodas[b], Benjamin Büttner[b], Christoph Kirchberger[c], Jesse Pappers[d], Lluis Martinez Ramirez[d], Antonia Graf[e], Julia Hansel[e], Roxani Gkrava[f] and Roman Klementschitz[f]

[a]Department of Civil Engineering and Management, Faculty of Engineering Technology, University of Twente, Enschede, The Netherlands; [b]Chair of Urban Structure and Transport Planning, Technical University of Munich, Munchen, Germany; [c]Institute of Spatial Planning, Research Unit Transportation System Planning, Technical University of Vienna, Vienna, Austria; [d]Business Technology and Operations Department, Mobility, Logistics, and Automotive Technology Research Centre, Vrije Universiteit Brussel, Brussel, Belgium; [e]Institute of Political Science, University of Munster, Munster, Germany; [f]Department of Landscape, Spatial and Infrastructure Sciences, Institute for Transport Studies, University of Natural Resources and Life Sciences, Vienna, Austria

ABSTRACT

A variety of shared mobility hubs, offering shared mobility and other services, have emerged in many cities across the globe. This paper provides a literature review on of the definition and categorisation of shared mobility hubs, guidance for the design of these hubs, and develops a multidimensional typology for shared mobility hubs. The typology, named the SmartHubs Integration Ladder, is based on three integration dimensions: physical, digital, and democratic. The literature review shows that digital and democratic (participation) integration dimensions, and universal design principles are typically missing in shared mobility hub concepts, definitions and planning practice. This implies that existing shared mobility hubs will not reach their full potential in terms of user and societal value. The "smarter" shared mobility hubs are physically, digitally, and democratically, the more user and societal value can potentially be created.

ARTICLE HISTORY
Received 1 July 2022
Accepted 16 July 2023

KEYWORDS
Mobility hubs; Shared mobility; Integration; Universal design principles; Open-data platform

1. Introduction

In recent years, mobility hub development has received increasing attention amongst both policymakers and businesses, stimulated by the growth of shared mobility services in many cities across the globe. The core idea of a mobility hub is that it creates a spatial connection between multiple transport modes, offering a physical location for users to switch between modes. Mobility hubs are defined and operationalised in many ways in the literature, for example as multimodal interchanges of traditional transport modes

CONTACT Karst Geurs k.t.geurs@utwente.nl Department of Civil Engineering and Management, University of Twente, Enschede, the Netherlands

(Monzón & Ciommo, 2016) or consolidators of shared transport modes (mainly car sharing) (Liao & Correia, 2020). The mobility hub concept is not new. Rongen et al. (2022), for example, links the first "node-based" concept in Dutch transport policy documents to the introduction of Park-and-Ride in the mid 1970ies. However, the emergence of shared mobility requires a comprehensive evaluation of the role of mobility hubs in transport planning. Firstly, the sudden appearance and rapid expansion of shared (micro-)mobility services in many cities challenged city administrations and raised many regulatory and planning questions, including parking provision (Reck & Axhausen, 2021). Secondly, many different forms of shared mobility hubs have been or are being implemented, ranging from small neighbourhood hubs with a couple of shared vehicles to large hubs at railway stations with several shared vehicles. These differences in focus raise questions on what a shared mobility hub is and what it is not, and what type of hub is potentially more successful or effective to improve the transport system and its societal impacts.

This paper aims to provide guidance for the design of shared mobility hubs as new and emerging concept in research and transport planning practice, and to develop a multidimensional typology to categorise shared mobility hubs by conducting a literature review on the definition and categorisation of shared mobility hubs. A comprehensive shared mobility hub typology is currently lacking in the scientific literature and planning practice. Our review focuses on shared mobility hubs and differs from earlier literature on mobility hubs as public transport hubs (e.g, see Zemp et al., 2011). Moreover, we go beyond recent shared mobility hub categorisations from in the academic literature which focus on physical characteristics (e.g. Weustenenk & Mingardo, 2023). In this paper, we identified three main dimensions of integration: physical, digital, and democratic integration. Firstly, digital technologies are becoming increasingly important as new mobility services, especially of shared modes, usually rely on digital interfaces for the planning, booking, and payment of services as well as information provision. Secondly, most shared mobility hub implementations have been top-down, leading to a lack of scientific evidence on the advantages and disadvantages of bottom-up co-creation approaches (van Gils, 2019). The co-creation of mobility hub design with (potential) users, matching the design with user needs, could promote the use and acceptance of the mobility and non-mobility services provided at the hub, and thus increase its societal impacts.

The literature review methodology will be presented in Section 2, followed by Section 3 which examines how shared mobility hubs are defined and then focusing on identifying the crucial integration aspects which influence the uptake and societal impact of mobility hubs in Section 4. The "SmartHubs Integration Ladder" is presented in Section 5 and Section 6 concludes the paper and presents a research agenda to address the remaining gaps. In the remainder of the paper, we refer to shared mobility hubs as "hubs" or "mobility hubs", unless stated differently.

2. Literature review methodology

The literature review methodology used in this paper is based on academic literature and transport planning and policy documents and other grey literature available in English, German, and Dutch. The review did not strictly follow the guidelines for a systematic literature review from the PRISMA guidelines (Moher et al., 2009), as most literature on shared mobility hubs is recent. The search for academic literature was based on five steps:

(1) The first step included the use of the keyword "mobility hub" in the academic databases of Scopus and ScienceDirect. In total, 39 academic papers were found to have this term in the article title, abstract, or keywords. Most papers have been published in recent years: 21 papers were published after 2021, 13 between 2015 and 2020, and only 5 before the year 2015.
(2) The second step was based on forward and backward snowball reviews conducted on the papers found.
(3) Thirdly, to expand the review of the academic literature, the following keywords were used (and the Dutch and German translations of "mobility hub"): intermodal hub, multimodal hub, transport hubs, (integrated) multimodal mobility, intermodality, integration of shared mobility and public transport, seamless mobility, smart hubs, shared mobility, MaaS, Park&Ride, micromobility, resilience/vulnerability of hubs, physical and digital integration in transport, democratic integration, participation and co-creation.
(4) Fourthly, grey literature on mobility hubs (such as guidelines) and transport planning documents was searched. Google Scholar was searched using the keyword "mobility hub" and its Dutch ("mobiliteitshub" and "mobipunt") and German equivalents ("Mobilitätsstation"). Additional grey literature and planning documents were collected based on the knowledge of over 50 researchers, planners, and practitioners involved in the SmartHubs project (SmartHubs, 2021).
(5) Finally, all references were stored in an online library, which was used to select literature for two distinct parts of the literature review: definitions (section 3) and integration principles (section 4).

The sources were read and screened for quality, and usefulness for this review, and labelled as: definition, inclusivity, physical integration, digital integration, social integration, governance, and policies. Sources were excluded when they did not fit the topics discussed in this paper (definition and integration principles). In addition, grey literature sources were also excluded if, based on the author's judgement, the source was not of a high-enough quality. However, most of the grey literature included was from government organisations or commissioned by them, which were assumed to be of a sufficient quality. In total, 81 sources were selected (see Table 1) of which 27 are journal articles, 13 are books or book chapters, 5 are conference proceedings, 6 are theses and 30 is grey literature (e.g. reports, planning documents). Of the sources, 36 contain a definition of what a mobility hub is, 36 cover aspects of physical integration, 12 cover aspects of digital integration, and/or 21 cover aspects of democratic integration (e.g. co-creation, user participation).

3. Definition of shared mobility hubs

The mobility hub concept essentially addresses the general principles of integration in urban transport strategies as described by May et al. (2006). According to these authors, the integration of policy instruments can occur in four broad ways: (1) integration between policy instruments involving different modes, (2) integration between policy instruments involving infrastructure provision, management, and pricing, (3) integration between transport and land-use measures and (4) integration with other policy areas such

Table 1. References reviewed, listed by source type and specific use in the review.

Reference	Source Type	Definition	Physical Integration	Digital integration		Democratic integration
Advier/SVP (2021)	Grey (report)	x	x	(x)	(x)	
Advier (2021)	Grey (report)		x	x	x	
Amoroso et al. (2012)	Conference paper	x				
Anderson et al. (2017)	Journal paper	x	x			
Ansell and Gash (2008)	Journal paper					x
Ansell and Torfing (2021)	Book					x
Aono (2019)	Grey (report)	x	x	(x)		
Arnstein (1969)	Journal paper					x
Blad et al. (2022)	Journal paper	x	x			
Bolger et al. (1992)	Journal paper		x			
Bösehans et al. (2021)	Journal paper	x				
Chidambara (2019)	Journal paper		x			
Coenegrachts et al. (2021)	Journal paper	x	x			
CoMoUK (2019)	Grey (report)	x	x	x	(x)	
Conticelli et al. (2021)	Journal paper		x			
Crow (2021)	Grey (report)	x				
Cui (2021)	Master's thesis		x		(x)	
DELVA et al. (2019)	Grey (report)	x				
Dryzek, 2000	Book (scientific)					x
Durand et al. (2021a)	Journal paper			x		
Durand et al. (2021b)	Grey (report)			x		
Emerson et al. (2012)	Journal paper					x
Fallast and Huber (2015)	Grey (report)	x				
Fischer, 2012	Book (scientific)					x
Frank et al. (2021)	Journal paper	x	x			
Garde et al. (2014)	Conference paper	x	x			
Gemeente Utrecht (2021)	Grey (report)	x	–			–
GoSEStran (2020)	Grey (report)	x	x			x
Goudappel et al. (2021)	Grey (report)	x				
Graf and Fuchs (2015)	Book chapter					x
Graf et al. (2018)	Book chapter					x
Hasan and Al-Khafaji (2021)	Conference paper		x			
Heinelt (2010)	Book					x
Horjus et al. (2022)	Journal paper			x		
IGES Institut (2021)	Grey (report)	x	x			
Indrakesuma (2018)	Master's thesis		x			
Jansen et al. (2015)	book section	x		x		
Jittrapirom et al. (2017)	Journal paper			x		
Karner et al. (2020)	Journal paper					x
Kast (2021)	Grey (report)	x	x			x
Luo et al. (2021)	Journal paper		x			
Mather (1983)	Journal paper		x			
Meadowcroft (2004)	Book chapter					x
Metrolinx (2011)	Grey (report)	x	x			
Miramontes (2018)	Doctoral thesis	x		x		
Mobiliteitsalliantie (2020)	Grey (report)	x	x			
Monzón and Ciommo (2016)	Book		x			
Mouw (2020)	Bachelor thesis	x	x			
Muller et al. (2021)	Journal paper			x		
Nag et al. (2019)	Grey (report)		x			
Natuur & Milieu (2020)	Grey (report)	x	x			
Navrátilová et al. (2021)	Conference paper	x	x			
Newig and Fritsch (2009)	Journal paper					x
Pappers et al. (2020)	Book chapter					x
Pfertner (2017)	Master's thesis	(x)	x	(x)		
Preston (2012)	Grey (report)		x			

(*Continued*)

Table 1. Continued.

Reference	Source Type	Definition	Physical Integration	Digital integration	Democratic integration
Rehme et al. (2018)	Book chapter	x			
Rongen et al. (2022)	Journal paper	x	x		
Rube et al. (2020)	Grey (report)	x	x	x	
Rupprecht Consult (2019)	Grey (report)				x
Schelling (2021)	Master's thesis	x	x		
Schemel et al. (2020)	Grey (report)	x	x		
Schneidemesser et al. (2020)	Journal paper				x
SUMC (2019)	Grey (report)	(x)	x		
Silva and Uhlmann (2021)	Journal paper	(x)	x		
Smith (2009)	Book (scientific)				x
Sochor et al. (2018)	Journal paper			x	
Tavassoli and Tamannaei (2020)	Journal paper		x		
Urban Design Studio (2016)	Grey (report)	x	x		
van Gils (2019)	Grey (report)	x			
Witte et al. (2021)	Grey (report)	x			
Wright and Hook (2007)	Grey (report)		x		
Wüstenhagen et al. (2007)	Journal paper				x
Zientek et al. (2018)	Grey (report)	x			
Zukunftsnetz Mobilität NRW (2022)	Grey (report)	x			

Note: x: contains information used in the review; (x): contains limited information that is taken into account in the review.

as health and education. The main added value of the shared mobility hub concept is that it targets a transport planning approach that integrates all these four dimensions. The added value of our concept for users and citizens is ensuring that the planning and design of hubs follows the principles of user-centred universal design, which will be discussed in Section 3.

We found 36 sources that include a definition of a (shared) mobility hub (or a translation/synonym) of which 10 are peer-reviewed academic sources and 26 are from the field of planning practice, research project reports, or theses. In the academic literature and planning practice documents, a broad diversity of what is understood under the term mobility hubs (or mobility station, mobility point) leads to varied definitions. The common point of all definitions is the spatial connection between multiple transport modes including shared mobility which provides a physical location for users to switch between modes. The concept also relates to the digital integration of mobility offerings in Mobility-as-a-Service (MaaS) platforms. Hubs, however, can vary in size, layout, and distance to public transport stops and urban centres. The offer of services may also differ from place to place. For instance, small hubs offer a few car-sharing vehicles and bike-sharing. Larger hubs such as those at railway stations may provide access to public transport, a taxi stand, and bike parking facilities and often offer a mix of shared mobility service types (shared bicycles, scooters, charging stations, etc.).

Table 2 shows the essential and optional characteristics of shared mobility hubs as mentioned in the literature: availability of or proximity to public transport, availability of shared mobility, availability of multiple modes, transfer between modes, non-mobility related facilities (e.g. lockers, activity centres), physical integration, digital integration (e.g. digital pillar with services and ticketing, MaaS), and democratic integration (e.g. co-

Table 2. Shared mobility hub characteristics used in the literature.

	Public Transport	Shared Mobility included	Multiple modes	Transfer between modes	Non-mobility related facilities	Physical integration	Digital integration	Democratic integration
Advier/SVP (2021)	(x)	x	x	x	(x)	x	(x)	-
Amoroso et al. (2012)	-	-	x	x	-	-	-	-
Anderson et al. (2017)	x	x	x	x	-	-	-	-
Aono (2019)	(x)	x	x	x	-	x	-	-
Bösehans et al. (2021)	-	x	x	-	-	-	-	-
Blad et al. (2022)	x	x	x	x	(x)	x	-	-
Coenegrachts et al. (2021)	-	x	x		-	-	-	-
CoMoUK (2019)	(x)	x	x	x	x	x	x	-
Crow (2021)	-	-	x	x	x	-	-	-
DELVA et al. (2019)	-	-	x		(x)	-	-	-
Fallast and Huber (2015)	-	-	x	x	-	-	-	-
Frank et al. (2021)	x	x	x	x	x	x	-	-
Garde et al. (2014)	x	-	x	x	-	x	-	-
Gemeente Utrecht (2021)	-	x	x	x	x	-	-	-
GoSEStran (2020)	-	-	x	-	x	x	-	x
Goudappel et al. (2021)	-		x	x	(x)	-	-	-
IGES Institut (2021)	x	x	x		-	x	-	-
Jansen et al. (2015)	x	-	x	x	-	-	x	-
Kast (2021)	x	x	x	x	-	-	x	x
Metrolinx (2011)	x		-	x	-	x	-	-
Miramontes (2018)	x	x	x	x	-	-	x	-
Mobiliteitsalliantie (2020)	-	-	-	x	-	x	-	-
Mouw (2020)	(x)	x	x	-	-	x	-	-
Natuur & Milieu (2020)	(x)		x	x	x	x	-	-
Navrátilová et al. (2021)	x	(x)	x	x	-	x	-	-
Rehme et al. (2018)	-	-	x	x	-	-	-	-
Reisviahub.nl (2021)	(x)	(x)	x	x	x	-	-	x
Rongen et al. (2022)	-/x	x	x	x	-	-/x	x	
Rube et al. (2020)	-/x	x	x	x	-	x	-	-
Schelling (2021)	-	x	x	-	x	x	-	-
Schemel et al. (2020)	-	-	x	x	-	-	-	-
Urban Design Studio (2016)	x	x	x	x	(x)	x	-	-
van Gils (2019)	(x)	x	x	x	-	-	-	-
Witte et al. (2021)	-	-	x	x	x	-	-	-
Zientek et al. (2018)	-	-	x	x	-	-	-	-
Zukunftsnetz Mobilität NRW (2022)	-	-	x	x	-	x	-	-

Note: x: explicitly mentioned in the definition/essential elements; (x): walking distance to PT; other characteristics: optional element; (-/x) score depends on the type of hub.

creation, participatory planning). Aspects of visibility in public space and digital integration are considered in only some of the definitions of mobility hubs. Similarly, digital integration is described as an add-on in existing mobility hub planning guidelines, as the level of digital integration can affect the potential uptake of the mobility offerings (CoMoUK, 2019).

The involvement of users or participatory planning has received little attention in mobility hub research and planning. Exceptions are the hub development strategy for a network of bus and train stations in the Provinces of Groningen and Drenthe in the Netherlands, where public and social services are integrated with mobility services (Reisviahub.nl, 2021). The municipality of Amsterdam has used a participatory mobility hub planning approach as part of a European project, based on a survey in which citizens could state their preferences for the type and provider of shared mobility services (e.g. shared cars, electric cargo bikes, e-bikes, scooters) (eHUBS, 2021).

The literature shows that although public transport and shared mobility are often part of a mobility hub, there is no agreement on whether their integration is required. Hub definitions often include public transport services or include proximity/walking distance to a public transport stop as an essential hub component. This implies that public transport stops such as trains, trams, and metro, with shared mobility services within walking distance, are defined as mobility hubs.

Beyond the presence of multiple forms of mobility, there is less agreement on the mobility and non-mobility characteristics or elements which are considered essential for a hub. Additional mobility-related or non-mobility-related facilities provided at mobility hubs or extra functions are included as essential elements in some definitions (e.g. information pillar or sign) and as optional elements in others (e.g. parcel storage, activity centres) (CoMoUK, 2019; Urban Design Studio, 2016).

Most definitions focus on the mobility and transfer components of hubs and include the presence of multiple modes and transfer between modes as requirements. From these, we derived the following definition: "a shared mobility hub is a physical location where different shared transport options are offered at a dedicated, non-temporary and recognisable location, and public transport is available within walking distance".

4. Mobility hub integration principles

Different integration aspects influence the use and societal impact of shared mobility hubs. The core idea behind the mobility hub concept is physical integration, i.e. the physical connection of multiple transport modes (transport integration) and connections to shops, amenities, and points of interest (land use integration). In addition, as noted in Section 1, shared mobility hubs also relate to digital integration and "democratic" integration, to integrate the needs and interests of user groups and other stakeholders in the design of hubs.

The following subsections provide an overview of the literature on the inclusive design principles (section 4.1), the physical (section 4.2), digital (section 4.3), and democratic (section 4.4) integration dimensions. We incorporate these dimensions into the SmartHubs Integration Ladder, which is presented in Section 5.

4.1. Inclusive design

The accessibility and inclusiveness of mobility hubs is a central concern, especially in the context of vulnerable populations and disadvantaged users (e.g. older people, people with impairments, people with low digital skills, migrants or ethnic minorities, children) who might experience barriers to using facilities and vehicles. Nevertheless, it is not considered as a separate integration dimension but an intrinsic element of the physical, digital, and democratic integration dimensions. Thus, the physical elements of the hub, digital navigation and information features as well as the different services that are offered at the hub (transport services, retail, etc.) should be accessible to and usable by the greatest possible number of people with a diverse range of needs. Consequently, it is assumed that individual attributes such as age or other physical characteristics which may affect a person's ability to move, are considered in the design of hubs. The inclusion of vulnerable groups in the democratic integration dimension is also important. It is pivotal that the needs and skills of vulnerable groups are taken into consideration (Kedmi-Shahar et al., 2020).

To evaluate whether the design of a hub is inclusive, we use the principles of universal design. Universal design (Story, 2001) goes one step further than complying with current and upcoming legal requirements, assuming that access should be provided to everyone without requiring specific groups to use specially adapted infrastructure or services (e.g. bus stops accessible for wheelchair users without a need for assistance). Universal design refers to the creation of products, environments, or interfaces that can be easily used by the greatest possible number of people with a diverse range of needs without adaptation.

The application of Universal Design is guided by seven principles that must be considered throughout the design process (Story, 2001). In the context of the shared mobility hubs, the universal design principles, we operationalise the principles in the following way:

(1) Equitable use: The design of the hub is equally useful for people with diverse abilities.
(2) Flexibility in use: The design of the hub accommodates a wide range of individual preferences and abilities.
(3) Simple and Intuitive use: The use of the physical and digital elements of the hub is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
(4) Perceptible information: The design of the different elements of the hub communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
(5) Tolerance for error: The design of the physical and digital elements of the hub minimises hazards and the adverse consequences of accidental or unintended actions.
(6) Low physical effort: The different elements of the hub can be reached and used efficiently and comfortably and with a minimum of effort.
(7) Size and space for approach and use: Appropriate size and space are provided for approach, manipulation, and use of the different physical and digital elements of the hub, regardless of the body size of users or their mobility.

These seven universal design principles are embedded in the SmartHubs physical and digital integration ladders to enhance the usability and accessibility of mobility hubs.

4.2. Physical integration

A core feature of a mobility hub is to provide a seamless transition between different modes of transport (Metrolinx, 2011) that can be achieved by a physical integration of different transport modes. The factors necessary to achieve a physical integration of mobility services and other amenities at hubs is derived from the literature from 31 sources. Five main types of characteristics were identified in the literature for physical integration of hubs: (1) spatial factors, (2) proximity to different elements and the presence of barriers or conflicts, (3) visibility and recognisability, (4) accessibility for all design standards, and (5) place making strategies. These aspects were summarised in Table 2 and will be further described in the following sections.

4.2.1. Spatial factors

From a spatial perspective, the most common elements that are considered important in the literature when determining the location and physical integration of hubs are related to land use, points of interest, demographics, and the current public transport, walking and cycling infrastructure. Population density, as well as the density and diversity of the land-use (mixed-use development) could influence the function and coverage of the multi-modal hub (Nielsen et al., 2005; Urban Design Studio, 2016). The proximity of mobility hubs to essential services, such as education facilities and hospitals, can significantly increase accessibility levels (Anderson et al., 2017; Blad et al., 2022). Other points of interest (POIs) that increase the diversity of opportunities available for the users, as mentioned in the literature, include convenience stores, drug stores, coffee shops, food markets, shopping centres, sports facilities, entertainment venues, multiple retail, and pick-up/storage stations (Blad et al., 2022; Coenegrachts et al., 2021; Conticelli et al., 2021; Frank et al., 2021; Hasan & Al-Khafaji, 2021).

In addition, locating hubs in an attractive open space is recommended, where people can gather and interact with each other and the space (Metrolinx, 2011; Urban Design Studio, 2016). Short distances between these spaces and multi-modal transit stations, together with an attractive and secure pedestrian and cyclist infrastructure and services (including the connection between the network and the hub), can increase pedestrian and cycling shares in the area (Chidambara, 2019; Silva & Uhlmann, 2021).

These location characteristics are more commonly found in more densely populated urban spaces where land availability is scarce. Therefore, in some cases, infill development might be the most suitable approach as these are caused by typically underused urban infrastructure, with the potential to improve the public realm when used efficiently (Aono, 2019).

Finally, several studies indicate the importance of allocating hubs in proximity to public transport. Urban Design Studio (2016) and Nielsen et al. (2005) recommend that hubs are located close to the end and/or start of bus lines, to encourage users to reduce car dependency and increase the use of active modes as feeder modes (Anderson et al., 2017). In addition, hubs can also be important to improve transport services in under-served areas and areas which suffer from traffic congestion problems (Anderson et al., 2017; Blad et al., 2022; Coenegrachts et al., 2021; Frank et al., 2021; Miramontes, 2018; Mouw, 2020; Nielsen et al., 2005; Silva & Uhlmann, 2021).

4.3. Placement of elements in the vicinity of each other, and avoiding conflicts

Regarding the placement of modes close to each other, the main considerations found in the literature are maximum walking distance or travel time between the different transportation alternatives, and avoiding conflicts between modes (e.g. barriers between the modes that require crossing the road or an extensive walk to use different modes). The recommended acceptable distance in the literature is generally between 300 and 500 metres, while the travel time is 5 min (Blad et al., 2022; CoMoUK, 2019; Indrakesuma, 2018; Luo et al., 2021; Mouw, 2020; Nielsen et al., 2005; Wright & Hook, 2007). Longer walking distances are acceptable to larger public transport stops such as railway stations (500 m to max. 1 km) (Natuur & Milieu, 2020). However, these distances may vary based on different physical abilities. For older people, acceptable walking distances range from 200 to 400 metres (Nordbakke & Schwanen, 2015), while for people with mobility impairments, average acceptable distances range from 50 to 150 metres (Frye, 2011).

When different mobility options and services are located near each other or share paths, avoiding conflicts between the different modes is recommended (Aono, 2019; Urban Design Studio, 2016). To avoid conflicts, walking routes should be free of barriers and provide easy access; therefore, none of the elements from the hub itself should act as an obstacle (Urban Design Studio, 2016). In addition, active mobility is recommended to be separated from motorised vehicles and also smoothly integrated with traffic through ramps, intersections, traffic signals, etc. (Chidambara, 2019). Pavement markings can help avoid conflicts by indicating the space designated for each option, and people can be informed where their required option is located (Urban Design Studio, 2016).

The integration of high-quality and diverse infrastructure to increase opportunities and enhance the cycling share is also one of the most mentioned aspects in the consulted literature regarding active transport modes. This covers the variety of bike-share programmes and parking options, and particularly the integration of multiple options of available bikes (cargo, electric, trikes) (e.g. Aono, 2019; Miramontes, 2018).

After active modes, it is recommended that public transport has priority over private transport, and bus transport is separated from the general traffic (Monzón & Ciommo, 2016). Traffic calming measures in the area can help integrate the different modes of transportation. For example, motorised traffic can be slowed by angled or parallel on-street parking. Moreover, a distinction can be made between parking for private bicycles and shared bicycles. Any type of bike parking is preferably located as close as possible to the bike lanes. Whenever possible, car-sharing vehicles (and EV charging stations) can be grouped in "pods" of at least two or three vehicles per location (Aono, 2019). Typically, EV charging stations are located adjacent to parking lots (Coenegrachts et al., 2021).

4.4. Visibility, wayfinding, and information

When the elements of hubs are close to each other but not visible, wayfinding signs can inform people where the different options are located. This is especially important close to the acceptable distance limits. Furthermore, a recognisable logo is one of the most recommended practices. Creating a branding logo and increasing the visibility of hubs as a landmark can attract users and increase the sense of proximity and integration with other transport modes and points of interest (Urban Design Studio, 2016). The recognition of a

specific symbol/brand is particularly useful when considering a hub network as it makes individual hubs more recognisable to the users (Blad et al., 2022; CoMoUK, 2019; SUMC, 2019).

The provision of informative components such as digital boards, maps, information kiosks, and other sorts of assistance are appropriate visibility elements. Relevant information can be provided in various forms and formats, including analogue and digital form, and audible and tactile form (SUMC, 2019; Urban Design Studio, 2016; Wright & Hook, 2007). Additionally, making the same information available online, together with the provision of Wi-Fi access within the hub facilities further eases the process of trip planning for the users (Schemel et al., 2020; SUMC, 2019). Indrakesuma (2018) and Conticelli et al. (2021) point out that real-time information is particularly relevant for interchange purposes as it eases the trip planning process. This aspect is linked to the digital integration dimension (Section 4.3).

4.5. Design of mobility hubs that are accessible for all

Among the most frequently mentioned examples of features to ensure hubs are accessible for people with various needs, are barrier-free designs for the hub itself and adjacent areas and (walking) routes used to approach or leave the hub (Chidambara, 2019; Hasan & Al-Khafaji, 2021; Nielsen et al., 2005). Conticelli et al. (2021) listed specific relevant elements for creating a physically accessible environment such as "boarding equipment, ramps, escalators, staircase aids for bikes, wheelchairs, strollers, etc.". Additionally, Aono (2019) also considers elements such as wheelchair access, the provision of tactile information, walking surface guidance, and sheltered waiting areas. Other studies consider ramps, escalators, and elevators as further critical components (Wright & Hook, 2007), and suggest having assistance personnel during the operation of hubs to help users who may encounter difficulties. The provision, design, and comfort of waiting areas are important to facilitate transfers.

4.6. Design of mobility hubs as a place-maker

To strengthen the connection between people and the hubs, place-making can potentially maximise the shared value and increase acceptance and usage among the inhabitants. Place-making can increase people's feeling of belonging and comfort, i.e. safe, secure, in a clean, nice-looking area, where they can meet other people and carry out activities.

Urban Design Studio (2016) suggests the possibility of implementing tree canopies as an enclosing feature but also extending into adjacent streets. Regarding the design of these street areas, Aono (2019) presented case studies where the sidewalks were enlarged to create parklets and attractive and recognisable waiting areas. Besides the architectural design, incorporating these features is relevant for creating a pleasant environment for the users. Public furniture such as benches, planters, bicycle racks, sheltered waiting areas, and pedestrian lighting elements are encouraged (e.g. CoMoUK, 2019; Urban Design Studio, 2016). Several other authors also addressed the importance of using flexible and convenient designs and materials, including modular approaches that allow the easy disassembly of the infrastructure (Blad et al., 2022; Metrolinx, 2011;

Nielsen et al., 2005; Schelling, 2021; Schemel et al., 2020). Such a strategy might contribute to avoiding premature obsolescence and might have multiple benefits in terms of material consumption and the lifespan of the facilities.

A high-quality design of components of mobility hubs (e.g. architectural elements, bike and car parking facilities with clear logos and colours) can help make them more visible and attractive, which in turn can increase awareness of the multimodal mobility offer and the acceptance of the station (Miramontes, 2018). Other studies state the importance of providing coherent furniture, to enhance and ease mobility and increase levels of comfort (Aono, 2019).

Design characteristics that increase social safety and comfort include the provision of sufficient lighting and avoiding locating waiting areas in isolated sections (Aono, 2019; CoMoUK, 2019; Conticelli et al., 2021; Indrakesuma, 2018; Metrolinx, 2011; Mouw, 2020; SUMC, 2019; Urban Design Studio, 2016). According to multiple studies in the literature, the provision of closed and secured parking areas reserved for private bicycles is encouraged, especially if there is a higher incidence of stolen or damaged bikes in the region (Aono, 2019; Conticelli et al., 2021; Metrolinx, 2011; Urban Design Studio, 2016; Wright & Hook, 2007).

All the strategies and considerations described above are, naturally, subject to the respective land use plans in addition to other development plans or projects from the local authorities (CoMoUK, 2019; Schemel et al., 2020; Urban Design Studio, 2016). Particularly, the guidelines created by CoMoUK (2019) advise to always consider any potential space limitations and local permit regulations and to prepare for any design modification (most likely scaling down the initial proposal) that might be required. Lastly, none of the previously described elements will accomplish the goal of attracting users if the hub operates under unhealthy or polluted conditions. Hence, Wright and Hook (2007), Nielsen et al. (2005), Indrakesuma (2018), Chidambara (2019), and Conticelli et al. (2021) refer to cleanliness as a fundamental characteristic of hubs. Lack of maintenance and cleanliness can lead to poor acceptance and perception by the public. For instance, in a survey in Munich, Germany, 93% of the participants considered the cleaning of the stations as very important or important (Klanke, 2022). The different physical aspects discussed in this section are reflected in the physical Integration dimension of the SmartHubs Integration Ladder, described in Section 5. Table 3 presents a summary of the physical integration factors of mobility hubs based on the reviewed literature.

4.7. Digital integration

Apart from physical accessibility, digital accessibility is becoming increasingly important as new mobility services, especially of shared modes, usually rely on digital interfaces for the planning, booking, and payment of services as well as information provision. Digital mobility solutions assume that an interaction takes place between the user and a digital interface (smartphone, screen, computer, electronic display). Digital technologies have become indispensable to the use of shared mobility and public transport services and are thus possible determinants of the potential use of mobility services provided at mobility hubs. Digital integration describes the effort of integrating information on one digital platform and making it possible for different information platforms to access information using a standard format. Through digital integration, users can

Table 3. Summary of physical integration factors of mobility hubs.

Characteristics	Factors		Source
I. Spatial Factors	Population density	High population density	A, D, E, J, N, O, Q, R, W, Z
		High number of amenities	C, I, J, K, L, M, O, *P*, Q, R, S, T, V, Y, AA, AB
		University campuses, schools, and the hospitals	F, Q, R
		Tourist attractions	F, Q, R
		Public gathering spaces	C, J, K
	Land-use	Central areas	C, G, H, I, V, W, AC
		Mixed-use development	C, D, E, K
		Residential areas with low public transport coverage	G, H, I, N, O, R, W
	Transport infrastructure	High-frequency (major) transit service.	D, E, G, H, I, O, S, V, W
		Cycling and pedestrian infrastructure	E, F, H, K, L, *P*, R, S, T, V, Y
II. Placement of different modes of transport in the vicinity of each other	Reduction of conflicts	Avoid conflict between modes	C, D, E, F, G, J, K, L, *P*, S, W, AC
		Pedestrians first	A, C, D, E, F, *P*, AA, AB
		Reserved parking for cleaner vehicles	C, E, F, AB
		Bike parking next to bike lanes (difference between private vs shared)	E, L, *P*, R, W, AA, AB
	Information	Wayfinding signage	C, D, E, G, K, L, S, W, Y, AA, AB, AE
		Signage & branding	A, F, H, N, R, S, W, AA
		Digital information or information pillars	A, C, D, E, F, I, K, M, N, R, S, V, W, X, Y, AB
		Pavement markings	C, E, F, AB
III. Visibility of Hubs	Visibility of the station to passengers		A, C, D, H, N, R, Y
	Visibility among different modes		C, E, G, N, AA
	Stations well lit at night		C, M, T, Y, AB
	Coherent furniture		B, E
IV. Accessibility for all	Accessibility for all segments of the population		A, C, E, O, Q, T, W, Y, AB
	Barrier-free, universal gates and tactile information and guides		E, L, M, T, U, W, Y, AA, AB
	Waiting areas (sheltered)		B, C, G, J, K, L, R, S, V, X, Y, AB
	Gentle ramps, escalators, and elevators		S, W, Y, AB
	Assistance staff (to help users)		AB
V. Hubs as a place-maker	Social safety, security surveillance		A, C, D, E, K, L, N, S, T, V, Y, AB, AC
	Environmental building		A, C, E, K, M, S
	Visually interesting places		C, E, L
	Landscape, green and street furniture		C, E, K, L, S, T
	Drinking fountains and/or bathrooms		C, D, E, S
	Storage and/or urban freight facilities		C, D, E, I, Y, AB

(*Continued*)

Table 3. Continued.

Characteristics	Factors	Source
	Modular design	B, E, K, L
	Cleanliness	S, T, W, Y, AB
	Attractive and functional public gathering spaces	C, J, K
	Direct connection to shops, amenities, and points of interest	C, I, J, K, L, M, O, *P*, Q, R, S, T, V, Y, AA, AB

Mobility hubs: A:(CoMoUK, 2019), BfxSchelling, 2021), C:(Urban Design Studio, 2016), D: Mobility hubs (SUMC, 2019), E:(Aono, 2019), F: (Pfertner, 2017), G: (Miramontes, 2018), H: (Silva & Uhlmann, 2021), I: (Coenegrachts et al., 2021), J: (Cui, 2021), K: (Metrolinx, 2011), L: (Monzon & Ciommo, 2016), M: (Schemel et al., 2020), N: (Mouw, 2020), O: (Frank et al., 2021), P: (Petrović et al., 2019), Q: (Anderson et al., 2017), R: (Blad et al., 2022), Public transport stations S: (Wright & Hook, 2007), T: (Chidambara, 2019), V: (Nag et al., 2019), W: (Nielsen et al., 2005), Seamless /Multimodal/ Intermodal X: (Preston, 2012), Y: (Indrakesuma, 2018), Z: (Luo et al., 2021), AA: (Hasan & Al-Khafaji, 2021), AB: (Conticelli et al., 2021), Bike & Ride AC: (Tavassoli & Tamannaei, 2020), Park & Ride AD: (Bolger et al., 1992), AE: (Mather, 1983).

easily access information provided by multiple providers in one (digital) place, e.g. a mobile app or a website.

The Mobility-as-a-Service (MaaS) promise is to deliver digital integration of mobility option – – planning, booking, and payment using a single app or platform. MaaS is thus relevant for hubs: it makes it easier to use different transport modes and to improve digital access to the services of different providers present at the hub. The most important aspect of MaaS is that it relies on a digital platform (mobile app or web page) where travellers can access various aspects such as trip planning, payment, and real-time information (Jittrapirom et al., 2017). Note that a MaaS platform typically aims to integrate mobility services at a city or region level, and the amount of shared mobility offerings integrated in a city or region is likely to affect the uptake of the platform and thus the use of shared mobility at a specific mobility hub.

Sochor et al. (2018) developed a topological framework to characterise MaaS in levels varying from 0 to 4, as indicative of distinct levels of digital integration. We adapted and expanded this MaaS typology to include digital accessibility and universal design principles. Designing digitally accessible mobility services at hubs is important for the uptake of app-driven mobility services and for making the services accessible to different user groups. However, the role and potential of digital technologies related to mobility hubs are an understudied research area. Horjus et al. (2022) examined the potential use of shared mobility at a public transport hub in The Hague (Netherlands) and showed that the intention to use shared transport is higher for people with higher levels of digital skills, prior shared transport experience, who are younger, highly educated and used multiple means of transport during their trip. Therefore, to allow the greatest possible number of people with diverse range of needs and skills to use shared mobility services, a hub should go beyond the provision of a MaaS platform. Universal design principles 1 (Equitable use) and 2 (Flexibility in use) relate to a hub design that is useful and marketable to people with diverse abilities and provides choices in methods of use. Durand et al. (2021b) describe solutions to improve the digital accessibility of public transport services, including access to solutions that are potentially suited for mobility offerings at hubs, including analogue alternatives to plan, pay, and book trips (e.g. information kiosks with assistance), low-tech instruments such as helpdesk support, help buttons on ticket machines and the development of specific travel aids or apps for specific user groups such as people with disabilities. Other low-tech alternatives used by some ridesharing and demand-responsive services are third-party access services (e.g. Uber, Lyft) that allow elderly or caregivers to book trips for themselves or caretakers without a smartphone.

Universal design principles 3 (Simple and Intuitive Use) and 4 (Perceptible information) relate to the design of apps and other digital platforms to plan, book, and pay for mobility offerings at hubs. The platforms should be easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration levels and communicate necessary information effectively to the user. The different features discussed in this section are reflected in the digital integration dimension of the SmartHubs Integration Ladder, described in Section 5.

4.8. Democratic integration

It is one of the constitutional rights in democratic societies that "the demos" is "having a part in something" (Carter, 2005) – in this case the governance of their country, city, or neighbourhood.. The term "governance" indicates not only considering the government's actions but takes multiple levels, actors, and fields into account. The public planning process is complemented by the involvement of social movements, NGOs, citizens, charities, or participatory action research. The substantial role of the state and its institutions is still recognised but supplemented by additional actors and alternative planning processes (Karner et al., 2020).

Scholars and practitioners have developed different approaches to capture such decentralised forms of participation. Such approaches include Collaborative Governance (Ansell & Gash, 2008; Emerson et al., 2012), Democratic Innovation (Smith, 2009) or Co-creation (Ansell & Torfing, 2021). What distinguishes public participation and co-creation depends on the definition that is applied. At the core of public participation is the involvement of the public (Arnstein, 1969). Co-creation has been defined as an innovative approach that goes from problem identification to implementing a solution. Within a co-creation process, co-design is the step at which solutions are designed. Pappers et al. (2020) argue that public participation and co-creation share an emphasis on the involvement of the public, but that co-creation focuses on creativity and innovation.

Among these approaches, Participatory Governance explicitly emphasises participatory elements in the implementation of decisions (Heinelt, 2010). Scholars of Participatory Governance mention four central characteristics of Participatory Governance: appropriate representation of stakeholder interests, deliberative engagement of stakeholders, integration of different knowledge, and social learning (Meadowcroft, 2004, see also the democratic integration ladder in Section 5). Participation in Participatory Governance may occur at various levels (local, regional, national, supranational), in different forms and venues (including the internet) and constitutes a dynamic relationship between participation givers and takers (Heinelt, 2002; Kung & Zhu, 2022).

There are diverse ways to conceptualise participation under the theme of Participatory Governance. Newig and Fritsch (2009) distinguish three variables: first, the form and direction of information flow (from simple information to face-to-face exchanges), second, the amount of influence on the decision-making process, and third, the circle of involved people. A classic of the participation literature is Arnstein's participation ladder, with eight steps ranging from the manipulation of citizens to citizen control (Arnstein, 1969). This approach highlights the rights and duties of both takers and givers and allows for a more differentiated evaluation of what is going on in a process (see distinct roles in the next section).

Most conceptualisations of participation share a positive understanding of participation and a "the more, the better" logic. However, an a priori positive evaluation of participation has been criticised because participatory chances are not distributed equally in society, and participation takers are frequently the "usual suspects" (Graf & Fuchs, 2015; Schneidemesser et al., 2020). Moreover, some authors argue that the potential for and benefit of participation might be overestimated. They point to, for example a lack of transparency, the increasing complexity of decision-making processes and the existence of

powerful and diverse veto-players as inhibitors of a balance of power in participation (e.g, van der Linde et al., 2021).

Despite this critique on Participatory Governance, policymakers, administrations – including civil society – and third-sector organisations plea for a wide-ranging integration of citizens in urban mobility transitions to enhance the acceptance of transformation processes (e.g. see Ryghaug et al., 2023). Literature on Participatory Governance in the sector of mobility planning or mobility hubs is however rare. In the context of environmental policies in general, Participatory Governance is expected to contribute to an improved quality of decisions by incorporating local knowledge and opening the political discourse for environmental concerns. Also, stakeholder involvement is expected to increase acceptance, and improve compliance and the implementation of measures (Fischer, 2012; Meadowcroft, 2004; Newig & Fritsch, 2009).

While some emphasise the empowerment of citizens for reasons of democratic legitimacy (Dryzek, 2000), others highlight the meaning of market acceptance, especially when it comes to implementing new technologies (Wüstenhagen et al., 2007). Participatory Governance is not either-or, but a continuum between those two poles, located on a middle ground of more formative and more administrative approaches to better access empirical phenomena (Graf et al., 2018).

Participation can be included at different stages of governance, from developing guidelines and overall concepts to strategic plans or the onsite implementation of concrete measures (Elvy, 2014; Gil et al., 2011). Stake "holders" can be invited based on their rights, affectedness, or knowledge (see Schmitter, 2002) or chosen randomly. Furthermore, the roles of participation givers and takers are dependent on local contexts and the specific stages and goals of participation formats (Ernst, 2019).

When it comes to mobility planning documents, the European Commission for instance explicitly demands stakeholder participation in the development of sustainable urban mobility plans (SUMPs) (Rupprecht Consult, 2019). In the case of German cycling policies, Schneidemesser et al. (2020) describe improved political outcomes due to the integration of citizen knowledge into the policy-making process. A number of mobility hubs, project reports and guidelines also emphasise the role and importance of stakeholder participation (see Table 1; GoSEStran 2020; Kast, 2021). User participation is also mentioned as a key success factor to removing barriers, creating support, and increasing uptake of shared mobility services in rural areas (Advier/SVP, 2021).

In short, democratic integration is important for the development of hubs to create more democratic and inclusive hubs, achieve public support, and increase the usage of hubs. The different stages of participation discussed in this section are reflected in the dimension of democratic integration of the SmartHubs Integration Ladder described in Section 5.

5. Smarthubs integration ladder

Based on this literature review, a multidimensional typology for shared mobility hubs has been developed, i.e. the SmartHubs integration ladder, based on three integration dimensions: physical, digital, and democratic. Each dimension has 5 levels (from 0 to 4). As mentioned earlier, universal design principles are typically missing in mobility hub concepts and definitions in the literature and planning practice. Here, universal design principles

have been embedded in the SmartHubs physical and digital dimensions as a common threshold to enhancing broader usability and accessibility. The choice of what principles are most important is context-sensitive and tailored to each mobility hub. Therefore, the more principles considered, the better.

- Level 0 does not entail the application of any principle
- Level 1 involves the legally required accessibility criteria
- Levels 2, 3 and 4 consider universal design principles

The integration ladder enables the comparison of different hubs with different services, understanding potential effects, and aiding the integration of societal goals into hub developments. The levels of the integration ladders help distinguish smart mobility hubs from the pool of hubs. We define a Smart Mobility Hub as a hub that offers advanced levels of physical, digital, and democratic integration, i.e. minimum level 2 on physical, digital, and democratic integration. Figure 1 visualises the SmartHubs integration ladder based on the physical, digital, and democratic integration dimensions, while Table 4 presents a detailed explanation of each dimension and level.

Physical integration describes the effort of clustering mobility and non-mobility services together in the public space. Following the universal design principles and in addition to physical proximity, visibility and access without physical barriers increase usability and accessibility. Level 1 includes the consideration of minimum legal design requirements (e.g. allowing users with disabilities to easily access the hub), at level 2 and higher Universal design principles are considered in the physical mobility hub design.

Digital integration describes the effort of integrating information on one digital platform and making it possible for different information platforms to access information using a standard format. The digital integration levels expand the existing Mobility-as-a-Service topology (Sochor et al., 2018) with digital accessibility and universal design principles. The inclusion of analogue alternatives to plan, pay, and book trips, low-tech instruments such as helpdesk support and/or the offer of training to digitally low-skilled users

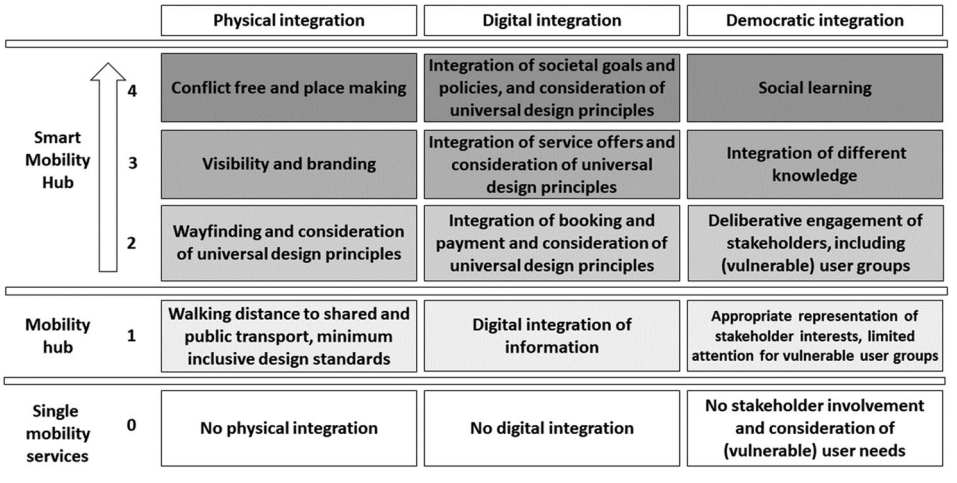

Figure 1. The SmartHubs Integration Ladder – summary.

Table 4. The SmartHubs Integration Ladder – description.

	Physical integration	Digital integration	Democratic integration
Level 4	Conflict free and place-making. At least two shared transport modes visible from a public transport stop with no conflicts or barriers, and information on using the services and at least two services. Universal design principles are considered. Placemaking and attractive space design.	Integration of societal goals, policies, and incentives. Local, regional, and/or national policies and goals are integrated into the service. Universal design principles are considered, including simple and intuitive app design and low-tech or analogue booking alternatives. Incentives for desired behaviour are implemented.	Social learning. Participation takers and givers, including vulnerable users, have networked, and integrated into the community, and participation becomes permanent and independent. Participation methods involves a permanent and independent exchange between participation givers and takers, so mutual understanding and interaction get institutionalised.
Level 3	Visibility, attractive hub design and branding. At least two shared transport modes visible from a public transport stop and at least one service (e.g. shop, parcel locker, kiosk), information about the service and potential conflicts, attractive design of the mobility hub and branding, including sheltered waiting areas. Universal design principles are considered.	Integration of service offers. Shared and public transport services at the hub are bundled, possibly subscription based. Universal design principles are considered, including simple and intuitive app design and low-tech or analogue booking alternatives.	Integration of different knowledge. Participation takers, including vulnerable users, argue or deny positions, their input is integrated into the participation process, and participation givers create room for decision-making.
Level 2	Wayfinding and universal design. At least two shared transport modes within acceptable walking distance to public transport with wayfinding and information on using the service and at least one service (e.g. parcel locker, kiosk) within acceptable walking distance. Universal design principles are considered, creating an accessible environment with relevant elements such as ramps, escalators, and elevators.	Integration of booking and payment and universal design. Easy access to services for end-users – such as a mobility marketplace or a one-stop shop where the user can find, book, and pay with the same app. Universal design principles are considered, including simple and intuitive app design and low-tech or analogue booking alternatives.	Deliberative engagement of stakeholders. Participation takers, including vulnerable users, argumentatively engage in decision-making, exchange of positions, active participation, participation givers invite participation and listen to stakeholder interests, including those of vulnerable user groups. Participating methods include a public hearing and invitation sto send feedback via mail and/or webform.
Level 1	Acceptable walking distance to shared and public transport. At least two shared transport modes within acceptable walking distance to public transport and at least one service (e.g. shop, parcel locker, kiosk) within acceptable walking distance. Minimum legal inclusive design requirements are considered.	Integration of information. Multimodal travel planners can be used to plan mobility offerings at hubs. Minimum inclusive design requirements are considered such as simple and intuitive app design.	Appropriate representation of stakeholder interests. Participation takers are asked to be part of a consultation process and are provided with relevant information. No or limited attention to involve vulnerable user groups. Participation methods include surveys and handing out flyers, brochures, etc.
Level 0	No physical integration. One shared transport mode, not at walking distance to public transport, no integration between the modes. No universal design criteria are considered.	No digital integration of shared and public transport mode options. There are separate services and platforms for each mode. No universal design criteria are considered.	No involvement or consideration of stakeholder interests and user needs.

are included at level 2 and higher to increase the usability of and access to the hub's mobility services for the greatest potential number of users.

Democratic integration is based on principles of participatory governance, encompassing the integration of citizens in the development of hubs to create more inclusive hubs catering to the needs of a wide variety of different users. The approach highlights the rights and duties of both takers and givers and allows for a more differentiated evaluation of what is going on in a process. The inclusion of vulnerable groups in the participatory planning approach is needed at level 2 and higher, to allow the inclusion of their specific needs and skills in the planning process.

6. Conclusions and discussion

A wide variety of definitions, operationalisations, and implementations of shared mobility hubs have been identified from the academic literature and planning documents. Most definitions focus on the mobility and transfer components of hubs and include the presence of shared multiple modes and the ability to transfer between modes as requirements for hubs. We define a shared mobility hub as a physical location where different shared transport options are offered at a dedicated, non-temporary and recognisable location, and where public transport is available within walking distance.

Based on this literature review, we developed a multidimensional typology for mobility hubs, the SmartHubs Integration Ladder, based on three dimensions: the physical, digital, and democratic integration. From the literature, five main groups of factors have been found to determine the level of physical integration: (1) spatial factors, including land use, points of interest, demographics, public transport, walking and cycling infrastructure, (2) proximity to different elements and the presence of barriers or conflicts, (3) visibility and recognisability, including wayfinding and information about services, (4) application of accessibility for all design principles, and (5) place making strategies. Digital integration describes how well information from various mobility options is integrated into a single digital platform, and how well the mobility services cater for the needs of people with diverse range of needs and digital skills. Democratic integration is based on principles of participatory governance, and describes how well stakeholder interests and needs of a wide variety of different users are included in the decision making process.

Each dimension has 5 levels, and to be "Smart", we argue that all components need to have a minimum level of integration, level 2 in our ladder. Furthermore, universal design principles are embedded in the SmartHubs physical and digital dimensions as a common threshold to enhance broader usability and accessibility. For travellers and citizens, the added value of mobility hubs can be expected to increase when the design is centred on the user's needs and constraints while following principles of universal design and physical, digital, and democratic integration dimensions. However, the review of grey literature reveals that digital and democratic integration dimensions and universal design principles are typically missing in mobility hub concepts and definitions in the planning practice, which implies that existing mobility hubs will not reach the full potential of their user and societal value.

The integration ladder can help to identify and categorise existing and new mobility hub developments and can assist researchers and policy makers to examine which hub designs are potentially more successful or effective at improving the transport system and its societal impacts. The integration ladder is also integrated into an interactive

open data platform – ODP (SmartHubs, 2021), developed to allow an easy "expert crowd" mapping of the operational/planned mobility hubs, including their levels of integration, allowing a comprehensive international analysis of mobility hubs.

The development of smart mobility hubs with high levels of integration (level 2 or higher) of all three integration dimensions goes beyond the state of the practice. In practice, hubs will meet some but not all criteria. The choice of what level of integration level that to be targeted is context-dependent, e.g. based on the socio-economic characteristics of the area. In general, the combination of applying universal design principles for physical and digital integration will be challenging in hub development. Firstly, applying universal design principles will help to make services accessible by the greatest possible number of people with a diverse range of needs. However, it does not answer the question if each mobility and non-mobility service and hub element should be made accessible for the greatest possible number of people, or only some services and elements. Secondly. the development of app-based shared mobility and mobility-as-a-service offerings typically does not go hand in hand with offering low-tech booking options or training for less digitally skilled persons. Finally, the democratic integration dimension requires the consideration of needs of vulnerable user groups. This goes beyond traditional public participation process of transport projects, which are typically assessed in terms of the number of opportunities for participation, their convenience and how easily people can access materials (Karner et al., 2020).

The integration ladder has been developed to provide a general typology of shared mobility hubs. However, the transport and wider societal impacts of hubs with specific characteristics and integration levels also depends on the local context. Several local contextual factors can affect the uptake of mobility services at hubs, including the socio-demographic characteristics of residents living around the hub, attitudinal factors, built environment factors, the availability and service levels of transport modes and local transport policies such as parking regulations and fees.

Several directions for future research can be identified. A first main direction of research is to conduct systematic research on the characteristics of mobility hub users and non-users, as this is lacking in the literature. However, since mobility hubs constitute a combination of individual sharing systems such as bike-sharing and car-sharing, looking at the users of these systems could provide insight into the current and potential users of mobility hubs. Furthermore, MaaS applications and pilots would provide additional information on the users of integrated multimodal mobility systems.

A second main direction for future research is to further explore the societal, environmental, and economic impacts of mobility hubs, considering both the early findings on the influence of existing hubs as well as the potential impact of future applications. In the literature there is surprisingly little evidence on the impact of various hub characteristics on the use of the mobility and non-mobility facilities provided at hubs, and under what local conditions. In particular, the extent to which the integration elements impact car ownership and use, mode choice, and emissions from transport needs more research. Moreover, to the best of the authors' knowledge, no studies have been done to examine how universal design principles can reduce digital inequities by lowering barriers to the use of digital mobility services available at hubs.

Future research could also focus on assessing the relative importance of the different integration dimensions and their levels across different local contexts. This can include

the development and application of a standardised survey among users and residents in different areas, including choice experiments, to examine trade-offs between integration dimensions and the willingness to pay for increasing levels of smartness of hubs. In addition to examining the impacts of mobility hubs, the local context needs to be taken into account, including socio-demographic characteristics of the residents living around a hub, attitudinal factors, built environment factors and local transport policies.

A third main direction for further research is related to the governance aspects of mobility hubs. The sharing of responsibilities and investments for the implementation of smart mobility hubs between multiple stakeholders are relevant topics for future research. Follow-up research can also explore the planning efforts (including investment costs) and governance implications of increasing the levels of physical, digital, and democratic integration levels.

Contribution of authors

Karst Geurs, conceptualisation and research design, data collection (literature), formal analysis, writing, review and editing, validation, overall supervision

Anna Grigolon, conceptualisation, data collection (literature), formal analysis, writing, review, and editing, validating,

Karla Münzel, conceptualisation, data collection (literature), writing, review, and editing

Konstantinos Gkiotsalitis, conceptualisation, review, and editing

David Duran-Rodas, conceptualisation (integration ladder), data collection (literature), writing, review, and editing

Benjamin Büttner, conceptualisation (integration ladder), data collection (literature), writing, review, and editing

Christoph Kirchberger, data collection (literature), writing, review, and editing

Jesse Pappers, conceptualisation (integration ladder), data collection (literature), writing, review, and editing

Lluis Martinez Ramirez, conceptualisation (integration ladder), data collection (literature), writing, review, and editing

Antonia Graf, conceptualisation (integration ladder), data collection (literature), writing, review, and editing

Julia Hansel, conceptualisation (integration ladder), data collection (literature), writing, review, and editing

Roxani Gkrava, data collection (literature), writing, review, and editing

Roman Klementschitz, data collection (literature), writing, review, and editing

Acknowledgements

The authors thank Aaron James Nichols (Technical University of Munich), Imre Keserü and Hannes Delaere (Vrije Universiteit Brussel) for their contribution to the SmartHubs Deliverable 2.1, which formed the basis of this paper.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the JPI Urban Europe, project number 99950070, [NWO Grant 438-21-431] supporting the contribution from the University of Twente, Innoviris [Grant EU UAC 2021 2A-2C] supporting the contribution from the Vrije Universiteit Brussel, [FFG Grant 884274] supporting the contribution from Technical University of Vienna and the University of Natural Resources and Life Sciences [BMBF Grant 01UV2151A] supporting the contribution from the Technical University of Munich and grant number [01UV2151B] supporting WWU.

References

Advier. (2021). *A planner's guide to shared mobility galaxy*. Uitgeverij SNKI. https://share-north.eu/wp-content/uploads/2022/05/Shared-Mobility-Guide_ENGLISH.pdf

Advier/SVP. (2021). Buurthubs Utrecht - Kookboek. SVP - Architectuur en Stedenbouw. https://advier.nl/wp-content/uploads/2021/07/Kookboek-Buurthubs-Utrecht_web.pdf

Amoroso, S., Castelluccio, F., & Santoro, N. (2012). WIT transactions on ecology and The environment. *WIT Transactions on Ecology and the Environment*, *1*, 955–966. https://doi.org/10.2495/SC120802

Anderson, K., Blanchard, S. D., Cheah, D., & Levitt, D. (2017). Incorporating equity and resiliency in municipal transportation planning: Case study of mobility hubs in Oakland, California. *Transportation Research Record: Journal of the Transportation Research Board*, *2653*(1), 65–74. https://doi.org/10.3141/2653-08

Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory*, *18*(4), 543–571. https://doi.org/10.1093/jopart/mum032

Ansell, C. K., & Torfing, J. (2021). *Public governance as co-creation: A strategy for revitalizing the public sector and rejuvenating democracy. Cambridge studies in comparative public policy*. Cambridge University Press.

Aono, S. (2019). *Identifying best practices for mobility hubs. Technical report. UBC Sustainability Scholar. TransLink*.

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, *35*(4), 216–224. https://doi.org/10.1080/01944366908977225

Blad, K., de Almeida Correia, G. H., van Nes, R., & Annema, J. A. (2022). A methodology to determine suitable locations for regional shared mobility hubs. *Case Studies on Transport Policy*, *10*(3), 1904–1916. https://doi.org/10.1016/j.cstp.2022.08.005

Bolger, D., Colquhoun, D., & Morrall, J. (1992). Planning and design of park-and-ride facilities for the calgary light rail transit system. *Transportation Research Record*, *1361*, 141.

Bösehans, G., Bell, M., Thorpe, N., Liao, F., Homem de Almeida Correia, G., & Dissanayake, D. (2021). eHUBs—identifying the potential early and late adopters of shared electric mobility hubs. *International Journal of Sustainable Transportation*, 1–20. https://doi.org/10.1080/15568318.2021.2015493

Carter, C. (2005). The role of participatory processes in environmental governance: The example of agricultural GMOs. In P. H. Feindt, & J. Newig (Eds.), *Partizipation, Öffentlichkeitsbeteiligung, nachhaltigkeit: Perspektiven der politischen Ökonomie* (pp. 181–207). Metropolis Verlag für Ökonomie.

Chidambara. (2019). Walking the first/last mile to/from transit: Placemaking a key determinant. *Urban Planning*, *4*(2), 183–195. https://doi.org/10.17645/up.v4i2.2017

Coenegrachts, E., Beckers, J., Vanelslander, T., & Verhetsel, A. (2021). Business model blueprints for the shared mobility hub network. *Sustainability*, *13*(12), 6939. https://doi.org/10.3390/su13126939

CoMoUK. (2019). Mobility Hubs Guidance. Retrieved May 30, 2023, form https://como.org.uk/wp-content/uploads/2019/10/Mobility-Hub-Guide-241019-final.pdf

Conticelli, E., Gobbi, G., Saavedra Rosas, P. I., & Tondelli, S. (2021). Assessing the performance of modal interchange for ensuring seamless and sustainable mobility in European cities. *Sustainability*, *13*(2), 1001. https://doi.org/10.3390/su13021001

CROW. (2021). Leidraad parkeren bij knooppunten en mobiliteitshubs. Retrieved May 30, 2023, from at (in Dutch): https://www.crow.nl/getmedia/498b31d5-cd34-4d00-8d13-16b8a84b1238/Leidraad-parkeren-bij-knooppunten-en-mobiliteitshubs.pdf.aspx?ext = .pdf

Cui, W. (2021). *Tarwewijk mobility hub: Migration of mobility as public space*. [MSc thesis]. TUDelft.

DELVA Landscape Architects / Urbanism, Site Urban Development, Skonk, & Goudappel Coffeng. (2019). Ruimtelijk raamwerk merwe-vierhavens rotterdam. Toekomst in de Maak.

Dryzek, J. S. (2000). *Deliberative democracy and beyond: Liberals, critics, contestations*. Oxford University Press.

Durand, A., Zijlstra, T., & Hamersma, M. (2021b). Een inclusief openbaar vervoersysteem in het digitale tijdperk: op het juiste spoor? (An inclusive public transport system in the digital age: on the right lane?). KIM, Den Haag. Retrieved March 30, 2023, from (in Dutch): https://www.kimnet.nl/publicaties/publicaties/2021/12/07/een-inclusief-openbaar-vervoersysteem-in-het-digitale-tijdperk-op-het-juiste-spoor

Durand, A., Zijlstra, T., van Oort, N., Hoogendoorn-Lanser, S., & Hoogendoorn, S. (2021a). Access denied? Digital inequality in transport services.. *Transport Reviews*, *42*(1), 32–57. https://doi.org/10.1080/01441647.2021.1923584

eHUBS. (2021). eHUBS - Smart Shared Green Mobility Hubs - Overview. Retrieved May 30, 2023, from https://www.nweurope.eu/projects/project-search/ehubs-smart-shared-green-mobility-hubs/

Elvy, J. (2014). Public participation in transport planning amongst the socially excluded: An analysis of 3rd generation local transport plans. *Case Studies on Transport Policy*, *2* (2), 41–49. https://doi.org/10.1016/j.cstp.2014.06.004

Emerson, K., Nabatchi, T., & Balogh, S. (2012). An integrative framework for collaborative governance. *Journal of Public Administration Research and Theory*, *22*(1), 1–29. https://doi.org/10.1093/jopart/mur011

Ernst, A. (2019). Review of factors influencing social learning within participatory environmental governance. *Ecology and Society*, *24*(1), 1. https://doi.org/10.5751/ES-10599-240103

Fallast, K., & Huber, G. (2015). Mobilitätskonzept Graz 2020. Massnahmenprogramm Graz: Magistrat der Stadt Graz Verkehrsplanung. Retrieved May 30, 2023, from https://www.graz.at/cms/dokumente/10191191_8038228/46b25ed3/20150622_ENDBERICHT_MOKO2020_MASSNAHMEN_BESCHLUSSFASSUNG_NOV.2015.PDF

Fischer, F. (2012). *Participatory governance*. Oxford University Press.

Frank, L., Dirks, N., & Walther, G. (2021). Improving rural accessibility by locating multimodal mobility hubs. *Journal of Transport Geography*, *94*, 103111. https://doi.org/10.1016/j.jtrangeo.2021.103111

Frye, A. (2011). Disabled and older persons and sustainable urban mobility. Thematic study prepared for global report on human settlements 2013. United Nations, Nairobi. Retrieved May 30, 2023, from https://unhabitat.org/sites/default/files/2013/06/GRHS.2013.Thematic.Disabled.and_.Older_.Persons.pdf

Garde, J., Jansen, H., & Bläser, D. (2014). Mobilstationen – Bausteine für eine zukunftsfähige Mobilität in der Stadt. REAL CORP 2014 – PLAN IT SMART! Clever Solutions for Smart Cities. Proceedings of 19th International Conference on Urban Planning, Regional Development and Information Society, 903-907.

Gemeente Utrecht. (2021). Deelhub De Grifthoek. Retrieved May 30, 2023, from https://www.utrecht.nl/wonen-en-leven/parkeren/parkeren-bezoeker/parkeergarages-in-utrecht/deelhub-de-grifthoek/

Gil, A., Calado, H., & Bentz, J. (2011). Public participation in municipal transport planning processes – the case of the sustainable mobility plan of ponta delgada, azores, Portugal. *Journal of Transport Geography*, *19*(6), 1309–1319. https://doi.org/10.1016/j.jtrangeo.2011.06.010

GoSEStran. (2020). Mobility Hubs. A Strategic Study for the Southeast of Scotland/SEStran region. Report. Steer; Transport Scotland. Retrieved May 30, 2023, from https://sestran.gov.uk/wp-content/uploads/2020/05/SEStran-Mobility-Hubs-Strategic-Study-Final-Report.pdf

Goudappel, appm, & Provincie Noord-Brabant. (2021). Ontwikkelplan Mobiliteitshubs West-Brabant.

Graf, A., & Fuchs, D. (2015). Energiewende konkret: Lokale transformationsprozesse und ihre normative einbettung in governance-strukturen des mehrebenensystems. In M. Heimbach-Steins (Ed.),

Jahrbuch für christliche sozialwissenschaften 56: Ethische herausforderungen der energiewende (pp. 107–133). Aschendorff.

Graf, A., Sonnberger, M., & Ruddat, M. (2018). Transformation gestalten oder verwalten? Zivilgesellschaft und energiewende. In L. Holstenkamp, & J. Radtke (Eds.), *Springerlink bücher. Handbuch energiewende und partizipation* (pp. 483–504). Springer VS.

Hasan, A. N., & Al-Khafaji, S. J. (2021). Integration of intermodal transport stations as a tool for urban renewal in the city of Baghdad. *IOP Conference Series: Materials Science and Engineering*, *1067*(1), 012030. https://doi.org/10.1088/1757-899X/1067/1/012030

Heinelt, H. (2002). Achieving sustainable and innovative policies through participatory governance in a multi-level context. In H. Heinelt, P. Getimis, G. Kafkalas, R. Smith, & E. Swyngedouw (Eds.), *Participatory governance in multi-level context: Concepts and experience* (pp. 17–32). VS Verlag für Sozialwissenschaften.

Heinelt, H. (2010). *Governing modern societies: Towards participatory governance (1st ed.). routledge studies in governance and public policy Ser*. Routledge.

Horjus, J. S., Gkiotsalitis, K., Nijënstein, S., & Geurs, K. T. (2022). Integration of shared transport at a public transport stop: Mode choice intentions of different user segments at a mobility hub. *Journal of Urban Mobility*, *2*, 100026. https://doi.org/10.1016/j.urbmob.2022.100026

IGES Institut. (2021). Mobistar. Grundlagenpapier für Mobilitätsstationen in städtischen Randlagen. Aschlussbericht.

Indrakesuma, F. N. (2018). *Maneuvering Mobility: Measuring Multimodality in New York City's Selected Transit Hubs* [Master thesis].Columbia University.

Jansen, H., Garde, J., Bläser, D., & Frensemeier, E. (2015). Städtische mobilstationen. Funktionalität und gestaltung von umsteigeorten einer intermodalen mobilitätszukunft. In H. Proff (Ed.), *Entscheidungen beim Übergang in die elektromobilität. Technische und betriebswirtschaftliche aspekte* (pp. 515–532). Springer.

Jittrapirom, P., Caiati, V., Feneri, A. M., Ebrahimigharehbaghi, S., Alonso González, M. J., & Narayan, J. (2017). Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges. *Urban Planning*, *2*(2), 13–25. https://doi.org/10.17645/up.v2i2.931

Karner, A., London, J., Rowangould, D., & Manaugh, K. (2020). From transportation equity to transportation justice: Within, through, and beyond the state. *Journal of Planning Literature*, *35*(4), 440–459. https://doi.org/10.1177/0885412220927691

Kast, Ö. (2021). *Hub programme Groningen and Drenthe*. State of hubs, governance, and future outlook. SMiLES research report #2. Retrieved May 30, 2023 from https://research.rug.nl/files/208904715/SMiLES_FINAL_hubs_2_governance_of_hubs_1.pdf

Kedmi-Shahar, E., Delaere, H., Vanobberghen, W., & Ciommo, F. D. (2020). *D1.1 – Analysis Framework of User Needs, Capabilities, Limitations & Constraints of Digital Mobility Services*, 105.

Klanke, P. (2022). *What are the Needs and Expectations Towards a Smart Mobility Hub?* [Master Thesis]. School of Social Sciences and Technology, Technical University of Munich. Retrieved May 30, 2023, from https://www.mos.ed.tum.de/fileadmin/w00ccp/sv/PDF/RG-MobJustice_Student-Projects/Klanke_2022_What-are-the_Needs-and-Expectations-Towards-a-Smart-Mobility-Hub.pdf

Kung, M., & Zhu, D. (2022). What about my opposition!? The case of rural public hearing best practices during the COVID, 19, *pandemic. Cities*, 120, 1–11. https://doi.org/10.1016/j.cities.2021.103485

Liao, F., & Correia, G. (2020). eHUBS - smart shared green mobility hubs. Deliverable 1.1 State-of-the-art related to eHUBS.

Luo, Q., Li, S., & Hampshire, R. (2021). Optimal design of intermodal mobility networks under uncertainty: Connecting micromobility with mobility-on-demand transit. *EURO Journal on Transportation and Logistics*, *10*, 100045. https://doi.org/10.1016/j.ejtl.2021.100045

Mather, J. J. (1983). Guidelines and standards for the planning, design, and operation of bus park-and-ride facilities. *Transportation Research Record*, *908*, 1–6.

May, A. D., Kelly, C., & Shepherd, S. (2006). The principles of integration in urban transport strategies. *Transport Policy*, *13*(4), 319–327. https://doi.org/10.1016/j.tranpol.2005.12.005

Meadowcroft, J. (2004). *Participation and sustainable development: Modes of citizen, community and organisational involvement. In: William lafferty (Hg.)*. Edward Elgar Publishing.
Metrolinx. (2011). Mobility Hub guidelines for the greater Toronto and Hamilton area. Metrolinx.
Miramontes, M. (2018). *Assessment of mobility stations. Success factors and contributions to sustainable urban mobility* [PhD thesis]. Technische Universität München, Munich.
Mobiliteitsalliantie. (2020). Startnotitie hubs. Retrieved May 30, 2023, from (in Dutch): https://mobiliteitsalliantie.nl/wp-content/uploads/2020/06/2020-06-11-Hubs-Startnotititie.pdf
Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ*, *339*(jul21 1), b2535. https://doi.org/10.1136/bmj.b2535
Monzón, A., & Ciommo, F. D. (2016). *CITY-HUBs: Sustainable and efficient urban transport interchanges*. CRC Press, Taylor & Francis.
Mouw, A. (2020). Applying the concept of mobility hubs in the context of the achtersluispolder [Bachelor Thesis]. University of Twente, Enschede, the Netherlands. Retrieved May 30, 2023. https://essay.utwente.nl/85058/
Muller, M., Park, S., Lee, R., Fusco, B., & Correia, G. H. A. (2021). Review of whole system simulation methodologies for assessing mobility as a service (maas) as an enabler for sustainable urban mobility. *Sustainability*, *13*(10), 5591. https://doi.org/10.3390/su13105591
Nag, D., M, B. S., Goswami, A., & Bharule, S. (2019). Framework for public transport integration at railway stations and Its implications for quality of life. *ADBI Working Paper*, *1054*), SSRN Electronic Journal. Retrieved May 30, 2023. https://doi.org/10.2139/ssrn.3551888
Natuur & Milieu. (2020). Mobiliteitshubs - Maak mobiliteitshubs aantrekkelijk en zorg voor diverse mobiliteit. Retrieved May 30, 2023, https://www.natuurenmilieu.nl/wp-content/uploads/2020/02/Brochure-Mobiliteitshubs.pdf
Navrátilová, K., Tichý, T., Fricke, A., Woisetschläger, D. M., Sedlák, J., & Ivasienko, P. (2021). *Application of Mobility Hub for Automatic Parking in the City*, *2021*, Smart City Symposium Prague (SCSP), 2021, 1-7.
Newig, J., & Fritsch, O. (2009). Environmental governance: Participatory, multi-level - and effective? *Environmental Policy and Governance*, *19*(3), 197–214. https://doi.org/10.1002/eet.509
Nielsen, G., Nelson, J. D., & Mulley, C. (2005). Public transport: planning the networks.
Nordbakke, S., & Schwanen, T. (2015). Transport, unmet activity needs and wellbeing in later life: Exploring the links. *Transportation*, *42*(6), 1129–1151. https://doi.org/10.1007/s11116-014-9558-x
Pappers, J., Keserü, I., & Macharis, C. (2020). Co-creation or public participation 2.0? An assessment of Co-creation in transport and mobility research. In B. Müller & G. Meyer (Eds.), *Towards user-centric transport in Europe 2: Enablers of inclusive, seamless and sustainable mobility*, 3–15. Springer International Publishing.
Petrović, M., Mlinarić, T., & Šemanjski, I. (2019). Location planning approach for intermodal terminals in urban and suburban rail transport. *PROMET – Traffic&Transportation*, *31*(1), 101–111. https://doi.org/10.7307/ptt.v31i1.3034
Pfertner, M. (2017). Evaluation of mobility stations in würzburg-perceptions, awareness, and effects on travel behavior, car ownership, and CO2 emissions. MSc Thesis, Technische Universität München, Munich, Germany.
Preston, J. (2012). Integration for seamless transport. International transport forum discussion papers, No. 2012/01, OECD Publishing, Paris. https://doi.org/10.1787/5k8zvv8lmswl-en
Reck, D. J., & Axhausen, K. W. (2021). Who uses shared micro-mobility services? Empirical evidence from Zurich. Switzerland.. *Transportation Research Part D: Transport and Environment*, *94*, 1–11. https://doi.org/10.1016/j.trd.2021.102803
Rehme, M., Richter, S., Temmler, A., & Götze, U. (2018). Urbane Mobilitäts-Hubs als Fundament des digital vernetzten und multimodalen Personenverkehrs. In H. Proff & T. Fojcik (Eds.), *Mobilität und digitale Transformation* (pp. 311–330). Springer Gabler Wiesbaden.
Reisviahub.nl. (2021). Retrieved May 30, 2023, from Province of Groningen and Drenthe, the Netherlands. https://www.reisviahub.nl/
Rongen, T., Tillema, J., Arts, J., Alonso-Gonzales, M., & Witte, J. J. (2022). An analysis of the mobility hub concept in The Netherlands: Historical lessons for its implementation. *Journal of Transport Geography*, *104*, 103419. https://doi.org/10.1016/j.jtrangeo.2022.103419

Rube, S., Ackermann, T., Kagerbauer, M., Loose, W., Nehrke, G., Wirtz, M., & Zappe, F. (2020). Multi- und Intermodalität: Hinweise zur Umsetzung und Wirkung von Maßnahmen im Personenverkehr - Teilpapier 3: Multi- und intermodale Mobilitätsdienstleistungen und intermodale Verknüpfungspunkte. Retrieved May 30, 2023, https://www.fgsv.de/regelwerk/dialog-zu-ausgewaehlten-regelwerken/downloads

Rupprecht Consult. (2019). Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan. Retrieved May 30, 2023, form https://www.eltis.org/sites/default/files/sump_guidelines_2019_interactive_document_1.pdf

Ryghaug, M., Subotički, I., Smeds, E., von Wirth, T., Scherrer, A., Foulds, C., Robison, R., Bertolini, L., Beyazit İnce, E., Brand, R., Cohen-Blankshtain, G., Dijk, M., Freudendal Pedersen, M., Gössling, S., Guzik, R., Kivimaa, P., Klöckner, C., Lazarova Nikolova, H., Lis A., … Wentland, A. (2023). A social sciences and humanities research agenda for transport and mobility in Europe: Key themes and 100 research questions. *Transport Reviews*, 1–25. https://doi.org/10.1080/01441647.2023.2167887

Schelling, J. (2021). Mobility hubs: How will they function, look and enrich the city. Master's thesis. Delft University of Technology. Retrieved May 30, 2023, from http://resolver.tudelft.nl/uuid:ef3f3d7a-2960-46b9-9cc4-567ccb0ee352

Schemel, S., Niedenhoff, C., Ranft, G., Schnurr, M., & Sobiech, C. (2020). Mobility hubs of the future – towards a new mobility behaviour. ARUP/RISE, Berlin/Götheborg, Retrieved May 30, 2023, from https://www.ri.se/sites/default/files/2020-12/RISE-Arup_Mobility_hubs_report_FINAL.pdf

Schmitter, P. C. (2002). Participation in governance arrangements: Is there any reason to expect it will achieve "sustainable and innovative policies in a multi-level context"? In J. R. Grote & B. Gbikpi (Eds.), *Participatory governance. Political and societal implications* (pp. 51–69). Springer Fachmedien.

Schneidemesser, D. v., Herberg, J., & Stasiak, D. (2020). Re-claiming the responsivity gap: The co-creation of cycling policies in Berlin's mobility law. *Transportation Research Interdisciplinary Perspectives*, *8*, S1–S12. https://doi.org/10.1016/j.trip.2020.100270

Silva, L. M. C., & Uhlmann, J. (2021). *Contributing factors for the underutilization of mobility stations: the case of the" Wien mobil station" in Vienna*. Revista Produção e Desenvolvimento, 7.

SmartHubs. (2021). *SmartHubs project website – https://www.smartmobilityhubs.eu*

Smith, G. (2009). *Democratic innovations: Designing institutions for citizen participation. Theories of institutional design*. Cambridge University Press.

Sochor, J., Arby, H., Karlsson, I. C. M., & Sarasini, S. (2018). A topological approach to mobility as a service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. *Transportation Business and Management*, *27*, 3–14. https://doi.org/10.1016/j.rtbm.2018.12.003

Story, M. F. (2001). *Universal design handbook* (2nd ed.). McGraw Hill.

SUMC (Shared-Use Mobility Center). (2019). *Mobility Hubs*. Retrieved May 30, 2023, from https://secureservercdn.net/50.62.89.79/6c6.77f.myftpupload.com/wp-content/uploads/2019/08/Mobility-Hubs_SUMC_Web.pdf

Tavassoli, K., & Tamannaei, M. (2020). Hub network design for integrated bike-and-ride services: A competitive approach to reducing automobile dependence. *Journal of Cleaner Production*, *248*, 119247. https://doi.org/10.1016/j.jclepro.2019.119247

Urban Design Studio. (2016). Mobility Hubs: A Reader's Guide. Urban Design Studio Los Angeles City Planning. Retrieved May 30, 2023, from http://www.urbandesignla.com/resources/MobilityHubsReadersGuide.php

van der Linde, L. B. A., Witte, P. A., & Spit, T. J. M. (2021). Quiet acceptance vs. The 'polder model': Stakeholder involvement in strategic urban mobility plans. *European Planning Studies*, *29*(3), S. 425–S. 445. https://doi.org/10.1080/09654313.2020.1735310

van Gils, L. (2019). eHUBS Smart Shared Green Mobility Hubs. eHUB technical and functional requirements. Retrieved May 30, 2023, form https://www.nweurope.eu/media/9927/dt111_ehub_technical_and_functional_requirements.pdf

Weustenenk, A. G., & Mingardo, G. (2023). Towards a typology of mobility hubs. *Journal of Transport Geography*, *106*, 1–9. https://doi.org/10.1016/j.jtrangeo.2022.103514

Witte, J. J., Alonso-González, M., & Rongen, T. (2021). Verkenning van het concept mobiliteitshub. Kennisinstituut voor Mobiliteitsbeleid (KiM). Retrieved May 30, 2023, form https://research.rug.nl/en/publications/verkenning-van-het-concept-mobiliteitshub

Wright, L., & Hook, W. (2007). *Bus rapid transit planning guide*. Institute for Transportation and Development Policy.

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, *35*(5), 2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001

Zemp, S., Stauffacher, M., Lang, D. J., & Scholz, R. W. (2011). Classifying railway stations for strategic transport and land use planning: Context matters!. *Journal of Transport Geography*, *19*, 670–679. https://doi.org/10.1016/j.jtrangeo.2010.08.008

Zientek, J., Illek, G., Posch, K.-H., Fabian, S., Stratil-Sauer, G., Pröll, M., Erdmann, M., & Franz, G. (2018). Leitfaden Mobilitätsstationen. Die Umsetzung von Mobilitätsstationen in Stadtentwicklungsgebieten am Beispiel Zielgebiet Donaufeld, Wien. Wien: Stadt Wien, Stadtentwicklung und Stadtplanung. Retrieved May 30, 2023, form https://www.digital.wienbibliothek.at/urn/urn:nbn:at:AT-WBR-575386

Zukunftsnetz Mobilität NRW. (2022). Handbuch Mobilstationen Nordrhein-Wesfalen. 3. aktualisierte und überarbeitete Auflage. Geschäftsstelle Zukunftsnetz Mobilität. https://www.zukunftsnetz-mobilitaet.nrw.de/media/2022/4/19/bf4aadb4f3be968af79e921de6b85bb2/ZNM-Handbuch-Mobilstationen-3.-Auflage.pdf