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Hubs for Freight and Passengers? Exploring the suitability of adding logistics functions to mobility hubs

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ABSTRACT

In the coming years, cities will have to deal with transportation challenges in terms of accessibility and sustainability. Passenger and freight transport is expected to increase, while the transport sector is a major contributor to greenhouse gas emissions and congestion in cities. Although historically passenger transport and freight transport were intertwined, the systems have developed separately from each other over the past century. This research focuses on finding integrated *logistics flows* and especially on finding the conditions under which these can be added to different types of mobility hubs. By collecting and structuring information from literature and expert interviews using a requirement analysis, possible logistics additions and associated conditions are mapped into frameworks. The results show that small consumer goods flows have the most potential to be added to mobility hubs. In addition, the frameworks show that they can be used as a first step in the analysis to investigate which logistics functions and under which conditions these could have potential on a mobility hub. Further research can, preferably quantitatively, examine whether the suggested logistics additions from the framework are applicable to more detailed areas.

Keywords: Integrated hubs, Passenger transport, Urban Freight Transport, Hub Frameworks.

INTRODUCTION

Following the Paris Climate Agreement in 2015, the nationally determined contribution (NDC) of the Netherland states a goal of reducing greenhouse gas emissions in the Netherlands by 49% compared to 1990 (1). According to the World Economic Forum (2) the number of delivery vehicles in cities is set to grow by 36% in the 100 largest cities in the world, and with that, emissions are estimated to grow by 32% and congestion by 20%. In addition, UNESCO (3) states that about 55% of the world's population lives in urban areas. This proportion is expected to increase to 75% by 2050 (3). In the Netherlands the Mobiliteitsalliantie (4) expects an increase in passenger transport by 13 to 20% in 2030 and freight transport by 4 to 19%.

Policymakers, called upon to address negative transport externalities, face spatial challenges due to the coexistence of passenger mobility and urban freight transport as two different systems. A promising solution direction, which in aviation has been familiar with for quite some time, is the integration of these two systems (5). Moreover, it is ironic that the idea of integration is not new either, since passenger and freight transport were already integrated centuries ago. In the nineteenth century, passenger and freight transport were integrated with, for example, trams, trains and buses. An illustrative example in the Netherlands is the tram line that connected Deventer with Borculo transported goods to and from factories and dropped off tourists at their hotels and guest houses at stops or stations along the route (6).

Despite a history in which both transport systems have already been combined and the emphasis in the (limited) existing studies on how promising the combination can be favorable to a liveable city, there appears to be little scientific literature based on research on combining these two transport systems, an exception forms the air transport industry. The studies found over land are about adding freight to existing public transport systems (7, 8) or innovations in crowd-shipping (9). In theory, these innovations seem possible, however, in practice, they prove difficult to implement due to the complexity, resistance and juridical issues to these initiatives.

In addition, mobility hubs, i.e., an emerging term referring to nodes with smart and new mobility (electric, shared mobility), are mentioned as an opportunity for bringing together sustainable modes of transport and changing unsustainable mobility behavior (10-12). Witte, Gonzalez, and Rongen (13) show in the exploration of the concept of mobility hubs that freight also can be considered as a possible function added to the mobility hub.

To the best of the authors' knowledge, no study so far has been found examining the addition of freight or logistics to mobility hubs. Neither research has been found that investigates under which conditions the above-mentioned innovations regarding a combination between passenger transport and freight transport can be possible. Also, no study has been found that discusses the different innovations in one study. This research tries to fill the gap by investigating whether and under which conditions the various innovations are possible at a mobility hub. Therefore, this research aims to answer the research question:

'*Which logistics flows and logistics innovations can be added to different types of mobility hubs under which conditions?*'

To answer the research question the research methodology is explained in the next section. The section thereafter discusses the findings from the literature and the findings retrieved from the expert interviews. Then the typology of frameworks developed is explained. The paper ends with the conclusions and recommendations.

RESEARCH METHODOLOGY

The research consists of several steps. In the first exploratory phase, via a literature review information is gathered about mobility hubs, logistics flows and innovations that enable a combination of passenger and freight transport. After this, stakeholder insights from theory and practice are obtained based on stakeholder analysis and interviews with experts. In the design phase, the information obtained from the exploration phase is analyzed based on a requirement analysis and presented in frameworks. Finally, the frameworks are validated based on a case study. Figure 1 shows the steps and the relationship between the steps and research questions.

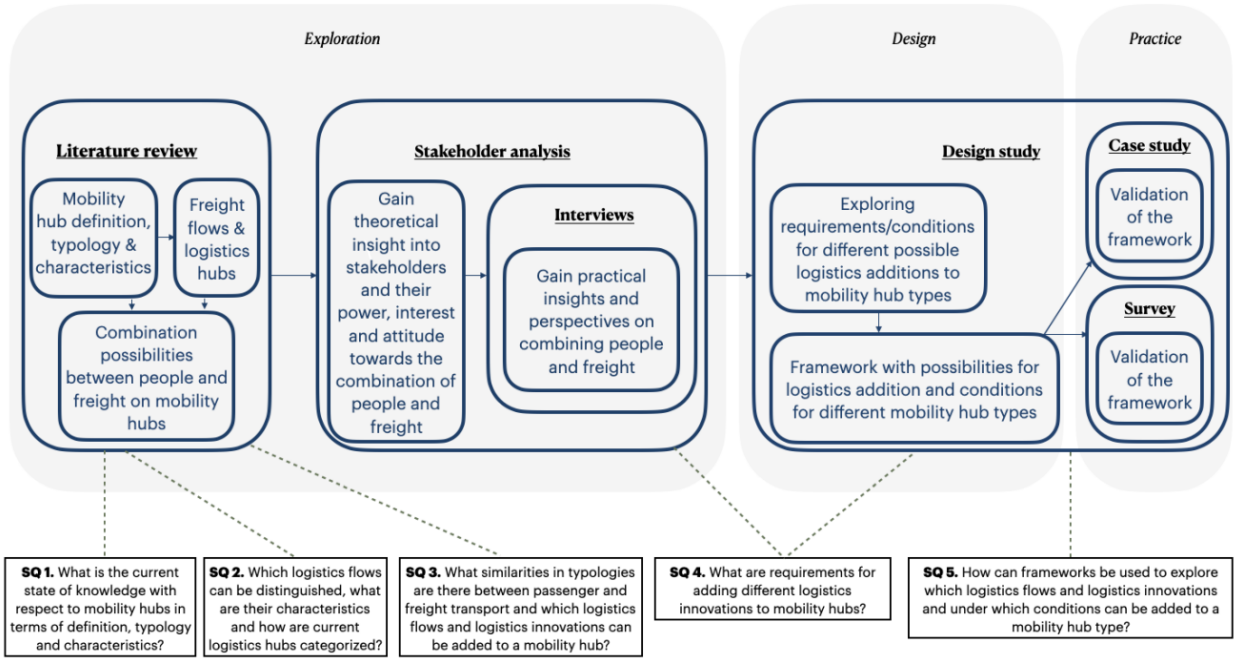

FIGURE 1 Research methodology approach (14)

Literature review

The aim of the literature review is to provide the reader with an up-to-date overview of the literature in a specific area (15). Various online databases can be consulted for relevant articles on hub characteristics and combinations of passenger and freight transport. According to Van Wee and Banister (15), a literature review can add value in several ways, such as providing empirical insights in which the state of knowledge, gaps in literature, or weaknesses of methodologies are presented. In this exploratory research, a literature review is conducted to define, characterize and categorize mobility hubs and to categorize freight flows and logistics hubs. In addition, possibilities are being explored for a combination of passenger transport and freight transport at a mobility hub.

Stakeholder analysis

Passenger transport systems have different stakeholders in both the public and private fields with different interests. The private side of city logistics is especially difficult because of the diversity of transported goods, the heterogeneity of the transportation means, and the involvement of multiple stakeholders with usually different goals and priorities (16). Therefore, a stakeholder analysis forms an essential part of the research (16, 17). A stakeholder analysis was used to generate knowledge about the relevant actors to gain insight into their behavior, interests, and resources they have to influence the decision-making processes. In addition, the stakeholder analysis has provided insight into which experts are interviewed.

Interviews

According to Holloway and Galvin (18), interviews are the most commonly used method of data collection. Due to the limited availability of information on the topic of logistics functions at mobility hubs, semi-structured interviews are held in this research. The interviews were held with 14 experts with the aim of collecting as much information as possible about combinations of passenger and freight transport. Due to COVID-19, the interviews were conducted online and lasted approximately 45 minutes each. The

interviews were recorded and transcribed verbatim. For all interviews transcription approval is requested from the interviewees and changes are made if necessary.

Design study

In the design phase, a systematic approach was used to arrive at requirements for various innovations and ultimately frameworks that can be used to explore which logistics functions can be added to mobility hubs. For this, a requirement analysis and design technique were performed. The overarching principle of Systems Engineering (19), an academic framework for product design, is followed in these techniques. Systems Engineering can be defined as a management technology that helps structure a problem through formulation, analysis and interpretation.

Case study

A case study is a form of qualitative research that allows in-depth, multi-faceted explorations of complex issues in their real-life settings (20). The purpose of the case study within this research is to validate the presented frameworks. It is not the intention to generalize the results of this case study to other cases, although this may be possible if other cases share the same characteristics. It was decided to look at a large neighborhood hub (Utrecht Merwedekanaalzone) and a hub on the outskirts of the city (Utrecht Transferium Westraven) in the Netherlands (14). These two hubs were chosen because they differ in size and therefore in the type of mobility hub. In addition, the Merwedekanaalzone is a much-discussed and attractive new way of area development that, according to experts, may serve as a blueprint for neighborhoods in other cities. The Transferium Westraven was chosen because it is the largest P+R location near Utrecht and because its location is strategic and falls outside the planned zero-emission zone. Merwedekanaalzone is an area with hubs that to a large extent still has to be constructed. Transferium Westraven is an existing transferium. The reason that both an existing and a hub under construction were chosen is that they can be investigated in which way the differences influence the results and whether there are specific limitations in the use of the framework.

Survey

Finally, surveys were conducted with experts to validate the frameworks. Experts have provided insights into the usability of the frameworks and have indicated points for improvement for the frameworks.

FINDINGS

This section presents the findings of the research. First, the findings of the literature review regarding mobility hubs, logistics flows, and logistics innovations are presented. This is followed by findings from the interviews conducted with experts from different backgrounds to explore the perspectives of combining the two ecosystems.

Literature findings

This section first presents the results for mobility hubs. The literature review has shown that it is difficult to give a general definition of a mobility hub and that a slightly different definition can be given, depending on the type of mobility hub and associated characteristics. Based on the definitions found (4, 10, 11, 13, 20-28), the following comprehensive definition for mobility hubs has been formed:

> 'Multimodal transport hubs that facilitate intermodal transfers by offering different modes of transport nearby. This can be private, public, or shared transport. They can fulfill different functions in spatial development. In addition tothe mobility function, the hub can offer retail, parking, and other facilities such as logistics. Finally, it is important that the services on such a hub are integrated via, for example, an app.'

In this research, based on the different distinctions found in literature (4, 10, 11, 13, 20-28), three

types of hubs can be distinguished, each with their own characteristics:

- A **neighborhood hub** is seen as a small hub that is mainly aimed at eliminating the private car from the first and last mile of a journey by, for example, offering shared modes of transport;
- A **city hub** makes traveling in the city possible by offering different modes of transport, such as bus, tram, metro, train, but also shared modalities. The aim is to increase the accessibility of the city center, but there is little space for private cars. Due to the large number of passengers at this hub, especially transfer passengers, other facilities are offered at the hub;
- A **city outskirts hub** is regarded as a hub on the outskirts of the city with the aim of attracting private passenger cars with the city center as their final destination by offering attractive parking facilities and public or shared transport options to travel further into the city. This hub is also known as a P+R location.

Figure 2 visualizes the different hub types and their characteristics distinguished in this research.

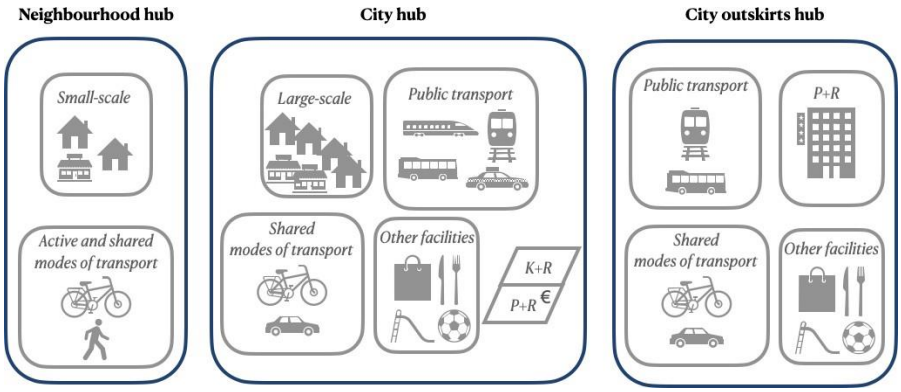

FIGURE 2 Similarities and Differences between all the Perspectives (14)

With regard to the logistic flows, little literature has been found that classifies the flows. Topsector Logistiek (29) distinguishes various flows, of which the following four logistic flows have been included in this study because they seem to have the most potential in a mobility hub. Table 1 shows the characteristics per logistics flow.

TABLE 1 Overview of Urban Freight Flows and Characteristics (14, 29)

Logistics flow	Type of deliveries	Characteristics
Construction	• Point-to-point • Services	• Construction site location is unique and temporary • Often heavy transport • Irregularly goods delivery, depending on the construction phase • Building materials delivered at the right time and quantity (Just-in-Time) • Fragmented character • Often urgent deliveries
Facilities	• (Ir)regular • Services	• Transport of goods, persons, the provision of services, and combinations • Transport of people without goods (services) with their own van • Covers a large part of the total number of trips with a van • Ad-hoc trips • Large group that does not provide goods or services (security companies) • Many different type of actors • Origin and home base often at service providers' home
Catering	• (Ir)regular • Various small • Point-to-point	• Variety of suppliers, delivery frequencies (seasonal demand) and used vehicles in the city • Specialists often drive inefficiently in the city for a few deliveries • Specialists are located throughout the Netherlands, which complicates electrification • Various small deliveries are on-demand where service level is most important • Hubs can be relevant for (ir)regular deliveries
Parcels	• Irregular	• Groceries: high stop time, delivered from hubs in or near city • Business to Consumer: stop density high, stop time low, collection points often used • Business to Business: stop time longer than to consumers, little delivery to collection points, deliveries during company opening hours • Failed deliveries and returns are challenges for consumer deliveries • Parcel carriers are generally efficient, but CO2 savings possible with collection points

In the last part of the literature review, combinations of passenger transport and freight transport were investigated. Four logistics innovations have shown potential at mobility hubs:

- Parcel lockers: these are lockable boxes where people can drop off or pick up their parcels 24 hours a day.

- Crowd shipping: the idea is that people (the crowd) can take packages along their route to drop them off at a certain point.
- Cargo hitching: with cargo hitching unused capacity in public transport is used for freight.
- Sharing public space: this is equivalent to multifunctional use of spaces or being an integrated hub where passenger mobility and logistics can take place side by side. The hub can be used for both passenger transport and logistics, for example as a transfer point where freight is transferred from conventional trucks into smaller sustainable ZE vehicles.

Interviews

The experts are generally enthusiastic about the addition of consumer packages and see this flow as a promising addition to mobility hubs due to the high interaction with people. The most frequently mentioned associated innovation is therefore the parcel locker with the greatest advantage that it is available 24 hours a day for parcel pick up and drop off. For large and heavy logistics flows, the experts believe that the desired locations for logistics hubs often differ from those for passenger hubs. For example, they see logistics activities more for locations outside the cities. The locations/stations where passengers come together are generally expensive as they are strategically located in the city. This means that at these locations you only want to add logistics with a high value to the station.

More or less the same logistics innovations are mentioned as those obtained from the literature. An addition mentioned by one expert is the use of (temporary) parcel lockers at local markets so that employees who work during the day can collect their fresh products from the market after working hours.

In addition, various experts suggested the possibility of transshipment of goods during the night, because in busy places, varying functions over time can offer opportunities. Furthermore, the same concerns have been expressed about the concept of crowd-shipping, i.e., in particular its legal and fiscal feasibility and reliability. Finally, the experts were particularly enthusiastic about the concept of sharing spaces and the Merwedekanaalzone is mentioned by almost all experts as a possible example for future neighborhoods.

The experts mentioned the same characteristics for logistic flows as identified in the literature. A new insight from the interviews relates to the facility/service flow. For periodic flows to large organizations, for example, they describe the possibility of having the goods in storage on the outskirts of the city, so that they can be delivered bundled at desired times. Another interesting insight regarding the service workers is the possibility of having service workers park at a hub to make the last mile to the customer by public transport. The latter point with regard to bundling employees is also mentioned for construction employees, as they sometimes also have to go to a construction site without goods. Table 2 provides an overview of the interviewed persons.

TABLE 2. List of interviewed participants (14)

Expert	Role	Function	Topic Involvement
Ministry of Infrastructure	The ministry is part of the national government and focuses on infrastructure-related topics	Project manager Logistics & Smart Mobility	Searching for opportunities that make the sector more sustainable
Municipality Nijmegen	The municipality is concerned with matters of importance to its residents. Municipalities have signed the climate agreement and are trying to influence people's behavioral choices by using local policy	Strategic policy advisor spatial development and mobility	Involved in both passenger mobility in the region and logistics in the region and municipality
Municipality Utrecht		Strategic project manager Merwede kanaalzone	Involved in the Merwede hub-project for many years

Municipality Amsterdam		Project leader logistics hubs	Focuses on logistics hubs
Transport District Amsterdam	A partnership of 15 municipalities in the Amsterdam region	Network Director Logistics	Focuses on sustainability within logistics
City Hub	City Hub offers private and business storage space on the outskirts of the city and arranges zero emission transport	Regional manager Randstad area	Responsible for the City Hub office in Utrecht
Izipack	Izipack arranges sustainable transport of packages	Founder & COO	Knowledge of the parcel flow and innovations within logistics
Hely	Shared mobility provider founded by PON & NS	Business developer	Involved in shared mobility and development of hubs
Breytner	Zero-emission transport company (100% electric distribution trucks)	Owner	Involved in Logisticshub010 in Rotterdam, a hub for zero-emission goods entering the city center of Rotterdam
Sweco	Consultancy and engineering firm	Sustainable mobility advisor/ Postdoctoral researcher RUG	Consultant role and researcher in the field of mobility and logistics
Transport & Logistics Netherlands	Represent the interests of road transport companies and logistics service providers at local, regional, national, and European levels	Policy advisor and sub-market secretary	Focuses on freight hubs from the city logistics policy area
TNO	TNO is an independent research organization that creates innovations	Senior Scientist Transport and Mobility	Researcher in the field of smart cities and logistics
Amsterdam University of Applied Sciences	An educational institution in Amsterdam	Professor City Logistics	Researcher in the field of city logistics

FRAMEWORKS

Using the information obtained from the literature and interviews, frameworks have been created. The frameworks are validated twice. The application of the framework to the case studies resulted in plausible logistical additions, as some of the results came quite close to the plans actually formulated in the urban development plan of the Merwedekanaalzone, a new residential area in the city of Utrecht, the Netherlands, quite close to the center.

The second validation step was done by experts, i.e., a survey was conducted with 9 experts. Critical comments were made about the color mapping of the framework. These comments have been partly adapted in the initial frameworks based on the first author's own judgement. The final frameworks are discussed in the following text. For each mobility hub type, the framework shows which innovations and which freight flows have potential. Three colors are used for this. The green color indicates that the innovation can be easily added to the mobility hub, the orange color indicates that it can be added under certain conditions and finally, the red color means that it will be difficult to add the innovation to the mobility hub.

Neighborhood hub framework

Out of the freight flows, (consumer) parcels seem to be the most likely addition, and construction or catering the least likely to happen. Parcels are light in weight and easy to transport for shared mobility users. Construction and catering flows are characterized as heavy and large flows, while in neighborhoods no heavy transport takes place. Furthermore, it is not possible to bundle (facility) service people because there is no space for this on this hub. Table 3 shows the neighborhood hub framework.

TABLE 3 Neighborhood Hub Framework (14)

Neighbourhood hub	**Freight flow**				
Innovation	Consumer parcels		Construction	Catering	Facilities
	Parcels	*Groceries*			
Parcel lockers					
Crowdshipping					
Cargo hitching					
Sharing public space					

Parcel lockers can easily be placed at neighborhood hubs. In this way, it can serve as a neighborhood point that is open 24 hours a day. Consumer parcels can be added. Groceries may be added if refrigeration technology for parcel lockers is available, hence the orange color for the catering/food flow. Heavy construction flows can never fit in a parcel locker, but light materials do have a lot of potentials. For facilities, the materials also have the potential to be bundled in a parcel locker.

The literature study has shown that crowd shipping is difficult for flows other than consumer parcels (30, 31), because there is a crowd that has to take parcels (transportable dimensions) along the route, so the goods must not be heavy and must not be perishable goods because food safety cannot be guaranteed. Only parcels or light materials have potential. However, what should be considered is that crowd shipping will only minimize traffic movements and maximize environmental benefits if it is picked up by existing trips, not new trips. Relatively short distances are covered in a neighborhood, which reduces the chance that a traveler will pass a parcel locker or address where the package must be delivered. It is, therefore, necessary to keep a close perspective on whether special trips are made for parcel deliveries (hence a yellow color instead of green color).

Since there is no public transport at this hub, cargo hitching is not a possible innovation to add. Finally, as the neighborhood hub has little space, the innovation of sharing public space is not possible.

City hub framework

Out of the freight flows, (consumer) parcels again appear to be the most promising. Construction is now possible under conditions because a city hub offers more space for the transshipment of large goods. Moreover, cargo hitching is an option because public transport is available. Table 4 shows the city hub framework.

TABLE 4 City Hub Framework (14)

City hub	**Freight flow**				
Innovation	Consumer parcels		Construction	Catering	Facilities
	Parcels	*Groceries*			
Parcel lockers					
Crowdshipping					
Cargo hitching					
Sharing public space					

As with neighborhood hubs, parcel lockers can easily be added to city hubs. Consumer parcels and light materials have the most potential. Bundling groceries in parcel lockers is still a (technical) refrigeration challenge.

Also, for the same reason as with neighborhood hub crowd shipping is only possible for consumer parcels or light materials.

Cargo hitching is possible at a city hub, as there is public transport that may have unused capacity available. However, city hubs are often busy hubs. In addition, construction flows have the property of being very unpredictable and having to be delivered just in time. In contrast, public transport operates according to fixed schedules and routes. This makes it difficult to combine the two. For consumer parcels, it is possible on the condition that there is unused capacity in public transport, perhaps hours at night can be considered. In addition, the flows must be predictable and be able to be sent on a fixed route. There must be good connections for sustainable pre-and post-transport, as the start and end points of public transport will probably not be the same as where freight has to be delivered. Finally, the reliability of public transport should not be affected. For the same technical reason mentioned above it is difficult for groceries to bundle in public transport. Catering can be added to public transport when it comes to non-refrigerated products. Facility/service people cannot be bundled on the city hub because the hub is not focused on providing many parking spaces so that people can transfer to public transport.

The innovation of sharing public space is possible for almost all flows of goods, provided there is sufficient (parking) space at the hub, it does not have a negative impact on the (environment of the) hub and there are reliable and high-quality public transport options for the last mile of facility/service people to the customer. Again, fresh groceries cannot be shipped easily due to food safety reasons, hence the red coloring for groceries.

City outskirts hub framework

Consumer parcels also have the most potential at this hub. Moreover, sharing public space has a lot of potential at this hub because a lot of space is available in this type of hub since it is located in places on the outskirts of cities. For construction, there is even now an option colored green. In addition, it can be noted that most innovations are possible with this hub. Table 5 shows the city outskirts hub framework.

TABLE 5 City outskirts Hub Framework (14)

City outskirts hub	Freight flow				
Innovation	Consumer parcels		Construction	Catering	Facilities
	Parcels	*Groceries*			
Parcel lockers					
Crowdshipping					
Cargo hitching					
Sharing public space					

For the innovation of parcel lockers and crowdshipping, the same substantiation applies as previously given for neighborhood hub and city hub. For the innovation of cargo hitching, the same findings apply as previously given for the city hub framework.

The innovation of sharing public space has a lot of potential for this type of hub. Hubs on the outskirts of the city are often located in more remote areas with sufficient parking spaces. Due to the available space at this type of hub for the transshipment of people and (heavy) goods, the parcel, construction and facilities flow is now green. Storage is now also possible for goods. The catering and groceries flows are not colored green because, as mentioned earlier, shipping perishable products still has technical challenges.

CASE STUDIES

Transferium Westraven

Transferium Westraven or P+R Westraven, located in the South of the city of Utrecht, very close to a motorway (A12) exit, is a covered parking garage. It has 1385 parking spaces. The aim is to allow parking to car drivers that have the center of Utrecht as their final destination and continue their journey to the center by sustainable shared transport modes. It offers opportunities for cheap parking and discounted use of public transport. With the express tram, the transferium has a fast connection to the (city)center of Utrecht or nearby towns such as Nieuwegein and IJsselstein, both south of the Transferium and Utrecht. There are also buses available and it is possible to rent a rental bike (ov-fiets). An important condition for successful use of this transferium is the need for the city to make it unattractive to park in the city center. The offer of shared transport at the transferium must be sufficient to operate with regular frequencies. In this way, the transferium becomes an attractive option.

The case study for the large neighborhood hub (Utrecht Merwedekanaalzone) can be found in (14).

Application of the framework

A transferium fits best with the characteristics of a city outskirts hub. As possible logistical additions, the framework indicates that parcel lockers and crowd shipping are good options for consumer parcels and possibly food/catering if food quality can be guaranteed. Cargo hitching is a possible option for consumer parcels and food/catering, given that there is often a public transport network available at these types of hubs. The condition is that there must be unused capacity in the public transport network available, the freight flows must be predictable and can be transported on a fixed route, and pre-and post-transport must connect seamlessly. The transshipment of consumer parcels and construction flows and bundling service employees would be possible without conditions. Moreover, it can be concluded that the logistical additions to P+R Westraven case seem plausible options.

CONCLUSIONS AND DISCUSSION

The results show that regarding logistics innovation, adding parcel lockers to all three types of mobility hubs has the most potential. This innovation has the most interaction with people. Regarding logistics flows, small flows of goods for consumers or businesses have the most potential, because they can be bundled in parcel lockers. When looking at crowd shipping and cargo hitching, this is where the most challenges lie. Crowd shipping mainly concerns the confidentiality of transport, since citizens (i.e., not employees) will be transporting other people's packages. The main challenge in cargo hitching is to keep public transport reliable, since loading and unloading goods can cause inconvenience in, for example, a longer travel time. Sharing public space is an innovation that requires a lot of space and in this research has potential, especially at city outskirts hubs or P+R locations. The challenge here is again that passenger transport should not be hindered by the logistics activities at the hub.

A more overarching conclusion of this research is that it is possible to add certain logistics functions to mobility hubs. A distinction can be made in, on the one hand, logistics functions that are in the same (transport) system and thus influence the system, such as cargo hitching and crowd shipping innovations. On the other hand, there are logistics functions that are not part of the same system, such as parcel lockers and sharing public spaces. Adding logistics functions that are in the same system is difficult because this is in some way at the expense of the efficiency, service level and costs of the passenger transport system. Adding logistics functions outside the system is easier because this has minimal influence on the passenger transport system. The frameworks contribute by providing initial insight into the likelihood of certain logistics innovations at a type of mobility hub and which next steps, based on the formulated conditions, are required to add various logistics innovations to mobility hubs.

Reflecting on the results, the research has succeeded in mapping out the potential of logistics functions at mobility hubs. The results of the framework are in line with expectations, because the further away from the city center, the fewer crowds and more space there is for bundling large and heavy logistics flows. The research has shown new insights by providing detailed insight into possible logistics additions and especially possible conditions under which logistics can be added to mobility hub types.

Still it is important to make a critical remark about the interpretation of the results when using the frameworks. The use of the frameworks should be seen as a first selection of probability, whereby the (technically) impossible options can be eliminated. After this, it is desirable to conduct further research on the remaining options in order to test the feasibility in the specific situation.

This research focuses on only a few mobility hub types and logistics functions. This means that not all possible solutions are included in the study. A limited number of papers were used for the mobility hub literature review because the aim of this paper is to distinguish several mobility hub types and not to provide a complete overview of the existing mobility hub studies. This has led to a generalized picture has been created of three types of mobility hubs, while in practice no mobility hub is the same, so no mobility hub will exactly match the descriptions of the mobility hub types in this study. Moreover, the options may differ per location depending on the local characteristics and situation (strategic location on the water, facilities in the area, stakeholders involved, demographic characteristics, support among local residents, cost structure, digitization and energy transition). This requires customization for each specific case and therefore no one-size-fits-all principle holds. For the logistics functions, this research has attempted to provide a complete overview of current logistics innovations related to passenger transport by using different search terms. However, it is not guaranteed that all possible innovations have been found.

Due to the exploratory nature of this research, the design study only generated practical frameworks for exploring logistics innovations at mobility hubs. In further research, it is recommended to do a detailed morphological design study for a specific logistic addition with potential. This gives more practical meaning to the option. Finally, this research specifically looked at potential logistics additions to mobility hubs. For further research, it is interesting to also look at potential logistics additions to other strategic locations such as gas stations.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: All authors; data collection: I. Chetouani; analysis and interpretation of results: All authors; draft manuscript preparation: J.H.R. van Duin, I. Chetouani. All authors reviewed the results and approved the final version of the manuscript.

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