

Hubs for Freight and Passengers?

Exploring the suitability of adding logistics functions to mobility hubs

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

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41 **ABSTRACT**

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

55

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

57 **INTRODUCTION**

58 Following the Paris Climate Agreement in 2015, the nationally determined contribution (NDC) of
59 the Netherland states a goal of reducing greenhouse gas emissions in the Netherlands by 49% compared to
60 1990 (1). According to the World Economic Forum (2) the number of delivery vehicles in cities is set to
61 grow by 36% in the 100 largest cities in the world, and with that, emissions are estimated to grow by 32%
62 and congestion by 20%. In addition, UNESCO (3) states that about 55% of the world’s population lives in
63 urban areas. This proportion is expected to increase to 75% by 2050 (3). In the Netherlands the
64 Mobiliteitsalliantie (4) expects an increase in passenger transport by 13 to 20% in 2030 and freight transport
65 by 4 to 19%.

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

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

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

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

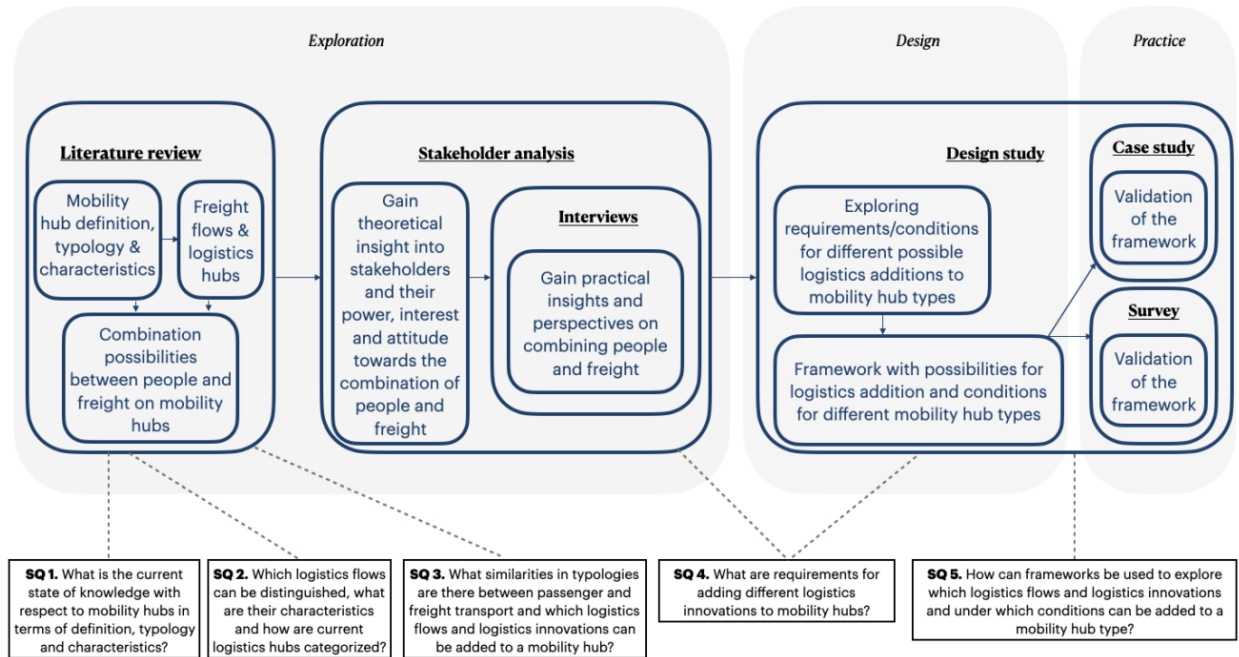
92 *‘Which logistics flows and logistics innovations can be added to different types of mobility hubs*
93 *under which conditions?’*

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

98
99 **RESEARCH METHODOLOGY**

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

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FIGURE 1 Research methodology approach (14)

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Literature review

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Stakeholder analysis

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Interviews

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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

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

140

141 **Design study**

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

148

149 **Case study**

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

164

165 **Survey**

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

168

169 **FINDINGS**

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

174 **Literature findings**

175 This section first presents the results for mobility hubs. The literature review has shown that it is
176 difficult to give a general definition of a mobility hub and that a slightly different definition can be given,
177 depending on the type of mobility hub and associated characteristics. Based on the definitions found (4, 10,
178 11, 13, 20-28), the following comprehensive definition for mobility hubs has been formed:

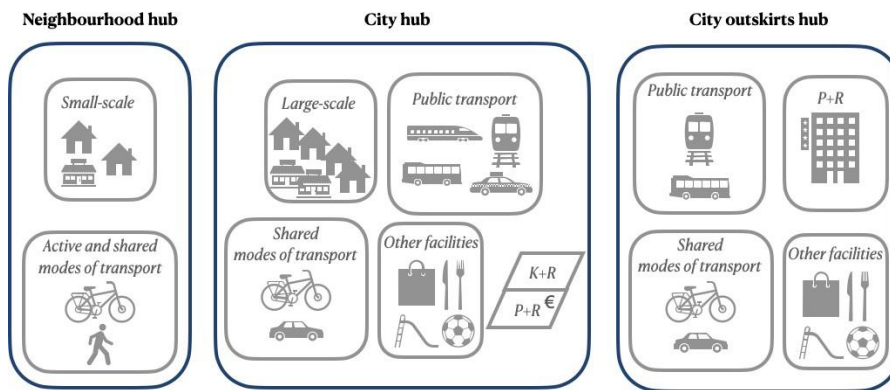
179 ‘Multimodal transport hubs that facilitate intermodal transfers by offering different modes of
180 transport nearby. This can be private, public, or shared transport. They can fulfill different
181 functions in spatial development. In addition to the mobility function, the hub can offer retail,
182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

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

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

- 186 • A **neighbourhood 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
- 187 transport;
- 188
- 189 • 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
- 190 of the city center, but there is little space for private cars. Due to the large number of
- 191 passengers at this hub, especially transfer passengers, other facilities are offered at the hub;
- 192
- 193 • A **city outskirts hub** is regarded as a hub on the outskirts of the city with the aim of attracting
- 194 private passenger cars with the city center as their final destination by offering attractive
- 195 parking facilities and public or shared transport options to travel further into the city. This hub
- 196 is also known as a P+R location.

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



198

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

200

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

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

Logistics flow	Type of deliveries	Characteristics
Construction	<ul style="list-style-type: none"> • Point-to-point • Services 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • (Ir)regular • Services 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • (Ir)regular • Various small • Point-to-point 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Irregular 	<ul style="list-style-type: none"> • 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

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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.

- 213 • Crowd shipping: the idea is that people (the crowd) can take packages along their
- 214 route to drop them off at a certain point.
- 215 • Cargo hitching: with cargo hitching unused capacity in public transport is used for
- 216 freight.
- 217 • Sharing public space: this is equivalent to multifunctional use of spaces or being an
- 218 integrated hub where passenger mobility and logistics can take place side by side.
- 219 The hub can be used for both passenger transport and logistics, for example as a
- 220 transfer point where freight is transferred from conventional trucks into smaller
- 221 sustainable ZE vehicles.
- 222

Interviews

223 The experts are generally enthusiastic about the addition of consumer packages and see this flow

224 as a promising addition to mobility hubs due to the high interaction with people. The most frequently

225 mentioned associated innovation is therefore the parcel locker with the greatest advantage that it is available

226 24 hours a day for parcel pick up and drop off. For large and heavy logistics flows, the experts believe that

227 the desired locations for logistics hubs often differ from those for passenger hubs. For example, they see

228 logistics activities more for locations outside the cities. The locations/stations where passengers come

229 together are generally expensive as they are strategically located in the city. This means that at these

230 locations you only want to add logistics with a high value to the station.

231 More or less the same logistics innovations are mentioned as those obtained from the literature. An

232 addition mentioned by one expert is the use of (temporary) parcel lockers at local markets so that employees

233 who work during the day can collect their fresh products from the market after working hours.

234 In addition, various experts suggested the possibility of transshipment of goods during the night,

235 because in busy places, varying functions over time can offer opportunities. Furthermore, the same concerns

236 have been expressed about the concept of crowd-shipping, i.e., in particular its legal and fiscal feasibility

237 and reliability. Finally, the experts were particularly enthusiastic about the concept of sharing spaces and

238 the Merwedekanaalzone is mentioned by almost all experts as a possible example for future neighborhoods.

239 The experts mentioned the same characteristics for logistic flows as identified in the literature. A

240 new insight from the interviews relates to the facility/service flow. For periodic flows to large organizations,

241 for example, they describe the possibility of having the goods in storage on the outskirts of the city, so that

242 they can be delivered bundled at desired times. Another interesting insight regarding the service workers is

243 the possibility of having service workers park at a hub to make the last mile to the customer by public

244 transport. The latter point with regard to bundling employees is also mentioned for construction employees,

245 as they sometimes also have to go to a construction site without goods. Table 2 provides an overview of the

246 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

251

252 **FRAMEWORKS**

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

258 The second validation step was done by experts, i.e., a survey was conducted with 9 experts. Critical
 259 comments were made about the color mapping of the framework. These comments have been partly
 260 adapted in the initial frameworks based on the first author’s own judgement. The final frameworks are
 261 discussed in the following text. For each mobility hub type, the framework shows which innovations and
 262 which freight flows have potential. Three colors are used for this. The green color indicates that the
 263 innovation can be easily added to the mobility hub, the orange color indicates that it can be added under
 264 certain conditions and finally, the red color means that it will be difficult to add the innovation to the
 265 mobility hub.
 266

267 **Neighborhood hub framework**

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

273 **TABLE 3 Neighborhood Hub Framework (14)**

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

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 277
 278 Parcel lockers can easily be placed at neighborhood hubs. In this way, it can serve as a
 279 neighborhood point that is open 24 hours a day. Consumer parcels can be added. Groceries may be added
 280 if refrigeration technology for parcel lockers is available, hence the orange color for the catering/food flow.
 281 Heavy construction flows can never fit in a parcel locker, but light materials do have a lot of potentials. For
 282 facilities, the materials also have the potential to be bundled in a parcel locker.

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

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

294
 295 **City hub framework**

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

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TABLE 4 City Hub Framework (14)

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

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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.

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

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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.

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City outskirts hub framework

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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.

342
343**TABLE 5 City outskirts Hub Framework (14)**

City outskirts hub	Freight flow				
	Consumer parcels		Construction	Catering	Facilities
	<i>Parcels</i>	<i>Groceries</i>			
Parcel lockers					
Crowdshipping					
Cargo hitching					
Sharing public space					

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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.

346

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.

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CASE STUDIES

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Transferium Westraven

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Transferium Westraven or P+R Westraven, located in the South of the city of Utrecht, very close

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to a motorway (A12) exit, is a covered parking garage. It has 1385 parking spaces. The aim is to allow

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parking to car drivers that have the center of Utrecht as their final destination and continue their journey to

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the center by sustainable shared transport modes. It offers opportunities for cheap parking and discounted

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use of public transport. With the express tram, the transferium has a fast connection to the (city)center of

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Utrecht or nearby towns such as Nieuwegein and IJsselstein, both south of the Transferium and Utrecht.

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There are also buses available and it is possible to rent a rental bike (ov-fiets). An important condition for

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successful use of this transferium is the need for the city to make it unattractive to park in the city center.

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The offer of shared transport at the transferium must be sufficient to operate with regular frequencies. In

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this way, the transferium becomes an attractive option.

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

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Application of the framework

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A transferium fits best with the characteristics of a city outskirts hub. As possible logistical

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additions, the framework indicates that parcel lockers and crowd shipping are good options for consumer

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parcels and possibly food/catering if food quality can be guaranteed. Cargo hitching is a possible option for

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consumer parcels and food/catering, given that there is often a public transport network available at these

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types of hubs. The condition is that there must be unused capacity in the public transport network available,

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the freight flows must be predictable and can be transported on a fixed route, and pre-and post-transport

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must connect seamlessly. The transshipment of consumer parcels and construction flows and bundling

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service employees would be possible without conditions. Moreover, it can be concluded that the logistical

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additions to P+R Westraven case seem plausible options.

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384 **CONCLUSIONS AND DISCUSSION**

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

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

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

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

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

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

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434 **AUTHOR CONTRIBUTIONS**

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

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