Mobility Hubs, an Innovative Concept for Sustainable Urban Mobility?

State of the Art and Guidelines from European Experiences

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Abstract Mobility hubs bring together, connect and provide users with several modes of transport. Cities adopt them to help reach many objectives simultaneously, mainly the reduction of air pollution, congestion, and car ownership. Each mobility hub is unique, but many of them have similar characteristics that allow them to be classified. Various typologies exist. Although the mobility hub concept is flexible, the implementation of a mobility hub adapted to the needs and objectives can sometimes be complicated, as it requires many steps and may face difficulties at each step. Despite the simplicity of the mobility hub concept. They seem to be an interesting, complex, and challenging topic to investigate. As part of the Interreg Mobi-Mix project, we have taken a close look at mobility hubs. Based on bibliographic research and discussions with experts and cities, we established a state of the art that will help to better understand the concept. Without focusing on economic aspects, cities will benefit from different European experiences and a number of recommendations for a better implementation of mobility hubs.

Keywords Mobility hubs · Sustainable mobility · Shared mobility · CO_2 · Car reduction · Modal shift

1 Introduction

Mobility represents one of the main pillars of the smart city concept (Brussels Smart City, 2022). In recent decades, mobility policies and transportation services have been evolving rapidly, mainly in large and medium-sized cities. The aim of public authorities is to meet the targeted objectives of sustainable mobility. In this context, we can notice many changes in the urban environment, infrastructure, amenities, and services. In addition to the reinforcement of public transport, cities also

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encourage the use of active modes, mobility that moves away from vehicle trips, and ownership of shared vehicles. Public–private partnerships are also being organized to better engage the transition to more sustainable mobility. Within this framework, it seems that *"mobility hubs present an opportunity to integrate different sustainable transportation options to enhance connectivity. […]. Mobility hubs have the potential to become a catalyst to prioritize low emission transportation options […]"* (Aono, 2019).

Mobility hubs are perceived to be one of several solutions or a mix of solutions that cities and regions could consider for more sustainable mobility to overcome the "all-car model." These urban facilities are likely to offer significant advantages over already existing solutions, such as encouraging the use of public transport, multimodality, walking, cycling, and shared mobility. Indeed, locating various modes of mobility in the same place would increase the visibility of the modes provided. In addition, other advantages can be mentioned, such as helping to make transit easier, allowing the possibility of multimodality, giving a wider and more flexible choice, improving accessibility, and compensating for the lack of public transport in many areas (CoMoUK et al., 2019).

The mobility modes provided by the mobility hubs can be integrated into MaaS (Mobility as a Service) applications to contribute to a more efficient, modern, and digital transport system to facilitate users' transit, access to information, reservations, or payment, for example. Mobility Hub implementation is one of the results and a representation of mobility policies. This mobility policy itself is the consequence of wider ideological, social, economic, and environmental orientations. Mobility hubs could offer cities new concepts of urban planning and can be seen as a form of implementation of TOD (Transit Oriented Development). Mobility hubs therefore contribute to the connection between two dimensions of the smart city, the human-centered dimension (collective intelligence: placing people at the heart of the city, needs-centered approach, low-tech) and the technology-centered dimension (artificial intelligence: technological solutions, techno-centered approach, high-tech…) (Cerema, 2022).

Therefore, what are the mobility hubs? What are their main objectives? What are the different types of mobility hubs? What are the most relevant mobility hub projects, and what should we learn from them?

In this chapter, we are seeking to answer these questions. We will start with a summarized review of the literature. Then, without focusing on economic aspects, we will suggest lessons to be learned from European experiences, followed by recommendations for better mobility hubs. We will finish by briefly presenting two ongoing projects within the framework of the Interreg 2 seas project Mobi-Mix in Norfolk and Valenciennes and will introduce the method used for analyzing their impacts, particularly in terms of CO_2. The first results, which seem promising, will be reported succinctly.

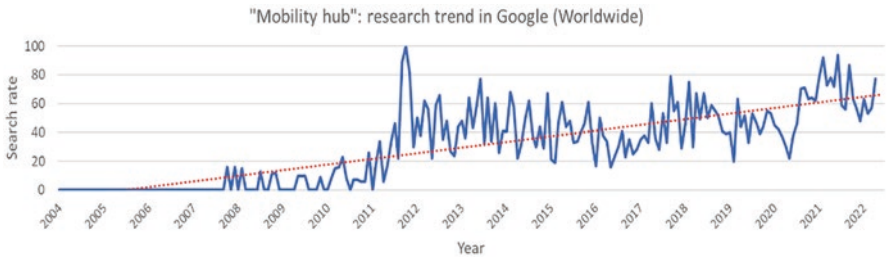

Fig 1 "Mobility hub" research trend (Google, 2022)

2 Understanding the Mobility Hub Concept

Using the term "mobility hub" is estimated to have emerged in the 2000s but has become increasingly well known in the last two decades. The first searches for the term "mobility hub" appeared in the mid-2000s (Fig. 1). The frequency of searches for this term fluctuated, with increasingly less frequent breaks until 2011. Since then, interest in the concept has not stopped and seems to be increasing (Google, 2022).

2.1 Mobility Hub Definition

It is very likely that the term mobility hub in its beginnings was not based on a theoretical concept. To the best of our knowledge, no specific author claimed to be the founder. However, it would seem, although not with absolute certainty, that Michael Glotz-Richter from the city of Bremen is among the first to adopt the concept since the early 2000s (Gray, 2017; IMS, 2019).

To date, there is still a lack of scientific literature on this subject. Several definitions of the term "mobility hub" are used simultaneously. However, in the corpus of operational literature, we identified approximately a dozen definitions of the mobility hub. Therefore, various definitions have been and continue to emerge. Each proposed definition depends on the status of the author and his experience, plans, and goals. Mobility hubs can be defined based on different parameters, such as their use (private/professional/both), location, and the service they provide. One of the major goals is to contribute to more sustainable mobility by reducing the predominance of private cars (especially internal combustion engines) and helping to change mobility behaviors toward more sustainable practices. The latter favors soft/active modes, shared modes, public transport, etc.

We did our best to cover all the available literature, which, despite its rareness, continues to evolve rapidly. We have therefore tried, within the framework of an insight report during the Mobi-Mix project,[1] to retain only the definitions that we

[1] Third Mobi-Mix insight report: "Mobility Hubs, a lever for a more sustainable mobility?"

felt were the most relevant. Some of the definitions can be confused with other facilities that have existed for a long time (multimodal hub, shared vehicle station, etc.).

To bring more clarity to the subject, it would be necessary to open a debate between different stakeholders to establish a consensus-based definition that will be considered as a reference. At this stage, we believe that the keyword in mobility hubs is "shared mobility." Public transport is also important. In addition, a hub is a central point that brings together several elements. For greater inclusiveness and ease of implementation, we propose to consider simply that *mobility hubs are urban infrastructures that provide at least several (two or more) shared modes of transport in the same place*. The mobility hub can be connected to public transport and provide other modes or services, features, and additional considerations. These are positive features that will be considered quality factors.

The fact that a location with only one shared mode can be considered a mobility hub can be discussed. Indeed, it can be seen as a classic shared-mode station (bike, car scooter). In this particular case, it seemed to us that the term "mobility point" or "shared vehicle station" could be more appropriate. Otherwise, to be considered a mobility hub, it has to have at least public realm improvements that might help with the differentiation of some vehicle-sharing stations. Equally, if the public transport is very close and well connected to the shared modes provided, it is possible to consider this as a mobility hub. In this case, several mobility hubs already exist, even though they may have not been designed/labeled as such.

It is important to remember that to improve the articulation and efficiency of networks, planners traditionally and most often connect and articulate the modes of transport to each other. Bringing together different modes of transport in the same place, such as multimodal hubs, is already a classic and logical approach. The originality of mobility hubs can be seen above all in the field that they provide shared mobility and other accompanying services.

It should be noted that when we mention the same location, it should not be restrictive. It could be the same place well delimited and distinguished from the surroundings that offer, among others, several modes. It could also be a more fragmented structure where various modes are located in different spatially separated places (due to lack of space, for example). However, these locations should remain very close and easily identifiable with a continuous visual link between them. This is not necessarily the best configuration from the functional point of view.

2.2 Mobility Hubs Requirement

The definition of the term "mobility hub" we adopt assumes a minimalist approach. This makes the concept more inclusive and easier to implement in the local environment. We consider the fact that at least two shared mobility modes are located in the same place to be sufficient to constitute a mobility hub. However, there are several other parameters that could affect the quality of the mobility hub and its success.

In the literature, some components can be necessary to consider/label an area as a mobility hub. Metrolinx identified recurring essential features that are required for an area to be designated a mobility hub (Metrolinx, 2011; Aono, 2019). In the Metrolinx approach, which differs from our proposal, a mobility hub should surround a major transit station (airport, train stations, public transport), provide more sustainable transportation options than solo used private cars, and be located in areas with high residential and employment density. Therefore, an important feature of a mobility hub is that it is serviced by one or more higher-level public transport modes that constitute its core. This core is bounded by a catchment area that takes advantage of the services that the mobility hub provides (Metrolinx, 2011). Mobility Hubs should also provide services and offer the possibility of accessing nearby amenities within a 5-minute walk or by using the proposed travel modes. *"Therefore, vehicle sharing options are highlighted as a key component to incorporate into mobility hubs"* (Metrolinx, 2011). Mobility Hubs will also need to be located in areas with high residential and employment density, but precise values are rarely mentioned in the literature.

According to the literature, urban facilities that can be considered "mobility hubs" should, in addition to providing shared travel modes, also fulfill four additional criteria:

1. Providing sustainable transportation options
2. Providing services and offering the possibility to attend nearby amenities
3. Surrounding major transit station
4. Located in high-density areas

Although we agree with the first two criteria, we must stress that the last two criteria do not seem to us to be needed.

Being located near a major transit station is certainly a qualitative consideration. On the one hand, it guarantees more travel options, but, on the other hand, it is also a very limiting factor. By definition, major transit stations are rare. Therefore, linking mobility hubs to them is very restrictive, especially as they mostly offer short- and medium-distance efficient modes (bikes and scooters) and aim to compensate for the effects of the first and last mile. In addition, the definition of a mobility hub requiring a major transit station will be redundant with the definition of a more classical multimodal hub. Being located close to a major transit station or public transport station in general is, however, encouraging for multimodal trips.

Locating mobility hubs only in areas with a high population or employment density is probably more cost-effective than locating them in low-density areas. However, high-density areas have often benefited from successive mobility and service policies, particularly with regard to public transport. The shared modes provided by mobility hubs, in this case, erode more modal split from active modes and public transport than from the car. In addition, replacing journeys usually made on foot or by public transport with journeys made on electric scooters could be far from sustainable.

In addition, low-density areas are often far from city centers and are usually relatively neglected by mobility policies and relegated to the second level. The

inhabitants of these areas, who regularly make long journeys, often have no choice but to use their private car. The solutions proposed to restrict this phenomenon are frequently limited to encouraging carpooling and setting up park-and-ride facilities at the entrance to cities. However, a well-meshed network of mobility hubs, with mobility hubs of different scales and with different services adapted to the location, could offer a real and reliable alternative to private cars.

2.3 Mobility Hub Objectives

When cities are planning mobility hubs, they usually establish a number of key objectives. The authors agree that the most important objective is *"the reduction of car ownership, car use and car use-related emissions"* (Aono, 2019; Claasen, 2020; Interreg NWE, 2019; SANDAG, 2019). Mobility hubs also provide alternative shared modes to private cars to help inhabitants to be mobile without needing a private car (Claasen, 2020; Miramontes et al., 2017). This then brings with it a number of benefits, such as fewer parking spaces needed on the street and a better and more efficient use of the available space (shareNL, 2018; Claasen, 2020) or enhancing equity and inclusivity, especially among seniors, people with disabilities and reduced income groups (SANDAG, 2019). Furthermore, it can lead to more connections between individuals within the same neighborhood on the basis of sharing (Claasen, 2020; ShareNL, 2018).

Aono has focused on seven main objectives:

1. Integration of sustainable transportation options
2. Improving user experience
3. Ensures safety and security
4. Develop a meaningful place-based identity through the introduction of significant and efficient placemaking strategies
5. The capacity to be flexible in introducing technological innovations and increasing resilience
6. Equity by ensuring that the accessibility and the availability of transport options within the various neighborhoods are being considered
7. Ability to forge meaningful partnerships (Aono, 2019)

The South–East Scotland Transport Partnership (SEStran) presented four main groups of objectives, each made up of various objectives. These groups are economy, accessibility, environment, and safety and health. The economic dimension aims not only to enhance connectivity through the inclusion of transport options and additional services but also to incorporate shared mobility to be complementary to the already established transport network (GO SEStran et al., 2020). In regard to the accessibility aspect, the aim is to promote inclusivity, especially for people with mobility impairments. The objective is also to improve accessibility for those with limited transport choices or no access to a car and to support people in their choices of transport by better integration and provision of information. With regard to the

environmental objective, the aim is to primarily support low-carbon choices and reduce emissions. Then, it is about enhancing the use of shared mobility as an appropriate alternative to the use of private cars and making it easier to migrate to more sustainable and active modes of transport and therefore to lower the number of cars, as well as encouraging behavioral change. This is due to an easier and fluent modal shift to more sustainable modes of transport. Finally, the health and safety criteria remain important in two aspects. The first is to guarantee the safety of people who are using the hub. The second is to build a feeling of place and of community and to reassign space in the public realm in place-making and efficient use of land (GO SEStran et al., 2020).

We can therefore deduce that mobility hubs can be considered urban and political tools at the disposal of cities. Its aim is not only to consolidate their environmental policies in terms of mobility but also to achieve broader social, security, and economic objectives. This was confirmed by the expressed intentions stated by the partner cities of the Mobi-Mix Interreg project.

2.4 Mobility Hub Types

Although we can consider "mobility hubs" as places where at least two shared modes are provided, all mobility hubs are not equal. This broad definition extends the acceptance limits of mobility hubs. It offers mobility hubs many possibilities and combinations of roles, sizes, and quality. In this case, it seems legitimate to classify mobility hubs into different categories. Many cities and authors already classify them according to many parameters, such as size, energy used, and target users. *"These distinctions are essential in understanding mobility hubs as a multifaceted concept, where the local context shapes the hub typology. Additionally, these existing typologies can help inform how to classify hubs […] in a way that suits the local transportation network"* (Metrolinx, 2008).

In this regard, based on their urban location and function, we can then distinguish between "regional mobility hubs," "community mobility hubs," and "neighborhood mobility hubs" (RTP, 2022):

- *Regional mobility hubs* serve multiple communities and regional activity centers. They have strong population and employment potential, resulting in substantial travel needs both coming from and going to these hubs. Among the public transport modes that can be considered are high-capacity public transport services (train and/or bus rapid transit), as well as both express and local bus systems. Regional hubs are distinguished according to their size, specification, availability, and type of public transport service, as well as their function.
- *Community mobility hubs* connect to major regional destinations and/or important functional entry points that provide interregional linkages, such as airports, emerging activity centers, universities and colleges, major parks and stadiums, and regional shopping *centers*.

- *Neighborhood mobility hubs* are placed alongside a high-capacity public transport line, which essentially ensures that residents of low-density, single-use areas not covered by the previous definitions will be able to access both high-capacity public transport services and local public transport services (RTP, 2022).

Another method to categorize mobility hubs is possible. The Regional Transportation Plan (RTP) for the Greater Toronto and Hamilton Area created by Metrolinx prefers to distinguish mobility hubs by their role in the transportation network. Metrolinx identified two types of mobility hubs. Anchor hubs and gateway hubs:

- The *anchor hubs* offer the potential to evolve the regional urban configuration and to be convergence nodes in the regional transport system. They incorporate the perimeter of the main public transport station and neighboring areas in the urban growth centers...
- The *Gateway hubs* are major nodes in the regional transportation network that are located at the junction of two or more currently operating or planned regional rapid transit lines and where significant passenger activity is expected (Metrolinx, 2011).

It is also possible to classify mobility hubs according to urban context and the transportation function the area serves. This method is used by Metrolinx. The goal is to make it easy to identify the *"specific needs and characteristics of the area"* (Aono, 2019; Metrolinx, 2011). Regarding the urban context, the mobility hubs are classified as follows: city center, urban transit nodes, emerging urban growth centers, historic town centers, suburban transit nodes, and unique destinations:

- *City Centre*: Such areas are densely populated regional centers with several destinations and therefore generate a large amount of employment and population. As a key destination, a multimodal environment with a high-quality walkable network is already in place. Due to the density of the surroundings, there is limited development land, and most of it will be on fill-in sites.
- *Urban Transit Nodes*: They refer to both major and local centers with moderately high to high density and a mixture of uses.
- *Emerging Urban Growth Centers*: In contrast to city centers and urban transport nodes, these areas have the possibility of development as land becomes more available. Unlike the two previous types of areas, they are typically more car-oriented.
- *Historic Town Centers*: Smaller town centers characterized by low to medium-density urban development. Such areas provide a combination of mixed development and a network of pedestrianized streets.
- *Suburban Transit Nodes*: These areas offer potential for further development because of the growing pressure for mixed-use facilities and the greater land availability. As with the emerging urban growth centers, these areas are usually auto-oriented.
- *Unique Destinations*: These areas, which are similar to the typology of destinations that are identified as Gateways and Anchor Points, both attract and engender

a large volume of activity and travel. For example, universities and airports are considered to be in this category (Aono, 2019).

Considering the transportation functions, the following sorting is used. Entry, Transfer, and Destination

- *Entry*: Those stations that have a considerable proportion of outgoing trips in the morning rush hour. Such areas are generally local public transport terminals, which have parking facilities for commuters' cars as well as bicycles.
- *Transfer*: They are transfer areas along the regional rapid transit system. Transfers can be made between rapid transit lines or other services delivered by several service operators.
- *Destination*: In contrast to the entry areas, the destination areas have a significant proportion of entering trips in the morning peak hours. Such areas are major destination zones with a high density of employment, recreational and institutional functions. Consequently, they are frequently covered by a high number of rapid transit lines (Aono, 2019).

LA Urban Design Studio (2016) employs these three typologies to categorize mobility hubs, which are neighborhood, central, and regional hubs. Such typologies represent the requirements for both the surrounding urban environment and the components of the hub (GO SEStran et al., 2020):

- *Neighborhood hubs* are smaller hubs that are based in low-density districts. These stations offer basic features along the street.
- *Central mobility hubs* are set within the urban context and provide more commodities, such as shared cars and bikes. These services are found all along the intersection and embedded in the district.
- *Regional mobility hubs* are the most significant hubs with regard to their scale and are within the context of densely populated urban areas. As a core area linked to other regional transit providers, these hubs have most of the features that are integrated into the station itself.

The Future Mobility Network is a knowledge and consultancy agency in the Netherlands, which is made up of a team of independent advisors and partners in actual and future mobility. They have been developing a number of different mobility hubs with a particular interest in electric mobility in Amsterdam, Nijmegen, Leuven, and Manchester. These so-called eHubs provide electric mobility and host infrastructure for local residents, commuters, and leisure travelers. Based on their model, there are four main eHubs that vary in size, location, and services provided. Their idea underlying these four categories is that the services of a hub should match the existing transport demand within that location. Therefore, the four eHubs are defined as minimalist, light, medium, and large (Aono, 2019).

- *Minimalistic*: This type of hub refers to a small-scale facility, where there is a minimum of one mode offered. The objective is to take advantage of the already existing infrastructure to have a minimal physical impact on the environment. The goal is then to use the existing infrastructure with minimum physical effect.

This hub includes components that can be easily set up or displaced and is appropriate for demonstrator projects. This type is not considered a mobility hub according to our proposed definition since it possesses a single mode of transport.

- *Light*: Similar to minimalistic eHubs, this category of hubs should be rather simple to implement or expand. However, they do involve at least two different options in regard to modes.
- *Medium*: Such hubs have a variety of different modes and are more permanent due to a mobility infrastructure with high physical impact. Furthermore, more space is required to host the various modes.
- *Large*: This refers to a large-scale hub that also includes multiple modes of transport but on a more extensive scale than medium-category hubs. These hubs tend to be oriented toward commuters and visitors.

Another hybrid topology combining size, location (urban environment), and services provided can also be used. This typology distinguishes large interchanges/city hubs, transport corridor/linking hubs, key destinations (business parks, hospitals, etc.), mini-hubs (or a network of mini-hubs), and market towns/village hubs (CoMoUK et al., 2019; GO SEStran et al., 2020):

- *Large interchanges/city hubs are characterized by the following*:
  (a) High transportation needs – a high volume of travelers to begin or to end a journey or to move from one mode to a different one.
  (b) Opportunity to decrease private car and taxi journeys by improving supply and raising awareness of sustainable modes of transport and by better connectivity of transport.
  (c) There may be limited availability of space, which may require a greater focus on prioritizing more sustainable and more efficient modes of mobility, as well as connections with both first- and last-mile modes of transport.
  (d) This category may also cover touristic destinations in urban areas.
  (e) Because of their large size, significant upgrades of the public area would probably only be achievable through a more ambitious project.
- *Transport corridor/linking hubs*
  (a) The main focus is on services that will connect inhabitants of the neighboring areas to the main transport infrastructure.
  (b) This is an opportunity to offer people more options for first- and last-mile travel.
  (c) Such a hub may also be implemented on Park and Ride (P&R) facilities and may also involve car parking.
- *Key destinations (business parks, hospitals, etc.)*
  (a) High user density.
  (b) It is necessary to ensure commuting links and back-to-basic options.
  (c) Based on areas that regularly and continuously attract a high number of visitors.

(d) *"Key destinations can include the following places: Universities and colleges; Hospitals; Tourist destinations; Business parks and key areas of employment; Industrial estates; Stadiums and event venues; Shopping centers; and Community centers."*

- *Mini-hubs (or a network of mini-hubs)*

(a) Transport services are more limited, and demand is lower.
(b) It is essential to guarantee that there are connections and solutions for returning to the base.
(c) *"Mobility hubs may be developed to meet local needs,* e.g.*, car clubs places to resolve parking issues, bike sharing or secured bike parking for flats without space to park bikes, or demand-responsive transport (DRT) to complete the limited bus network."*
(d) The locations of the mini-hubs can be established in suburban environments or in new housing developments.
(e) The network of mini-hubs has been successfully implemented in Bremen, Germany, but the concept has been expanding gradually, beginning with pilot projects for larger hubs.

- *Market towns/village hubs*

(a) Assess local requirements such as restricted public transport with shared electric bike fleets.
(b) Where space is available, these areas can be used to carry out a much wider spectrum of services, as long as there is a critical mass to guarantee viability.
(c) Some small town/market town hubs may also serve as tourist centers (consider those services where visitors can register with ease, which may subsequently boost the viability of the service on a seasonal basis for rural inhabitants) (GO SEStran et al., 2020).

Through these different classification approaches, Table 1 shows that it seems that the most recurrent and influential element on which the choice of the type of mobility hub is based on size and the urban environment (location). Particular attention is rightly paid to the existing transport infrastructure and offer. In addition to these parameters, it is necessary to point out that the population density and activities (work, leisure, education, health…) have a significant impact on the classification of mobility hubs and defining their size and of the services they provide.

To achieve more sustainable and fairer mobility, and above all in line with the various social, economic, and environmental policies of the city or region, it would be more judicious to proceed with the development of a global but evolving action plan. It will serve as a thoughtful guide with a long-term vision for setting up a network of mobility hubs. It will take into account the different characteristics of the urban environment, the population, the current or planned transport infrastructure, and other parameters if necessary. A single mobility hub, whatever its size, will certainly only have a one-off impact, and it is unlikely that a tangible change in

Table 1 Different classifications of "mobility hub"

Author	Classification	Criteria
RTP (2022)	1. Regional 2. Community 3. Neighborhood mobility hubs	Size, location, density, levels of travel generated, existing public transport…
METROLINX (2011)	1. Anchor 2. Gateway mobility hubs	Role in urban structure, existing transit lines…
METROLINX (2011) Aono (2019)	1. City center 2. Urban transit nodes 3. Emerging urban growth centers 4. Historic town centers 5. Suburban transit nodes 6. Unique destinations	Location, density, urban context, land availability, volume of activity and travel…
Aono (2019)	1. Entry 2. Transfer 3. Destination	Trip direction (outgoing, transit, entering), facilities and features, public transport…
Aono (2019) e-hubs	1. Minimalistic 2. Light 3. Medium 4. Large	Size, features (number of modes), ease to implement, physical impact…
LA Urban Design Studio (2016) GO SEStran et al. (2020)	1. Neighborhood 2. Central 3. Regional	Size, location, density, urban context, features…
GO SEStran et al. (2020)	1. Large interchanges/City hubs 2. Transport corridor/linking hubs 3. Key destinations (business parks, hospitals, etc.) 4. Mini-hubs (or a network of mini-hubs) 5. Market towns/village hubs	Size, location, density, level of travel, urban context

travel habits and modal shares will result at the city or region scale. For example, *"in the UK, Nexus had implemented the local hub idea in a single free-standing location at Ryton, west Gateshead, in 2002, but this proved to have a number of problems with it in practice and was closed in the late 2000s. We believe that this was another factor in the UK failing to embrace the mobility hub concept in the 2000s/2010s"* (mobihub.com, 2022). However, a network of mobility hubs will cover more territory, inhabitants, and passengers. Each of the mobility hubs that make up the network must obviously be adapted to the local context and to the role it plays in the global network. This adaptation could be visible through the size of the mobility hub, the modes, links, and the services it offers. The establishment of such a network could begin with the installation of test mobility hubs, which will be used to better adjust future mobility hubs.

3 Insights to Be Gained

Following the analysis of different European mobility hub projects,[1] we have tried to draw essential recommendations to cities and to make them benefit from the relevant practices: Bergen[2] and Stavanger in Norway,[3] Amsterdam in the Netherlands,[4] Flanders[5] and Leuven in Belgium[6] and Bremen in Germany.[7] This selection of projects is the result of a literature review as well as participation in the e-HUBS academy event of 2021, which allowed us to learn more about each project and to discuss in more detail with different stakeholders. Of course, many other mobility hub projects outside Europe can be mentioned, such as in Hong Kong (Zielinski, 2007), Vienna (GO SEStran et al., 2020), Scotland (Intelligent Transport, 2021), Plymouth City Council (Plymouth, 2022), Manchester (Tague, 2021), Linz (GO SEStran et al., 2020), San Diego (SANDAG, 2022), Toronto (Aono, 2019), Denver (Aono, 2019), Chicago (Aono, 2019), and Vyttila.

Each territory is unique. The space and the environment in the broad sense (natural, urban, political, legal, social, economic) that it offers for each mobility hub is just as specific. Therefore, it seems necessary to recall that to achieve the assigned objectives, each of these facilities must be adapted to its own specific context. An adapted solution should be provided. In this sense, each mobility hub will then be unique (size, vehicles offered, number of vehicles, services). *"There is not a perfect*

[2] Børjesson (2022a, b), ESPON (2022), Ove Kvalbein (2021), Stavnes Hisdal (2021), The Explorer (2020a), SHARE North et al. (2019), and Karbaumer (2018).

[3] ESPON (2022), Henrik Haaland (2022), Stavanger Kommune (2020, 2021a, b, c), Dirks Eskeland (2021), University of Stavanger (2021), e-MOPOLI (2020), The Explorer (2020b), Thorsnæs (2020), and Kleiner (2020).

[4] City of Amsterdam (2020, 2022a, b, c, d, e), City Ratings (2022), ESPON (2022), FUB (2022), eHUBS (2022), N-W Europe (2022), Basta (2021), Gemeente Amsterdam (2021), I amsterdam (2021), Intertraffic (2021), Liao and de Almeida Correia (2021), Copenhagenize Index (2019), Coya (2019), and Gemeente Amsterdam (2019)

[5] Be. Brussels (2022), Flandre (2021, 2022a, b, c, d), Statistics Flanders (2021, 2022a, b), Mpact (2022), SHARE North (2020, 2022), VISITFLANDERS (2022a, b), Belga (2021), CoMoUK (2021b), De Muelenaere (2021), Intertraffic (2021), Roelant (2021), Saelens (2021), Times (2021), Bailey (2020b), eHUBS (2020a), GO SEStran et al. (2020), CoMoUK et al. (2019), and Flanders Environment Agency (2018).

[6] Citypopulation (2022), eHUBS (2020b, 2022), European Commission (2022), ESPON (2022), KU Leuven (2022), Leuven (2030), NuMIDAS (2022), VISITFLANDERS (2022a), Evenepoel (2020, 2021a, b), Schmalholz (2021), Asperges (2020), VisitLeuven (2020), Leuven MindGate (2019), and Ripa (2019).

[7] Bremen (2022a, b, c, d, e, f, g, h), ESPON (2022), Karbaumer (2018, 2020, 2021a, b, c, 2022), Universität Bremen (2022), Transit Forward (2022), Wegweiser Kommune (2022a, b), Austin (2021), Chamberland et al. (2021), CoMoUK (2021a), Intertraffic (2021), Movmi (2021), ARUP (2020), Bailey (2020a), Bremer et al. (2020), GO SEStran et al. (2020), Lanagarth (2020), Actionfigure (2019), Aono (2019), European Commission (2019), IMS (2019), Pais (2019), SHARE North (2018a, b), Gray (2017), Miramontes et al. (2017), Frei Hansestadt Bremen (2014), Fairfax County, Virginia (2013), ITDP (2012), Britaninica (2009), and The Big Move (2008).

solution for mobility hubs, and the approach to planning and implementation of each hub will need to be tailored" (GO SEStran et al., 2020).

A network of strictly identical mobility hubs may not be ideal. This solution, which is typically designed to fit the majority of users, could prove to be effective on a city-wide scale. However, it does not consider the disparities and specificities of each area, which nevertheless are very diverse in the city. It could therefore create or reinforce inequalities. With an increasing concern for equity and to overcome disparities, it would be more appropriate to provide a multiscale solution. This means the development of a network with hierarchical mobility hubs (in terms of importance in the network, size, services offered), each of them adapted and specifically designed to answer the most local specificities.

This does not exclude the possibility of learning from other experiences. In this sense, several authors recommend key points for a successful mobility hub. For example, RTP highlighted six components they find necessary for a successful mobility hub:

1. Multimodal transportation facilities and services
2. Economic activity
3. Intensified/concentrated land uses and urban density
4. Pedestrian facilities and accommodations
5. Embedded technology
6. A strong sense of place (RTP, 2022)

Therefore, to fulfill the above conditions and to go further, the implementation of a mobility hub will necessarily be preceded by a substantial preparation period. This phase of the project follows several phases, in particular the integration within the urban mobility policies of the city.

There are a variety of tools that can be adopted to support the implementation of mobility hubs. They include zoning regulations, a global parking strategy, and the identification of potential development in the catchment area. This involves the creation of a master plan for the mobility hub area. The goal is to help ensure that new transport installations are adapted to the various modes of transport, that they also encourage and support changes in modal split, and that they facilitate living and working possibilities (RTP, 2022).

There are several individual aspects that define and characterize mobility hubs and are well documented and studied in the available literature: optimal location, key characteristics and components, and leadership on their development. Within this framework, S. Aono, from Translink, followed three steps. She first reviewed common phases used for planning mobility hub implementation. Second, she outlined several *"partnerships and responsibilities involved in mobility hub creation, both internally and externally."* This is under the *"four main different topics of planning, services and elements, land development, and funding."* Then, she explored existing strategies *"to understand common approaches used by existing mobility hub studies."* Finally, she identified *"other key considerations and common challenges found in mobility hub implementation"* (Aono, 2019).

In the same vein, Go SEStran states that *"establishing new mobility hubs can take time and requires careful planning – working with multiple partners on a*

complex development may not happen fast or easily" (GO SEStran et al., 2020). Like any other urban infrastructure, the implementation of one or more mobility hubs requires a series of steps such as planning, implementation, management, and maintenance or adjustment. It is worth pointing out here that it would be wise to involve at least future target users and local residents in these various steps. It would allow us to achieve a more consensus-based mobility hub that would better correspond to everyone's expectations. This kind of collective and inclusive planning will also strengthen local democracy and offer more transparency to citizens and users. We will develop here some major phases for the establishment of one or more mobility hubs: before, during, and after the implementation.

The idea of creating mobility hubs can be driven by a regional or national constraint in favor of more sustainable mobility. It may also express a more local desire. This desire arises from the awareness of elected representatives and/or citizens of the challenges of sustainable development and/or from the recognition of local problems. The latter are mainly related to the quality of urban space and mobility (i.e., congestion, noise or air pollution, accidents, etc.). It is important to point out here that convincing politicians is important during all steps of the project, especially where environmental policies are not yet considered a priority. It is also essential to stress that there are usually important negotiations with politicians, different departments of the territory, and other institutions concerned with mobility policy. This requires important and crucial coordination work.

When mobility hubs may appear as a suitable solution. Depending on the definition adopted, mobility hubs could take on different aspects and help to address issues that go beyond mobility (strengthening local life, inclusiveness, equity, etc.). Once the mobility hub option is chosen, the planning stage can begin. For this reason, communication between the city, residents, and users is already highly recommended for a more effective acceptance of potential future mobility hubs.

This first step can be considered a preplanning phase. Its goal is to develop *"a Vision and Framework for mobility hubs"* (GO SEStran et al., 2020).

While there may be political and public will, the implementation of mobility hubs or a network of mobility hubs requires a significant amount of time (1–2 years). The process includes several steps. We have highlighted seven of them and detailed the minimum measures included in each phase. In the following order:[1]

1. *Regulatory checking, feasibility, and integration*

   - Analysis of the regulatory context
   - Consider what funding is already available or can be made available
   - Consider economic aspect

2. *Urban analysis*

   - Analyze the needs and demands
   - Consider the urban environment in detail
   - Ensuring an adequate contribution to the various objectives of the city
   - Define clearer and more precise objectives

3. *Planning the (network of) mobility hubs*

   - Adopt a global vision
   - Prioritize the mobility hubs
   - Identify one or more test areas
   - The exact location of the mobility hubs can be precisely delineated
   - The conception of the graphic documents could be launched

4. *Building the first mobility hubs*

   - Identify the most appropriate stakeholders and partners
   - Use public procurement
   - Respect the principles of competition and foster innovation

5. *Impact measures and adjustment*

   - Define specific indicators
   - Collect a significant amount of data, negotiated in advance with the operators, continuously or regularly
   - Measure indicators
   - Adjustments may be necessary

6. *Generalization and wider implementation*

   - Anticipate problems and be better prepared to deal with them
   - Generalize the mobility hubs and thus create a more complete and more efficient network
   - Choose new locations according to the results of the mobility hub tests

7. *Adaptation and permanent improvement*

   - Maintain the attractiveness
   - Reach increasingly ambitious targets
   - Improvements (of vehicles, services, facilities, etc.) can continuously be considered

3.1 Choice of the Type of Mobility Supply

The choice of mobility modes to be provided in a mobility hub is often a delicate step, as it partly influences the success of the hub in achieving its objectives. It is important to be attentive to the needs and expectations of users and local residents. In some cases, it is necessary to take into consideration the goals of organizations covering large areas and their proper mobility plans (universities, businesses). However, this should not exclude the possibility of innovation. The involvement of associations and private partners is also important. It would be better to first focus on working with existing providers in the region. If there is none, it would be

necessary to consider the need to launch services as a network (as in Bremen and Bergen). Isolated services may have more difficulties and work optimally only in very few cases. The partners, providers of shared modes, based on their experience, can use their own methods to evaluate the potential success (particularly in terms of use and profitability) of one or other modes in any given location.

In all cases, several parameters must be considered. We can cite as examples, without being exhaustive, land use, density, multimodal transportation network, transit density and service level, density of destinations, community demographics, individuals' ability to access transportation options, cost, efficiency, reliability, safety, and enjoyability of the options available, policy and programmatic structure already in place such as parking areas, cost of parking, shared mobility service areas, and similar (Crowther et al., 2020).

3.2 Choice of Partners/Providers, the Mix of Mobility Solutions

Like most urban operations, the implementation of a mobility hub often requires the mobilization of many and diverse participants and stakeholders. *"And the process of implementing mobility hubs is most successful when all responsible authorities for land use planning, urban design, transportation planning, and transportation engineering are all integrated into the design of a corridor"* (O'Berry, 2015). A mixture of public, private, political and associative stakeholders is not rare! Indeed, it is quite the opposite. We recall that the use of a pedagogical approach, a communication strategy, and participative and local democracy is also recommended. In this way, citizens and users are important partners. The several stakeholders involved in the success of a mobility hub should not work separately from each other. They should all be seen as committed partners, mobilizing their resources, knowledge, experience, and know-how for the success of the collective mobility hub project. *"As a concept that involves several public and private services, a key element in mobility hub implementation is partnerships"* (Aono, 2019).

Among the stakeholders involved in mobility hubs, we can highlight, for instance, the following: *"public transport operators, local community groups including residents and businesses, other government agencies and transport authorities, landowners and property developers, not-for-profit organizations including disability and other community groups, technology providers, major employment sites and other key trip generators, assets, infrastructure and utility companies, other established mobility hubs"* (GO SEStran et al., 2020). S. Aono states that *"the type of partnership and the stakeholders involved can vary across four main categories that are involved in mobility hub implementation"*: planning, services and elements, land development, and funding. Based on the work of S. Aono and discussions with European cities and private partners, Table 2 summarizes the roles of different

Table 2 Roles of different stakeholders in mobility hubs, based on the work of S. Aono and discussions with European cities and private partners (Hached, 2021)

Planning	*Municipal government*	Sets objectives for mobility hubs
		Adapt plans, regulations and urban planning documents
		Encourages local democracy by involving users and citizens in the different phases of the project
		Incorporating policies that promote mobility hubs and transit-oriented development in citywide plans
		Guide development around mobility hubs through different planning tools and incentives
		Encourage development while reducing processing times
		Initiate and develop a mobility hub plan
		Selects the operators in the mobility hub through public competitions or call for tenders while ensuring competition
		Regulates and controls the use of vehicles (provided in the mobility hub) in the public space
	Public transit agencies	Increasing service levels and improving transit infrastructure in a way that enhances customer service. This includes accessibility, safety, furniture, service, and information elements,
		Coordinate schedules both among different transit services and with the surrounding employers and institutions so transfers are made easily and match employee schedules
		Help address equity and accessibility by setting a precedent for subsidized fare programs
		Can reserve or create spaces in their station plans to lease for commercial and retail uses
		Can integrate mobility hubs into their stations or surroundings
		May consider mobility hubs as a way of improving access to public transport, especially in terms of the first and last mile
		Continuously assesses the impacts of the mobility hubs and their alignment with the objectives based on, among other things, anonymized data provided by the various partners. (If necessary, recommend improvements.)

(continued)

Table 2 (continued)

Services & Elements	*On-demand ride-share agencies*	Can form partnerships with transit agencies to encourage trips to and from major transit stations to ensure these services complement each other
		Utilize ride-hailing services to reduce parking demand
	Vehicle share services	Can encourage transit use through partnerships with the local government and/or transit agencies
		Integrate shared mobility with existing transit services is through an integrated access card
		Supply, maintain, and manage vehicles
		Opt for the least polluting vehicles
		Ensure that users of their vehicles comply with safety and local regulations
	Technology companies	Can help produce and operate mobile payment or trip planning app
		Obtain valuable travel data such as popular travel destinations and preferred travel modes
		Provide the necessary data for the city
		Promoting a variety of transportation modes
		Incorporate transportation options into their MaaS app
		Design and operate services that integrate payment and information technology for transportation services through their branch
		MaaS app provides information to the user regarding the available transit services near their location, while also acting as a mobile ticketing kiosk
	Wi-Fi providers	Critical to enhance user experience during their travel
		Direct sponsorships from advertising or technology companies
		Charging users for the Wi-Fi service
		Partnering with service providers
	Business Improvement Associations (BIA)	Can ensure transit plazas are utilized by holding public events and festivals that support local artists and community culture
		Help maintain the area as a clean and safe place and contribute to placemaking through initiatives that promote safety and active street uses
		Aligns with the common objectives of mobility hubs, where placemaking and safety are valuable elements for a successful mobility hub
		Potential for further partnerships with BIAs as mobility hubs present several elements that will help flourish local businesses such as shuttle services or on-demand ride-hailing
		There are opportunities to collaborate with BIAs to fund certain hub initiatives

(continued)

Table 2 (continued)

Land Development	*Private developers*	Help promote transit-oriented development by developing mixed-use buildings near mobility hubs
		By utilizing city incentives, developers can contribute to the incorporation of public art, public spaces, cycling or pedestrian amenities in new development
		Help develop buildings that accommodate both private and public sector agencies to achieve diversity in land use and achieve higher density
		Help connect public infrastructure with private buildings
Funding	*Federal/provincial government*	Help cost-share transportation investments and capital projects
		Recognizes the potential for senior levels of government to encourage development around mobility hubs by locating federal or provincial facilities near potential mobility hub locations.
	Sponsors	Help provides funding
		Sponsors provide payments to support the bike share system or components of the bike share program in exchange for branding on the bikes and stations

stakeholders in mobility hubs (Aono, 2019). Note that the stakeholders and roles may vary slightly from one project to another and from one country to another.

It is often the city, as manager of the urban space and project owner, who assumes the responsibility for the creation of mobility hubs. It has the leading role. The city initiates contact with various actors (mobility, energy, etc.) and brings them together around the same project. Although some cities could manage mobility hubs on their territory themselves, the majority outsource the service to private partners and providers.

The selection of private partners is often a delicate step, as the interests of private partners must be reconciled with the various objectives of the city. These include the social objectives of equity, safety, resilience, innovation, competition, etc. Cities frequently use a call for proposals to ensure competition. It also clearly specifies the conditions, obligations, and limits of the various future contractual parties and the objectives of the mobility hubs. The selection is therefore made on the basis of the best responses. Often, at least two (usually three) private partners are selected. The aim is therefore not only to ensure competition and innovation in the long term but also to foster resilience.

Once private partners are selected, this does not usually mean that they have a completely free hand. The city should still have the authority to control, adjust and adapt regulations. Some cities are very sensitive to the reactivity of private partners in solving problems that may arise and adapting to the requirements (temporary parking bans, speed limits in certain areas, provision of data, etc.). Although this concerns shared scooters, we can mention the Norwegian city of Bergen. It has developed internal software that allows communication in a fluid way with private

partners. It allows them to locate each of the shared scooters in their territory and to display information on the identity of the private partner who manages them, the level of their battery charge, the last time they were used, etc. This system makes it possible to detect, for example, a large concentration of scooters in a particular area of the city and a lack of them elsewhere. The city then immediately informs the private partner, who is then required to dispatch the vehicles in a more harmonious manner. The partner then has limited time to meet this request, and if he fails to do so, he may be subject to financial sanctions (or even suspension of the partner's license and therefore a ban from operating). The particularity of the system developed by the city of Bergen is that it is collaborative. City agents and every citizen can report problems with shared scooters (such as parking problems) via a dedicated application. The priority of solving problems by private partners is obviously given first to the city and the city agents. Through this software, the city can specify on the map of the city the zones of traffic/parking of scooters that are allowed or not, set speed limits, open temporary parking places… These modifications are communicated in a fluid way to the private partner, which allows him to integrate and adapt them rapidly.

3.3 Difficulties During Mobility Hub Implementation

As with most actions in the urban space, planners will be confronted with difficulties and opposition when setting up mobility hubs. The difficulties encountered can take several forms (legal, territorial, economical, social, cultural), and the opposition can come from different profiles (inhabitants, local companies, associations, politicians). In this sense, some authors, such as S. Aono, list various difficulties commonly encountered. Among the possible challenges, we can mention, in a non-exhaustive way, the following examples: parking demand, land ownership, misalignment between transit and development, and equity considerations (cost of services, language and cultural barriers, accessibility) (Aono, 2019). To face these challenges, involving the different protagonists from the beginning of the project, taking into account their opinions and concerns, using pedagogy, diplomacy, and seeking consensus can, generally, be useful to solve many of these problems and improve the overall acceptability of the project.

In addition, when designing mobility hubs and selecting private mobility providers, cities focus on these social issues. In this case, engagement activity through local charities that already have strong community links can be an important tool (CoMoUK, 2021c). Some cities negotiate and/or condition the selection of private partners by an effective commitment to provide an equivalent service in all areas of the city. Private partners are often reluctant to consider the economic profitability of mobility hubs and the safety of their vehicles. However, some cities take care to minimize these risks by offering subsidies and more privileged locations.

4 Ways Forward: How Can Cities Advance

Most modern cities, especially large metropolises, offer undeniable advantages on the one hand but generate negative externalities on the other. The latter actually raises various and serious problems both on the environment (air pollution, water pollution, noise pollution, lighting) and on their inhabitants (deterioration of health, insomnia, stress, fatigue, security). Because of their urban forms, zoning (mainly induced by the Industrial Revolution and postwar urban planning), and the distribution of resources (work, shops, services, etc.), cities separate the places of demand and the places of supply. This inevitably generates greater or lesser distances to travel and thus greater or lesser mobility flows.

In addition to these negative effects of the urban planning of recent decades on humans and the environment, large cities create strong centralities and such a regional weight that it blurs neighboring towns and villages, gradually emptying them of their shops, services, etc., reducing their ability to retain or attract jobs, and thus emptying them of their inhabitants. This cycle of spatial specialization will contribute, on the one hand, to the sprawl of large cities and the accentuation of their negative externalities and the gradual decline of neighboring cities. In one way or another, the need to travel greater distances may increase regionally to reach the major city and within the major city itself.

The city (or urban space) is thus a very complex spatial object where different issues coexist (social, economic, environmental). The urban planner should always keep in mind a very broad and global vision when conducting any action on the territory. He should surround himself with a large panel of specialists and listen to citizens and various stakeholders to make the most balanced decisions possible. This is far from an easy task. Every intervention on the territory, whatever form it takes, can have positive effects in one sector and negative effects on the other. It is in this context that T. Saint Gérand's concept of spatial ergonomics takes on its full usefulness (Saint-Gérand, 2002).

To date, few cities can be proud to offer a sufficiently solid infrastructure capable of ensuring sustainable, peaceful, and equitable mobility. In this context, we can mention the detailed analysis of the ergonomics of access to resources in active modes in the Eurométropole de Strasbourg, which highlighted various disparities and their nature (Hached, 2019; Hached & Propeck-Zimmermann, 2020). Mobility hubs can therefore play an important role at the city and/or regional level that is not limited to more sustainable mobility. The objectives in implementing mobility hubs should go beyond mobility issues to look more broadly at the problems of the city and thus be part of a more global solution. To be part of this more integrative solution, different parameters should be taken into account when designing and implementing mobility hubs.

Following discussions with experts from the partner cities of the Mobi-Mix project, as nonexhaustive examples, we can consider some key parameters:[1]

- *Spatial distribution* that allows everyone to move throughout the whole studied territory without the need to own a car (a hierarchically structured network of mobility hubs) (Claasen, 2020; GO SEStran et al., 2020; Aono, 2019; Metrolinx, 2011; Waldron, 2007).
- *Multifunctionality*, which, in addition to providing mobility services, makes it possible to ensure additional services that are not available on-site. The aim is also to promote neighborhood life and activity while meeting local needs (GO SEStran et al., 2020; Aono, 2019; Queirós & González, 2019; SmartRail World, 2017; LA Urban Design Studio, 2016; 218 Consultants et al., 2015; O'Berry, 2015; Arup, 2014; Vahle, 2014; Midgley, 2009; Yeates & Jones, 1998).
- *Inclusiveness* in its broadest sense, for all users on an equitable basis regardless of age, physical ability, income… (GO SEStran et al., 2020; Aono, 2019; Metrolinx, 2011).
- *Security and safety* for the users themselves as well as third parties, whether physically, morally, or more virtually (such as personal data) (GO SEStran et al., 2020; Aono, 2019; LA Urban Design Studio, 2016; Metrolinx, 2011).
- *Comfort and ease of use* to make the use of mobility hub services as easy and comfortable as using one's own vehicle or even easier (RTP, 2022; GO SEStran et al., 2020; Aono, 2019; LA Urban Design Studio, 2016; Metrolinx, 2011; Waldron, 2007).
- *Reliability and resilience* by providing a stable and regular quality of service, in particular by supplying a sufficient number of vehicles so that the user can be sure of their availability when they need them. The aim is also to have a service that is sufficiently reliable and resilient (in financial and qualitative ways) to be part of the mobility policies of cities (ASQ, 2022; Raza, 2020; Aono, 2019; Géoconfluences, 2015; UNDRR, 2007).
- *Adaptation to technology habits and needs*, either at the level of vehicles or services (reservation, payment...) while allowing backward compatibility (GO SEStran et al., 2020; Aono, 2019).
- *Communication*, targeted and adapted to each interlocutor whoever they are, politician, user, opposition, neighbor, partner... The aim is to use pedagogical methods and to understand the needs, the concerns, or the problems and thus to find the essential compromises (Karbaumer, 2021c; Karbaumer & Metz, 2020).

> All of this should occur within an urban setting designed for the way people and families would like to live, work and enjoy themselves. At the same time, the mobility hub is only one part of the equation. Because the transit system is the key connector to and between mobility hubs, the mix of land uses in the surrounding area is crucial to making it a destination conducive to transit choice. In other words, when developing the mobility hub concept […], we need a fundamental shift in thinking – away from land use patterns designed primarily for cars. That is why […] [the concept of] mobility hub is so important. They are the connection points in a transit-oriented metropolis – a concept very different from the car-based cities and towns we see today (CII – Kerala et al., 2022).

5 Further Research

Within the framework of the Mobi-Mix project, two European cities have chosen to set up two mobility hub demonstrators. These two cities are Norfolk and Valenciennes.

The shared mobility impact assessment in general and mobility hub impact assessment, in particular, is currently underway in the Mobi-Mix project. A sequential methodology has been developed to assess the impact of different shared mobility solutions deployed by Mobi-Mix partner cities. It allows to provide information at each phase of the project, adapting to the available data. The impact analysis is therefore carried out through three different approaches (exploratory, ex-ante, and ex-post evaluation). Surveys are conducted in each phase. The results and feedback of each phase make it possible to refine the estimates made in the previous phase and to minimize bias. In this way, they contribute to improving the precision of the method as a whole.

No empirical measurement of carbon emission changes has been included in this assessment, and all impacts are a result of measuring behavioral change. Converting these behavioral changes (changes in vehicle-km and passenger-km) into CO_2 savings will be achieved by applying standard emission factors per transport mode. Furthermore, it is important to highlight that the methodological approach is focused on the assessment of short-term impacts given the time frame of the proposed Mobi-Mix pilot projects.

The first estimations of the impacts of the mobility hub predict a positive impact on CO_2 reduction in the two partner cities, Norfolk and Valenciennes. The assessment is based mainly on estimates of change reported in mobility behavior surveys and on similar cities' experiences. The amount of CO_2 emission reduction depends on several parameters, such as the new shared modes being adopted (bicycle, scooter, car), the energy they use (fossil, electric, muscle), and the modes being abandoned (car, public transport, bicycle, walking…). Therefore, by sharing 50 bikes, 10 scooters, and 2 cars, Norfolk would replace 81,437 km done by private cars per year with less polluting vehicles and save approximately 23 tons per year in the short term. In the long term, following an estimated trend of behavioral change, the reduction in driving distances is estimated to reach 359,544 private car kilometers per year. Fifty-seven tons of CO_2 emissions per year, could be saved. With 100 shared bikes and 20 shared scooters, Valenciennes could lower CO_2 emissions from private cars by 67 tons per year in the short term and save 215,987 km done by private cars per year.

6 Conclusion

Within the framework of the Mobi-Mix project, we have taken a close look at the mobility hub concept. To do so, we carried out a literature review, attended specialized presentations, and discussed with experts from several cities. Two partner

cities, Norfolk and Valenciennes, have chosen to implement mobility hub demonstrators and are studying their impact on CO_2 reduction and the adoption of more sustainable modes of transport.

Finally, what is a mobility hub? To the best of our knowledge, no author claims authorship of the term. The concept seems to have emerged from the reality of the field. However, various definitions exist. Some are more restrictive than others. They depend strongly on the project, the city, or the status of the person who defines it. This multitude of definitions could lead to confusion with other clear and well-established terms, such as multimodal hub. For this reason, we advocate for a discussion between stakeholders to find consensus for a definition that leaves a margin of maneuvers to the planners and offers flexibility of implementation. As the term "hub" expresses a centrality and thus a plurality of objects, we propose to define the mobility hub as a "place that regroups shared mobility modes." Although the presence of more than one shared mode suffices to define a mobility hub, it is recommended to integrate or to be connected to public transport. Other modes and facilities can also be integrated.

Thanks to its flexibility, the mobility hub concept can become a facility that allows the city/region to meet several objectives simultaneously. The primary objective is to enable more sustainable and less polluting mobility while reducing the use of private cars (especially private internal combustion engine vehicles). Depending on the location and design of the mobility hubs, other objectives that are part of the city/region's policy may be reflected in them. In particular, inclusiveness (for all, without depending on abilities, ages, genders…), equity (spatial and income equity…), safety (for users and others, data safety), etc. These parameters should be monitored to help make continuous adjustments to the mobility hub. A method of impact monitoring (focusing on CO_2 and taking into account the aforementioned parameters) is being developed within the framework of the Mobi-Mix project.

Each mobility hub is unique, but many of them share similar characteristics that allow them to be classified. Several typologies exist. However, most classifications consider the users for whom mobility hubs are intended (individuals, professionals, tourists, etc.), their temporality (temporary or permanent), their location (city center, suburban areas, etc.), their functions in the mobility network, their size and the vehicles they provide. The size of a mobility hub is often correlated with the surrounding density and the number of users. The type of vehicles provided often depends, among other factors, on the location of the mobility hub and the length of the expected trips. We believe that the classification of mobility hubs is relevant in the context of a network of mobility hubs and in contrasting mobility hubs from different cities or countries. Therefore, each city/region could adopt its own classification according to local specificities or objectives. However, the target users, the temporality, the geographical location, the size, and the type/number of vehicles and services offered all remain important parameters for defining a typology.

Although the mobility hub concept is flexible, the implementation of a mobility hub adapted to the needs and objectives can sometimes be complicated, as it requires several steps and may face difficulties at each step. Among these steps, we can mention foremost the emergence of the idea of creating a mobility hub and convincing

both citizens and politicians of its usefulness. Then, we can mention the feasibility study and the verification of the correspondence to local regulations (if not, it will be necessary to plan the modification of these regulations). An analysis of the urban area enables a mobility hub network to be planned and adapted to meet the particular objectives of each city/region. The creation of first mobility hubs that serve as demonstrators may be necessary. Depending on the learning from these demonstrators, adjustments can be made and considered for future mobility hubs. Once the network of mobility hubs has been built, the process is not finished, and a process of continuous adjustments and modifications is recommended. The main difficulties that may arise are generally linked to the opposition of local residents, the choice of locations for mobility hubs, the choice of private partners if there are any (some cities can manage mobility hubs themselves, but the majority rely on private partners), and the modes of mobility to be provided.

Despite the possible challenges in implementing mobility hubs, the whole process could be worthwhile to allow cities/regions to meet several objectives at the same time. To support cities in this approach, we have proposed in this document several recommendations and guidelines for implementing better mobility hubs. First, it is necessary to create (or establish) features within the urban environment that support the implementation and functioning of mobility hubs (pedestrian and bicycle facilities, reduced traffic speeds, strict parking policies, pleasant urban environments, etc.). Second, it is important to consider mobility hubs as a network, where each node is adapted both to its function in the network and to local parameters. A mobility hub can be functional and provide additional services to meet the needs of local residents or users (e.g., cafés, snack bars, pick-ups of deliveries). The mobility hub should also be inclusive, helping everyone to meet their own mobility needs, regardless of their physical condition, age, or income. Safety and security within the mobility hub itself, and when using the vehicles it provides, are also important. In addition, to compete with private cars and be more attractive, comfort and ease of use are key considerations. When creating mobility hubs, cities/regions should ensure the reliability and resilience of the partners with whom they collaborate, as well as the flexibility of the infrastructure and its ease of adaptation to future technologies and compatibility with older technologies. Finally, the involvement of all stakeholders and communication is key when implementing mobility hubs. They should support all steps and be adapted to different stakeholders.

Within the framework of the Mobi-Mix project, two partner cities, Norfolk and Valenciennes, have been implementing mobility hubs. An evaluation method has been developed to monitor cities' objectives of reducing CO_2 and car use. Several indicators have been identified. A three-stage estimation and evolutionary method punctuated by surveys has been developed. It is based on the experiences of the other cities and takes into account the possible variations due to local contexts. Although there are still a number of reserves to be highlighted at this stage, the impact estimates of the mobility hub demonstrators in Norfolk and Valenciennes tend to confirm that it is possible to achieve the targeted objectives, in particular the reduction of CO_2, and even to go beyond them. In this regard, mobility hubs could

be an important lever in future mobility policies by helping to reach more sustainable mobility.

Finally, the mobility hub concept seems to be an interesting, complex, and challenging topic worth investigating. The analysis of the impacts of this type of infrastructure is still to be fully achieved. It requires the collection of a multitude of data and their combination in a judicious way to establish sound measurements. It should also be remembered that mobility hubs are part of a more global context, which is relevant to consider. The question could also be asked as to whether this type of infrastructure could meet the needs of users at the lowest cost, harm, and risk. In this case, we are referring in particular to the research of T. Saint-Gérand on spatial ergonomics (Saint-Gérand, 2002) and that of W. Hached on the ergonomics of access (Hached, 2019).

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