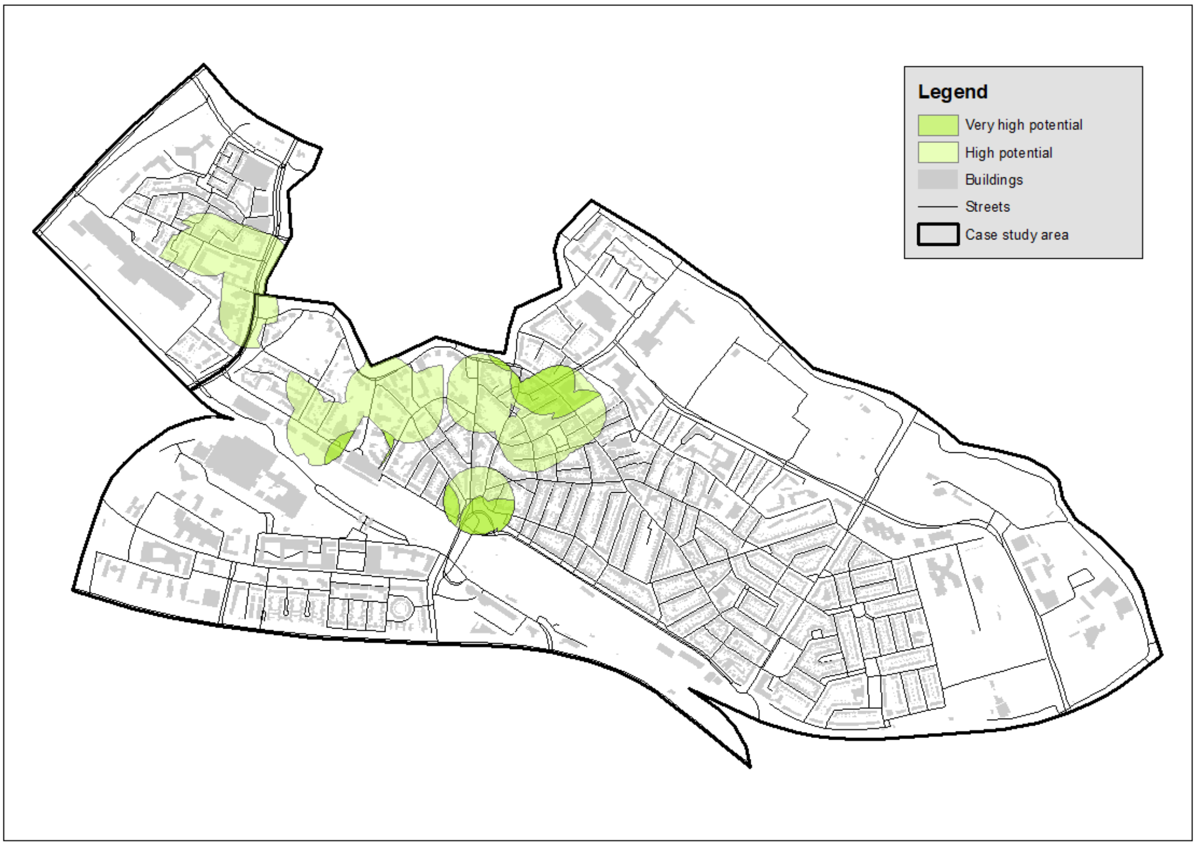
# Developing a methodology for finding suitable locations for neighborhood hubs in the neighborhoods Assendorp and Kamperpoort in Zwolle, the Netherlands





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Master thesis Spatial Planning

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## Summary

Hubs and “knooppunten” are a popular topic in current research and policy documents, always describing a slightly different picture of what a hub entails and which categories might be used. Neighborhood hubs in special are a relatively new development in the hub concept, and they might have the potential to transform the way people move, meet and make use of amenities in todays neighborhoods.

This explorative research investigates how suitable locations for neighborhood hubs can be identified to combine societal, mobility-related and energy related functions in the case of the neighborhoods Assendorp and Kamperpoort in the Dutch city of Zwolle. Neighborhood hubs are understood as nodes in the spatial network where different functions of the mobility, society and energy side come together. They can form the starting and end point of the daily trips of the local residents, providing them with different modes of transportation, easily accessible amenities and locally generated sustainable energy. For the research, first a literature review was applied to derive potential indicators that represent the suitability of a location. Afterwards, expert interviews with experts on the three topics of mobility, energy and society and with local knowledge were conducted. In the expert interviews, general questions on the three functions of a neighborhood hub were asked and the potential indicators derived from the literature were ranked in the order of their importance for the selection of a suitable location for a neighborhood hub. The ranking was used as a basis for the selection of GIS methods, which were used to display the five most important indicators in the case study areas. The two neighborhoods were then analyzed on the basis of the results of the five indicators, detecting the areas with the highest potential for placing a neighborhood hub.

The research resulted in a wide range of different potential indicators collected from the literature and the experts, of which almost all are perceived to have some relevance for the search for a location for a neighborhood hub. Moreover, the ranking resulted in a first indication of which five factors might be the most important for the context of the two case neighborhoods. The applied GIS methods revealed that it is possible to reach useful results with the application and combination of different methods and arrive at potential areas that could actually be transformed towards the placement of a neighborhood hub. The research has provided important insights into the three functions of a neighborhood hub as well as potential indicators that can be further explored in future work.

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## List of abbreviations

| Abbreviation | Meaning |
|---|---|
| EV(s) | Electric vehicle(s) |
| ICT | Information and communication technology |
| MaaS | Mobility as a Service |
| TOD | Transit Oriented Development |

# 1. Introduction

Urban planners today face a huge number of challenges: climate change, demographic change and the growth of cities are just some of the relevant examples. Organizing urban mobility in a smart way has become one of the key challenges for planners, which will have a significant effect on how and where people live, travel and can take part in their community life.

In mobility planning in the Netherlands, several important (societal) trends are arising that have great potential for influencing mobility patterns. The first is the energy transition, which strongly concerns not only housing, but also mobility (Goudappel Coffeng, 2019, p. 4; Government of the Netherlands, 2019, 79, 92). As mobility in the Netherlands today strongly depends on fossil fuels, which due to their finiteness offer no future prospects, the sector has to rapidly develop a feasible mixture of alternative ways of transportation.

The second trend are the general sustainability and health issues arising especially in cities, that have to be tackled. The main focus here is on aspects such as circular production and sustainable agriculture, heating and climate resilience, but it is also linked to the building, infrastructure and mobility sectors, including aspects such as too high emissions of harmful gasses (Goudappel Coffeng, 2019, p. 4; Government of the Netherlands, 2019, 105, 113; Marsden & Rye, 2010).

A third trend is the increased connectivity and the emergence of the service economy: Due to the increasingly easier use of the internet and low-cost technology, it is becoming possible to be extensively connected also in the field of mobility. With the rise of the Internet of Things (IoT), business models are developing that offer “Mobility as a Service” (MaaS). This also blurs the boundaries between private and collective use (examples: UBER, OV-fiets) (Goudappel Coffeng, 2019, p. 4; Government of the Netherlands, 2019, 26, 116).

Another important trend is the development of new means and forms of transport, such as e-bikes, cargo bikes, e-scooters, other light electric vehicles and shared mobility / MaaS in general (Government of the Netherlands, 2019, 26, 87).

The fifth trend is the necessary inner-city densification of most of the urban regions of the Netherlands. This development is needed, since it is expected that the population of urban regions will increase substantially in the next years and that accessibility can only be maintained through densification (Government of the Netherlands, 2019, 26, 106, 113, 115). Especially in a country like the Netherlands with the highest population density in Europe, the sustainable use of land is essential (The World Bank, 2019). Due to the high degree of densification, however, new solutions must be found in the field of mobility in order to make this densification possible at all (Goudappel Coffeng, 2019, p. 4).

With the trends in the Netherlands in mind, the focus of this thesis is the so-called “mobility hub”. The concept has received much attention in the mobility field in the last years; in their most basic form, mobility hubs are places where a user can change from one mode to another (Provincie Groningen en Drenthe, 2020a). A hub can be anything from a big international train station to a bus stop (Aono, 2019, p. 4; Schutte, 2019, p. 25). A review of the policy literature on the topic of “knooppunten” and hubs can be found in Appendix 1. These hubs might have several important potentials for tackling some of the mobility challenges of the coming years as well as support the societal development towards more sustainability (Ibraeva et al., 2020, p. 110; Loo & Du Verle, 2017; Smith et al., 2018, p. 596; Yang et al., 2016). They moreover have the potential to support urban communities and increase the social inclusion and connection in today’s defragmented society (Blijham, 2009, p. 71; Flap & Völker, 2004, 53, 56; Kaal, 2011, 534, 537). The ever-increasing number of personal cars and increased rates of congestion in urban areas, combined with the movement of population groups into agglomeration areas puts high pressure on the mobility systems today (Gemeente Amsterdam, 2017, p. 15; Huang & Wey, 2019, p. 1; KiM, pp. 5–6; Planbureau voor de Leefomgeving, 2019). Solutions need to be found that will reduce the use of land and resources, while improving the mobility and accessibility of residents.

Mobility hubs could play an important role in this development, as they offer the opportunity of a differently structured mobility system; a system not based on private use, but on shared use of intensively used assets, such as shared electric vehicles (Martin & Shaheen, 2016). Moreover, the hubs can, if applied on a bigger scale, increase the accessibility of formerly car dominated places and reduce the necessity of owning a private car. In their essence. hubs function as transition points between the transport system and urban functions; by increasing the number of those transition points, the connectivity of urban areas can be increased (Handy, 2002, pp. 10–11). The specific focus of this research are the smallest forms of these hubs, which operate at neighborhood level, and are therefore called neighborhood hubs. These neighborhood hubs are of particular importance for solving first-and-last mile problems of locations and reducing the necessity to own a personal car by providing a lot of its' beneficial functions (e.g. increased mobility, accessibility, flexibility) without the negative aspects (e.g. space usage, high costs, high emissions, congestion) (Handy, 2002, p. 23; Martin & Shaheen, 2011, pp. 1084–1085). It can be said that neighborhood hubs have the potential to support the development towards several of the above-named trends in urban areas in the Netherlands and can play an important role in solving mobility problems of now and the future.

These and a lot of additional aspects of the concept of neighborhood hubs are discussed in the course of this research. The outline of the research is as follows: In the remainder of the first chapter, neighborhood hubs are defined, the research problem statement, the research aim and the research questions are discussed and in chapter 1.3. the relevance of the research is explained. The second chapter contains the theoretical discussion about the concept of the neighborhood hubs in the current scientific context, the three functions of a neighborhood hub as conceptualized in this research are explained, and the potential indicators for the selection of a location for a neighborhood hub derived from the literature are discussed. In chapter 3, the methods that were applied in the course of the research are explained: in chapter 3.1, the research strategy is outlined, in chapter 3.2, the applied method of the case study is explained, in chapter 3.3, the literature review is discussed and in chapter 3.4, the applied expert interviews and the ranking are discussed. Afterwards, the applied GIS analyses are outlined in chapter 3.5. and the validity and reliability of the research methods are discussed in chapter 3.6. In chapter 4.1., first the general of the expert interviews are shown, then the results of the ranking are discussed (chapter 4.2.) and in chapter 4.3., the results of the GIS analysis are displayed. Finally, in chapter 5, the results are discussed in the context of the research questions and the conceptual model, recommendations for future research are formulated and conclusions are drawn from the conducted research.

## 1.1.Definition of Neighborhood hubs

This Master Thesis aims at finding suitable locations for neighborhood hubs in two case neighborhoods in the city of Zwolle. To reach the research aim, it is necessary to discuss what exactly is meant by the term "neighborhood hub".

The term hub originates from computer sciences and is used to describe a junction, a connected point in a network (Computer hope, 2019; Merriam-Webster, no year). The concept of hubs in the urban planning context has no commonly agreed definition, which is why there is a range of different definitions in the field. Broadly, hubs are often described in the urban context as "the network of urban corridors that link and cross in and around a city or town" (Elshater & Ibraheem, 2014, p. 532). For the province of Overijssel, Schutte (2019, p. 46) has defined sub-local nodes in his categorization as the place where chain mobility starts or ends, for example an attraction or office. The city of Zwolle defines hubs as attractive, easily accessible facilities where car and bicycle parking is combined with the provision of shared vehicles and cars, bus stops and other facilities such as package safes and toilets or energy generation / return (Gemeente Zwolle, 2020a, p. 80). The Hub-initiative of the provinces Groningen and Drenthe defines hubs as places where you can transfer from one transport modality to another and where you can have a pleasant waiting time, while extra facilities make the hub a pleasant place to be (Provincie Groningen en Drenthe, 2020a). Other broad definitions are coined by initiatives from other countries, such as the mobipunt initiative of the province of Vlaanderen, Belgium: A “mobipunt” is a physical place where different functions (mostly mobility-related) meet. A “mobipunt” contains a diversified offer of mobility of which car sharing, public transport and bike parking are essential parts (Matthys, 2018, p. 6). Another example are the Mobility Hubs of the city of Burlington: “A mobility hub is a location that has several transportation options and is a concentrated point for a mix of uses such as transit, employment, housing, recreation and shopping” (City of Burlington, 2020). In contrast, the Mobil.Punkt initiative of Bremen, Germany, defines their hubs very broadly as Car-Sharing stations in public street space that are clearly visible and easy to reach (City of Bremen, 2020). It can thus be said that it depends on the definition and goals of the respective authority or organization, what exactly a hub is seen as, and which functions are connected to it.

In the current research, a mobility hub fulfills the function of an exchange place for different modes of transport on different levels as well as the addition of other functions that serve the user are integral parts of the concept (Elshater & Ibraheem, 2014, p. 532; Provincie Groningen en Drenthe, 2020a; Schutte, 2019). Examples of additional functions are office space, housing, recreation, shopping and community spaces, among others, which can make it a social hub as well (City of Burlington, 2020; Gemeente Zwolle, 2020a, p. 80; Heddebaut & Di Ciommo, 2018, p. 4; Matthys, 2018, p. 6). A hub can therefore be defined as a physical space in a mobility network where users can switch between different modes of transport (e.g. car, bicycle, public transport) and where different functions are grouped (Elshater & Ibraheem, 2014, p. 532; Koedood, 2020, 3, 12; Schutte, 2019). Moreover, the connection of shared mobility and EVs as well as the generation of sustainable energy are emerging topics in the realm of spatial planning. Including energy generation, storage and loading of EVs to create an energy hub can thus further integrate different functions of urban space and make them accessible for users.

Following from this, a neighborhood hub is defined in this research as a centralized mixed use place in a neighborhood where the user can choose between different modes of transport (mobility/transfer function), make use of (social) amenities (societal function) and the energy production and supply for (a part of) the neighborhood is centralized (energy function) (compare to figure 1) (Elshater & Ibraheem, 2014, p. 532; Goudappel Coffeng, 2019, p. 5; Koedood, 2020, p. 3). In figure 1, also the aspect of heat production at the hub and the distribution of it throughout the neighborhood is made visible. It is part of the conceptualization of neighborhood hubs done by the office &morgen, where the researcher did an internship during conducting this research. The office includes the heat production in their concept, but it was excluded from the discussion in the current research[1].

[1] However, the topic was discussed by some of the experts from the municipality of Zwolle.

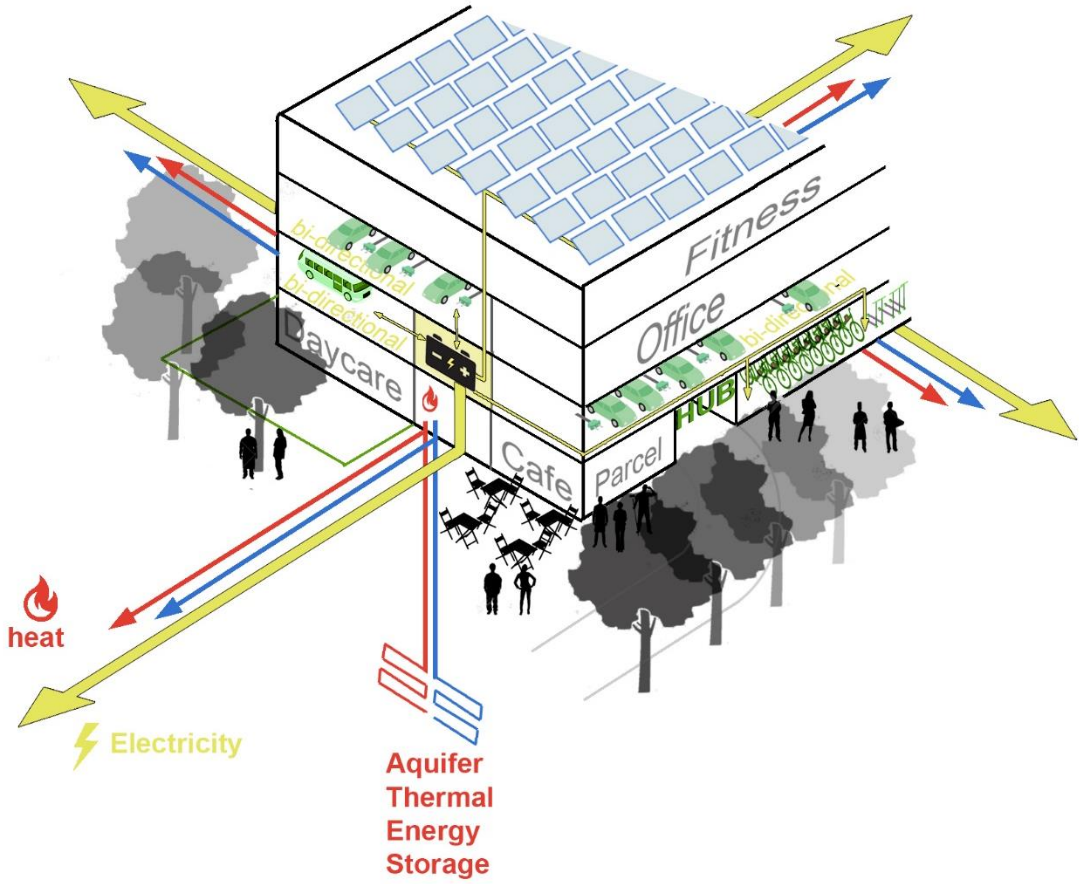


*Figure 1: Conceptualization of a neighborhood hub. Provided by &morgen.*

Ideally, neighborhood hubs are placed at strategic spots, where all types of residents can access them easily and make use of the different functions (Goudappel Coffeng, 2019, p. 5). Residents of the neighborhood should be able to access the hub within a short walk of around 250 to 300 meters (Litman, 2020, p. 29; Rattan et al., 2012, p. 31). Hubs might differ in the composition of mobility-, societal and energy-elements, as each place and resident-area has differing requirements (Koedood, 2020, p. 11). There are several possibly important aspects that could be taken into account while searching for a location for a hub: the spatial density, distance to public transport stops, presence of (social) amenities, a mixed-use area, the population density, other demographic factors, proximity to urban green spaces (UGS), proximity to new residential housing, real estate prices of the land and proximity to heat stress (compare to chapter 2.3.). Each of these aspects can have an influence on the possibility of the implementation and on the functioning of the neighborhood hub at a later stage.

Concluding from what has been discussed above, a suitable location for a neighborhood hub is understood as a place where the requirements of the three functions (mobility, energy and society) of a neighborhood hub are present.

## 1.2.Research Problem Statement, Research Aim, Research Questions

In chapter 1.1., the concept of neighborhood hubs for this research was discussed. This conceptualization was derived from scientific literature and policy documents. However, the focus is often on the conceptualization of a hub or the typologies into which hubs can be divided. There is a lack of scientific literature on which aspects are important for the selection of a location for a hub (Ibraeva et al., 2020, p. 127; Shared-use Mobility Center, no year, p. 4). In the case of neighborhood hubs, which have some connection to the topic of Transit Oriented Development (TOD), there is an abundance of scientific and policy literature on the broader topic, while neighborhood hubs themselves have mainly been covered in policy documents rather than in scientific research (Provincie Groningen en Drenthe, 2020a; Provincie Noord-Brabant, 2018, pp. 18–21; Provincie Overijssel, 2018, p. 25). Although there have been some insights into which role a neighborhood hub could play in a city and what determines the functioning of a hub as well as how these hubs could be supplied with shared vehicles (Gemeente Zwolle, 2020a, 44, 80; Schutte, 2019, pp. 46–47), there is little scientific knowledge about which locations are especially suitable for the positioning of hubs. The only available scientific information can be derived from the TOD literature, which is not completely suitable to the topic of neighborhood hubs because of the differences in size and characteristics (compare to chapter 2.2.1.) (Ewing, 1996; Loo & Du Verle, 2017).

Moreover, in policy documents there is sometimes no analysis of factors that lead towards a clearly delineated location search (BUUR, 2019, p. 23; Gemeente Zwolle, 2019, p. 44; Provincie Noord-Brabant, 2018). As is discussed more elaborate in chapter 2.1. and Appendix 1, neighborhood hubs are conceptualized with all kinds of different functions and scales in different policy documents, which differ often because of the case specificity. Each province or city develops their own slightly different view on what a hub is, and which aspects are or should be part of it. Although adaptation to the specific case is important for the hub to function in that specific case, an investigation of the aspects that (should) define the location of a hub is a largely unexplored aspect. This is partly due to the fact that decisions on the location of such projects are usually not (only) made on the basis of scientific knowledge, but rather on the basis of, amongst other things, the ownership of the land, the interests of local residents, companies and other stakeholders, as well as higher-level national, provincial or city policies (Provincie Noord-Brabant, 2018; Provincie Noord-Holland, 2015; Provincie Overijssel, 2018). This is an aspect not to be neglected in the selection of a site, which is of great importance in actual planning. However, it goes beyond the framework defined for this thesis and is therefore only dealt with partially.

Finding a methodology for finding suitable locations can therefore be beneficial to the scientific knowledge by providing a clarification of which factors can influence the suitability of a location in what way, which factors are most important for the selection of a location and which methods are most suitable for measuring these factors. This research can clarify these questions and introduce further questions that can be researched in the future. For the development of policy in the future, this research can contribute to the list of factors to be taken into account when analyzing the urban form and searching for suitable locations for neighborhood hubs. Moreover, it can help to identify the most important factors to analyze for the selection of a location. It can also provide a methodology to apply for the search of suitable locations based on scientific methods.

***Therefore, the research problem was formulated as follows: A lack of a scientific methodology for finding suitable locations for neighborhood hubs has been identified. Suitable locations of neighborhood hubs can have a significant influence on the mobility patterns in urban areas in the future as well as on the social connection between inhabitants and on the electricity supply of the neighborhoods.***

Resulting from the research problem, the research aim was be formulated:

***The research aim is to develop a methodology for identifying suitable locations for neighborhood hubs in the case of the neighborhoods Assendorp and Kamperpoort in Zwolle, the Netherlands, in order to combine societal, mobility-related and energy-related functions at the hubs.***

The research aim is thus twofold: first, to develop a methodology by identifying indicators for finding suitable locations for neighborhood hubs, and second to test the methodology in the case study. This is done by applying a literature review for potential indicators, expert interviews to select the key indicators and several GIS analyses to select those locations with the most potential for neighborhood hubs in the case neighborhoods.

The research functions as an exploration of the topic of neighborhood hubs and their application in a case neighborhood and also provides a potential methodology for the search for suitable locations for other cases. Exploratory research aims are typically chosen if the knowledge base on the topic is relatively small (van Thiel, 2014, p. 15). A subject about which little is known is researched and the outcome of the research are “detailed, empirical descriptions” (van Thiel, 2014, p. 15).

The research aim is both inductive and deductive. Inductive research is commonly conducted when there is little knowledge on the topic (van Thiel, 2014, p. 24). The goal of inductive research is to arrive at so called axioms, “the building blocks of models and theories, which specify the suppositions made on possible relations between the characteristics of the units of observation that are studied” (van Thiel, 2014, p. 25). The inductive part of this research is the qualitative identification of potential indicators for selecting suitable locations. Thereby, the relation between the indicators and the location of the neighborhood hubs is explored. In deductive research, which, in the research cycle, normally takes place after inductive research, the axioms and theories can be tested in different backgrounds. In deductive research, “[on] the basis of a theory, a model of the research situation is constructed” (van Thiel, 2014, p. 26) and then tested. In the current research, the testing of the developed methodology in a case study serves as an evaluation of whether the methodology provides reliable and usable results for this case and is therefore the deductive part of the research.

Following from the research aim discussed above, the main research question was:

***How can suitable locations for neighborhood hubs be identified to combine societal, mobility-related and energy-related functions in the case of the neighborhoods Assendorp and Kamperpoort in the Dutch city of Zwolle?***

The research question is, in line with the research problem and research aim, an exploratory question (van Thiel, 2014, p. 18). It therefore aims to arrive at a deeper understanding of the concept in question and to provide a (preliminary) structure of the context. Thus, it aims at searching for a method of finding out which locations are suitable to the conceptualized hubs and tries to identify factors that influence the suitability. The main question was divided in four sub-questions, which serve to answer the main question collectively. Therefore, the sub questions were as follows:

1. ***Which indicators can be identified for the societal, mobility-related and energy-related functions?***

The function of sub-question one is to develop an understanding of aspects that influence the functioning of a hub and its’ mobility, energy and societal functions, by deriving potential indicators from scientific and policy literature. This is done by applying a literature review to selected scientific and policy documents and describing the derived potential indicators. The list of potential indicators is used as a basis for answering the second sub-question.

2. ***Which of the potential indicators can be selected as relevant for selecting suitable locations for neighborhood hubs?***

The function of the second sub-question is to decide which of the potential indicators are relevant for the selection of suitable locations for neighborhood hubs. This is done by conducting expert interviews with selected experts on the topics of mobility, energy and societal functions of the neighborhood hubs and having those experts select key indicators from the list of potential indicators. The outcome is used as a basis for answering the third sub-question.

3. ***Which methods can be applied and combined to measure the key indicators?***

The function of the third sub-question is to decide which methods can be applied to measure the selected indicators. Depending on the key indicators, different methods can be chosen. The question is answered by reviewing scientific literature on measuring the selected indicators using the software ArcMap of ERSI and selecting suitable measuring tools. The goal of the GIS analysis is to display the selected indicators in the two case neighborhoods and thereby test, whether such a methodology is working out for the selecting of a location for a neighborhood hub. The outcome is used as a basis for answering the fourth sub-question.

4. ***What are the results of applying the selected methods in the case study neighborhoods?***

The function of the fourth sub-question is to analyze the results of the application of the selected methods for measuring the key indicators in the two case study neighborhoods. This is done by interpreting and evaluating the results of the GIS analyses.

The four sub-questions together form a basis for answering the main research question.

## 1.3. Scientific and societal relevance

In this chapter, the scientific and societal relevance of the research is explained. The scientific relevance is based on the research gap that the author aims to address, and the societal relevance shows the benefits a selection method for locations of neighborhood hubs can have for the mobility and energy system in a city and for the local residents.

**Scientific relevance**

The research gap that is addressed in the current research is threefold:

First, methods for finding suitable locations for neighborhood hubs have not yet been researched in detail, in contrast to the different typologies that are established. In the already lacking scientific literature on neighborhood hubs that fit with the conceptualization used in this research, there is almost no focus on which aspects define a suitable location of neighborhood hubs (Bell, 2019, pp. 4–5; Diemer et al., 2018, p. 219; Martinez & Rakha, 2017, p. 4; Monzon et al., 2019, pp. 1127–1128). Moreover, policies mostly do not focus on how to decide upon the place where a hub should be situated. This is partly because of the conceptualization of hubs being focused on train stations, which of course already have a location and represent an important part of the existing infrastructure in a city (Provincie Groningen en Drenthe, 2020a; Provincie Noord-Brabant, 2018). On the other hand, this is often because the policies currently including the topic are vision documents and do not yet focus on the details of the implementation (BUUR, 2019; Gemeente Zwolle, 2019, 2020a). As the concept of hubs in Dutch policies is relatively new, no sufficient number of implementations and their scientific evaluation, also of the location, has taken place yet (Gemeente Eindhoven, 2003). Moreover, the focus of scientific, policy and advisory office documents often rather lies on the categorization of hubs, instead of scientific ways to find suitable locations for them (Bell, 2019, pp. 4–5; Diemer et al., 2018, p. 219; Goudappel Coffeng, 2019; Martinez & Rakha, 2017, p. 4; Provincie Noord-Brabant, 2018).

Second, the exact combination of mobility-related, energy-related, and societal aspects in the hub concept has not been researched yet, although research in shared electric vehicles and their loading stations is numerous (Bünger & Michalski, 2018; Cooper et al., 2019; Laporte et al., 2015; McKenzie, 2020; Moghaddam et al., 2018). In this research, the focus is mainly on the mobility function of the hub with integration of parts of the energy function, while the societal function of a hub is more or less neglected (Schreier, H., Grimm, C., Kurz, U., Schwieger, B., Kessler, S., Möser, G., 2018).

In policy documents, the societal function of hubs is often discussed, but mainly not on the neighborhood level (Provincie Noord-Brabant, 2018, pp. 18–21; Provincie Noord-Holland, 2019). This is rather part of the policies on social inclusion, participation of residents, social climate and well-being of municipalities, but thematically and physically less connected to the other two aspects (Gemeente Zwolle, 2020b, pp. 20–21). However, with the potential deterioration of communities in modern cities and the trends towards individualization and flexibility, the social dimension of hubs should be an important part of the conceptualization (Mollenhorst, 2015, p. 110; van Kempen & Bolt, 2012, pp. 441–442; Wellman & Leighton, 1979). It can be seen in recent workshops or discussions on the topic of hubs in Dutch cities that the focus lies more and more also on the societal function of a hub. It can enrich the experience of being at a neighborhood hub and can encourage more people to use the hub. This should therefore be an elementary part of a location search for a hub.

Thirdly, there is a large amount of scientific literature on the topic of TOD, which, however, mainly refers to the USA and Asia and only to a small extent about Europe or the Netherlands (Boarnet & Compin, 1999; Cervero & Sullivan, 2011; Curtis, 2008; Ibraeva et al., 2020; Sung & Oh, 2011). Some research is focusing on how to transfer the concept of TOD to the Dutch context (Markink, 2016; Pojani & Stead, 2015; Thomas et al., 2018). However, this focuses almost exclusively on the train system and addresses large stations and their distribution function. This is of course because the concept of TOD is itself mainly focused on a better integration of the train system with points of interest (Cervero & Sullivan, 2011, p. 210).

Thus, the scientific exploration of a methodology for finding suitable locations for neighborhood hubs can add to the structural analysis of new mobility forms, shared mobility, integration of mobility with the energy network, organization of neighborhoods and social inclusion in neighborhoods.

**Societal relevance**

Hubs can have several positive benefits for a neighborhood, among which are increased accessibility of transportation and services for all user groups, a more flexible and easy of changing modes of transportation, a reduction of space usage by private cars, a reduction of heat stress and several other aspects that can benefit the residents in the neighborhood (Gemeente Zwolle, 2017, pp. 28–29; Provincie Groningen en Drenthe, 2020b, 2020a; Provincie Overijssel, 2016, p. 2, 2017, 2019, p. 5). However, these benefits can only be realized to their full potential if the location of a hub is chosen carefully. As has been argued in the scientific relevance section, there has not been a lot of research on the topic of finding suitable locations for these hubs, which is why this research tries to address that topic.

If a methodology can be found for selecting suitable locations for neighborhood hubs, then the costs of implementing such hubs can be reduced, as they might be placed at locations where businesses see a business case in cooperating with the hub and it can be partly financed by this. Moreover, selecting a suitable location for hubs based on multiple important factors reduces the risk of investing money into something that is not used by the residents of the neighborhood afterwards. Additionally, the inclusion of several different factors into the decision for a location can increase the suitability of the location to the residents, which might increase their willingness to use the hub.

The collection and ranking of different factors that might influence the selection of a location can add to the knowledge base on the topic of neighborhood hubs and support municipalities in taking all the different aspects into account when selecting.

The selection of potential indicators from the literature review serves to find out which spatial aspects have an influence on the functioning of a neighborhood hub. Functioning here is meant as that the selection of the location results in a neighborhood hub that fulfils its' three functions without causing additional problems for the area. The hub is supposed to improve the mobility situation without increasing the impact mobility has on the public space, it should serve as an energy provider and distributer without causing problems for the energy network and reducing the costs as good as possible for the builder and it should attract people to make use of the different functions at the hub without having negative effects on the surrounding. To reach this goal, the decision for a location of a hub must be taken with regard to all aspects that can have an influence on the functioning of the hub in the urban system.

It is important to state the good and reliable mobility service at the hubs as well as safety and social security are the most important aspects for users to make use of the hubs. The hub itself can have the best additional functions, but if the services are not reliable or the users do not feel safe there, they will not make use of the hub (Iseki et al., 2007, p. 3).

If a methodology is found for the selection of suitable locations for hubs on the basis of a range of different factors, then this methodology might not only be useful for the municipality of the case study, but it could also help other municipalities in deciding about the locations.

# 2. Theoretical background

This chapter forms the theoretical exploration of both the concept of neighborhood hubs and aspects that might influence the selection of a location for a neighborhood hub. Therefore, in chapter 2.1., the conceptualization of neighborhood hubs in scientific research is discussed in more detail. In chapter 2.2., the three functions of a neighborhood hub as conceptualized in this research, mobility, energy and society, are explored. In chapter 2.3., potential indicators which might represent the suitability of a location for a neighborhood hub are discussed. Finally, in chapter 2.4., the conceptual model used in this research is explained.

## 2.1. Conceptualizations of neighborhood hubs in science

In this subchapter, it is discussed how neighborhood hubs are conceptualized in scientific research. This sub-chapter helps to arrive at an overview of what neighborhood hubs are and how they are perceived in different contexts.

**Definitions of hubs**

The word hub is a widely used term in transportation planning, which can be applied to describe everything from an airport, sea ports, rail terminals towards big and small PT stations (Elshater & Ibraheem, 2014, p. 533; Heddebaut & Di Ciommo, 2018, p. 1) and in its' most generic form describes a range of different types of physical junctions in the mobility network (Rybels et al., 2017, p. 1). More specifically in the context of urban transport planning, the terms hub, mobility hub, transport hub, intermodal hub, city hub and neighborhood hub (Dutch: "buurthub") have been widely used in recent years to describe interchanging points of different scales in the urban fabric, where users can change between different modes of transportation (e.g. PT, car, bicycle, walking) (Aono, 2019, p. 3; Bartsen, 2019, p. 38; Schutte, 2019, 4, 8; Shared-use Mobility Center, no year, p. 2). According to Elshater and Ibraheem (2014, p. 532), the hub concept refers to "the network of urban corridors that link and cross in and around a city or town". The main function of a hub is therefore the "interchange with other modes of public transport, where traffic exchanges across several modes of transportation" (Elshater & Ibraheem, 2014, p. 532). According to Monzon et al. (2019, p. 1126), the "function of an interchange station is to reduce distance between transport modes, therefore to facilitate multi-activities patterns".

Martinez and Rakha (2017, p. 2) provide a differing definition of a mobility hub for a mid-sized city: "a destination-based model that capitalizes on an available infrastructure with much reliance on the private sector and community based efforts to generate links to zone of high activity". This definition is focusing less on the spatial and more on the organizational aspects of a hub as well as on the effects it can have on its' surrounding area. Rybels et al. (2017, p. 1) agree on the developments towards a zone of high activity, when describing that the concept of hubs does not only describe the interchanging points of the network, but also the surrounding area or neighborhood that is influencing the hub and is influenced by it (Rybels et al., 2017, p. 1; Schutte, 2019, p. 8). Thereby, the attractiveness and productivity of the transportation at the hub is determined (Rybels et al., 2017, p. 1).

**Existing typologies in scientific research**

In scientific research, there is a rich variety of classifications or typologies of hubs from different contexts and perspective. According to Elshater and Ibraheem (2014, p. 532), "[hubs] can be categorized in many ways: by size, use, relate[ed] to the context, style, predominant function, architectural form, location, and so on". The most common and most important features that characterize hubs are their position in the network, their scope and the associated or existing functions. However, different categorizations are possible, depending on the context, such as the categorization of Martinez and Rakha (2017, p. 4), which is based on activity and infrastructure parameters.

Hubs are often defined in terms of their position in the network (Bell, 2019, pp. 4–5; Martinez & Rakha, 2017, p. 4). Bell (2019, p. 4) argues, that “the centrality of the location and its relation to other stations in the transport system” is one of the key features of a hub. Definitions of hubs differ in their scope: A distinction is made between hubs with greater reach and those with less reach, ranging from country-wide influence, city-wide influence to neighborhood-wide influence (Bell, 2019, pp. 4–5). From the range of existing categorizations, several are displayed here for illustration; these do not claim to be complete but serve as an overview.

- Diemer et al. (2018, p. 219) define five place types (Local, Neighborhood, Municipal, Regional, State) and four land use types (Residential, Commercial, Public and Semi-Public).
- Bell (2019, pp. 4–5) defines four types: the transport hub in the urban center of cities, the suburban mobility hubs, regional centers and public transport gateways (the smallest and basic “unit” of intermodal hubs).
- Martinez and Rakha (2017, p. 4) categorize mobility hubs in terms of their locations into collectors (takes advantage of a thriving node with high traffic volumes), activators (capitalizes on mobility behavior in a moderate to high activity area) and generators (generates new mobility and activity and links underserviced areas).
- Monzon et al. (2019, pp. 1127–1128) classify “urban interchanges” according to two dimensions, “that interact to define the needs of the ‘interchange place’ and consequently the size of the building and its characteristics”. These two dimensions are, on the one hand, functions and logistics, and on the other hand local constraints. Functions and logistics describe the demand (number of passengers), the modes of transport (and their degree of importance), and the (number and quality of) services and facilities. Local constraints describe the relative location of the interchange with respect to the main local demand attractions, the surrounding area features and whether the site is part of an integrated development plan of the respective city (Monzon et al., 2019, p. 1128).
- In TOD, transit stations are typically classified according to their scale (international, national, regional, local) and their position in the network (hub or spoke) (Elshater & Ibraheem, 2014; Peng et al., 2017; Transit Oriented Development Institute, no year; Urban Design Studio, 2016, p. 7). However, in TOD, mostly no sub local level, which would display the neighborhood hubs discussed in this research, is defined. The reason for this is that the focus of TOD is on the rail network and not or only less on the bus network, which might provide this smaller level of hubs. As there are no train stations that are as small as the neighborhood hubs considered here, the concept is lacking this scale level.

From the scientific background of hubs and neighborhood hubs, a very heterogeneous picture is visible; hubs are conceptualized differently depending on the context and scale level of the specific project. Moreover, there is no commonly agreed definition of hubs, which makes it more difficult to line out what exactly the concept includes and what not. In the Dutch and international policy on the wider topic, there is a similar discussion going on. Especially in the Dutch context there is a wide range of publications that focus on “knooppuntontwikkeling”, but also on the concept of hubs discussed in this research. An overview of the policy literature on these topics is discussed in chapter 4.1.

## 2.2. The three functions of neighborhood hubs

In this sub-chapter, the three functions of a neighborhood hub as conceptualized in this research as well as their potential benefits to the hub and the neighborhood are discussed. This chapter basically outlines the concepts and theories based on which the potential indicators were derived. In chapter 2.2.1, the mobility function and its’ theoretical origin is discussed. Moreover, the concepts mobility and accessibility are explained and different mobility concepts, such as shared mobility and the first-and-last mile problem are discussed. Afterwards, the societal function of a neighborhood hub is discussed, and it is outlined which benefits this function could bring to the hub. in the last sub-chapter, the energy function of a hub is elaborated upon.

### 2.2.1. The mobility function

In transport planning, two concepts are especially important: Mobility and Accessibility. They have great influence on each other and are themselves influenced by other parameters, such as land use, behavior of people or for example the availability of public transport or other services. Both concepts form the basis of the theoretical background of this research, which is why they are discussed in detail in this sub-chapter.

**Mobility and Accessibility**

Mobility can be defined as the potential for movement or the ability to get from one place to another, while accessibility can be referred to as the potential for interaction (Handy, 2002, 2005). Both concepts are important to the mobility of people and goods within a city or neighborhood. Accessibility is always connected to "how easily opportunities can be reached according to their spatial distribution" (Farber & Grandez, 2017, p. 881; Handy & Niemeier, 1997), while mobility is referred to as being "capable of moving or of being moved readily from place to place" (Handy, 2002, p. 3).

Mobility (meaning potential mobility) is generally increased, if there is more space dedicated for moving from one place to another. Traditionally, this is connected to road traffic by automobiles. The expansion of a motorway firstly increases the potential mobility in the surrounding area. Thereby, accessibility can also be increased. However, actual mobility as well as accessibility can decrease, if the new highway is congested or leads to more usage of it, which can lead to congestion (induced demand) (Cervero, 2002; Lee et al., 1999, pp. 13–14).

***Increasing and reducing mobility and accessibility***

There are several factors that affect mobility, accessibility, or both. Moreover, factors that increase mobility can also reduce accessibility and the other way around. In general, three types of transport strategies can be distinguished: Mobility-enhancing strategies, accessibility-enhancing strategies, and mobility-limiting strategies. Mobility-enhancing strategies are understood as "[focusing] on improving the flow of traffic and improving the performance of the system" (Handy, 2002, p. 6). They typically include road building, including the construction of new roads and the expansion of existing roads. Moreover, the growing market of ICT-infrastructure is understood to have a mobility-enhancing function, as ICT aims at increasing the efficiency of the transportation system and at making better use of existing capacity (Handy, 2002, p. 6).

Mobility-limiting strategies describe strategies that aim at actively reducing or preventing mobility (normally by car). They aim at changing the behavior of people by reducing the utility of driving in comparison with the alternatives and thus discouraging people to drive (Handy, 2002, p. 5). These strategies include "physical barriers to driving, such as auto-restricted zones, and pricing strategies, including gas taxes, parking fees and congestion pricing" (Handy, 2002, p. 5). The potential of mobility-limiting strategies to reduce driving of people is there, but without combination with other strategies, it comes at the cost of reduced ability to participate in needed and desired activities.

Accessibility-enhancing strategies aim at improving access to desired or needed activities (Handy, 2002, p. 10). Accessibility includes two main factors: impedance (the time or cost of reaching the destination) and attractiveness (the qualities of the potential destination) (Handy, 2002, p. 4). Accessibility is generally increased if the amount of options that are in reach is increased. Accessibility-enhancing strategies include a “variety of land use strategies and strategies to provide services via telecommunications technologies” (Handy, 2002, p. 10; Litman, 2020, p. 30). They can lead to changes in behavior by improving the alternatives to driving, either by providing potential activities nearby or by reducing the need to travel to activities at all. Land use strategies can include, among others, New Urbanism, TOD, Infill Development, Main Street Programs and Street Connectivity. Not all these strategies can be discussed in detail here. However, it must be noted that their common aim is normally to provide more activities and a more diverse range of activities in closer proximity to the inhabitants of an area.

***Planning for accessibility and the resulting benefits***

To plan for accessibility has several benefits for the inhabitants of an area: first, choices of activities are expanded, as there are more and diverse uses in the surrounding area. Moreover, the need to drive to access activities is reduced (Handy, 2002, p. 6). Examples of this are small-scale retail developments in residential areas, that bring shops within walking distance, or introducing a circulating bus route that links residential to commercial places (Handy, 2002, p. 6). Not only do these strategies reduce the personal costs in terms of money and time of their inhabitants, but they also reduce the community costs of building roads as well as the environmental impact of mobility. There are multiple factors that can affect the accessibility of a location, which are discussed in the following paragraphs.

Handy argues, that although planning for mobility “can be compatible with planning for accessibility” the focus on mobility planning has helped to reduce accessibility in the US (Handy, 2002, p. 4). Although this might not be true to the same extent for the Netherlands, this shows one of the most important influence factors of accessibility: Land use can have a significant influence on how accessible an area or city is (Litman, 2020, p. 7). Land use describes how amenities, activities, living areas, working areas and all other uses are distributed over a region, city or neighborhood (Yigitcanlar & Kamruzzaman, 2014, pp. 2121–2122). In line with what has been argued above, compact, mixed-use urban development is beneficial to the accessibility of the inhabitants of a city (Litman, 2020, p. 30). The accessibility of people is increased by including more and diverse functions in an area. These are functions of daily and long-term needs, such as bakeries, supermarkets, cafés, other commercial uses, leisure activities, social services, UGS and much more.

The accessibility of a location is of course influenced by the accessibility of the single transport modes to the location. Typically, it is cycling and walking infrastructure that is missing in most locations, and sometimes also public transport infrastructure. Moreover, accessibility is affected by the quality of the system integration of the different transportation systems (e.g. cars, public transport, cycling, walking) (Litman, 2020, p. 13). Poor quality of integration is often a major barrier for other modes of transport to be used more intensely.

The accessibility of a location also depends on the constitution of the person in question. People who are carrying heavy loads, people with children, people with disabilities or older people often experience less accessibility than the average person (Litman, 2020, p. 13; Martens, 2012, 2017).

The accessibility of a location is furthermore influenced by the attractiveness of the location itself and the way towards the location. The situation at place, such as existence of restrooms, changing rooms, bicycle parking and other factors has a significant influence on the accessibility of a place (Litman, 2020, p. 13; Monzón et al., 2016, p. 1125). Moreover, aspects such as safety, transfer conditions, information, design, environmental quality and comfort of waiting time can play an important role for the users (Litman, 2020, p. 30; Monzón et al., 2016, p. 1125). Wide sidewalks and safe bicycle lanes for example can increase the attractiveness of a location for these modes of transport (Bell, 2019, p. 4; Litman, 2020, p. 30; Monteiro & Campos, 2012, p. 638). Moreover, aspects such as block size, pedestrian routes, landscape, pavement quality or presence of amenities can influence the attractiveness of the route and encourage people to use the location (Monteiro & Campos, 2012, p. 642).

### *TOD as an accessibility-enhancing strategy*

As an example of an accessibility-enhancing strategy, the concept of TOD is discussed here, because it has similar origins as the concept of neighborhood hubs discussed in this research. TOD is a land use strategy which is understood to be accessibility-enhancing. TOD can be described as "land-use and transport planning that makes sustainable transport modes convenient and desirable, and that maximizes the efficiency of transport services by concentrating urban development around transit stations" (Ibraeva et al., 2020, p. 110). It normally features "compact and mixed-use activities configured around light or heavy rail transit stations, interlaced with pedestrian amenities" (Cervero & Sullivan, 2011, p. 210). Its' main aspects are the design of the area focused on the transit station, non-motorized access of the station (e.g. bicycles, pedestrians), shared use of vehicles, minimal parking as well as compact development and mix of uses (Cervero & Sullivan, 2011, p. 211; Noland & DiPetrillo, 2015, p. 42; Sung & Oh, 2011).

The concept was originally developed by Calthorpe (1997) for the USA as a response to increasing congestion, parking pressure, urban sprawl, emissions and increasing costs of investment into the national highway system (Ewing, 1996; TCRP, 1997, 2002). It has since then been intensely researched in different contexts (e.g. USA, Europe, Asia) (Sung & Oh, 2011; Wey et al., 2016) and implemented in several cities in the USA, Australia and Asian countries (e.g. Perth, San Diego County, Seoul, Beijing) (Boarnet & Compin, 1999; Curtis, 2008; Kong & Pojani, 2017; Shared-use Mobility Center, no year, p. 4; Sung & Oh, 2011).

The focus of research on TOD until recently has been mainly on "considerations about planning or policy dimensions such as the coordination of transit and land uses, the scheduling and frequency of transit services, the integration of public transport ticketing, and the implementation of development control mechanisms" (Pojani & Stead, 2015, p. 2). Following from that, research into the design of TOD and the surrounding areas has been conducted (Pojani & Stead, 2015; Stojanovski, 2019). Different potential influence factors, such as walking distance, attractiveness of the built environment, mixed use and spatial density are discussed in the scientific literature (Kong & Pojani, 2017; Noland & DiPetrillo, 2015, p. 43; Stojanovski, 2019, pp. 5–6). Although these aspects cannot be adopted for neighborhood hubs without reflection, they can give a first indication of what potential influence factors can be that influence the suitability of a location for a neighborhood hub.

The concept of TOD has a strong connection with the topic of hubs, as both concepts are focusing on the same land use measures, however on different scale-levels. While TOD is focusing on increasing city-, region or even country-wide accessibility, neighborhood hubs are aimed at increasing neighborhood-wide accessibility. Both concepts rely on the notion of providing more possibilities for the users of the stations or hubs. Both stations and hubs are in their most basic sense a node in a network, the physical places forming the interfaces between transportation and functions (Peek & van Hagen, 2002, p. 1).

### *Differences and similarities between TOD and neighborhood hubs*

While both concepts are based on the same ideas of enhancing accessibility, one of the main differences between the concept of TOD and the neighborhood hubs is that TOD is implemented at a higher scale level. While the discussed neighborhood hubs supply only a part of a neighborhood, the scales in TOD range from local to international, whereas local refers to the main station of a city. The concept of neighborhood hubs can therefore be seen as an extension of TOD to the local circumstances, or as a smaller version at a lower scale level. Because the scale level is different, the functions implemented at the station or hub also differ. While in TOD there is actual development of residential housing and mix use areas around the existing or developing transit station, the functions that are implemented at the hub are integrated in the hub or in the direct surrounding, meaning the scale of several houses. The second difference, which is also depending on the first one, is that TOD is focusing on the railway system, while neighborhood hubs do not necessarily include public transport. It is at the core of the concept of neighborhood hubs that they should function as the spokes of the main train station (&morgen, 2020; Provincie Noord-Brabant, 2015, p. 6; Schutte, 2019, p. 47). A parallel can be drawn here, as the function of neighborhood hubs is to connect people with the transit stations, while it is the function of transit stations in TOD to connect people with higher level or other stations.

### Hubs as combination of different concepts

Neighborhood hubs as conceptualized in this research are however not only based on TOD, but can include several different mobility concepts, such as shared mobility, MaaS, chain mobility and the first-and-last mile problem. These concepts are discussed in the following and their potential for the concept of neighborhood hubs is outlined.

#### *Shared mobility*

The concept of shared mobility is based on the growing trend of the so called "sharing economy", which is based on people preferring to lease, rent or lend assets, such as cars, bicycles and scooters, instead of buying and owning them themselves (Engel-Yan & Passmore, 2013, p. 82). Shared mobility can be defined as "the shared use of a vehicle fleet by members for tripmaking on a per trip basis" (Martin & Shaheen, 2016, p. 3). The concept dates to the years 1965, when the first bicycle sharing program was launched in Amsterdam (Laporte et al., 2015, p. 342). A lot of different models have been developed for the shared use of vehicles, which range from (private) car- and van-pooling to public and private companies offering vehicles to rent for a certain period of time, which is called MaaS (Hietanen, 2017; Holmberg et al., 2016; Smith et al., 2018).

MaaS can be defined as "a mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider" (Hietanen, 2017; Smith et al., 2018, p. 593). However, Holmberg et al. (2016) argue that "the MaaS concept encompasses a wide range of transport services, from peer-to-peer services (e.g. BlaBlaCar) to services that attempt to optimize the connection between personal cars and PT (e.g. Ha:mo)" (Smith et al., 2018, p. 593). It is often used as an umbrella term that describes a wide range of transport services, including packaged offerings of transportation, intermodal planning, booking and payment functionalities and multiple transport modes and mobility packages (Kamargianni et al., 2016). What is especially important about the concept it its' user-centric design and the focus on customization (Jittrapirom et al., 2017, p. 14). The paradigm change that is happening through MaaS is that mobility functionality is shifted from being accessed through the purchase of a product towards being the outcome of a service (Cooper et al., 2019, p. 39). These services are typically arranged on a trip by trip basis and do not require the user to own any assets themselves (Cooper et al., 2019, p. 39).

Shared mobility and MaaS models can be station-based, meaning that the shared vehicles have to be returned to a station of that company, or can be flexible (or "free-floating"), meaning the vehicles can be left in any location the user chooses (e.g. public parking spots) (Boyacı et al., 2015, p. 719; Cooper et al., 2019, p. 39; Martin & Shaheen, 2016, p. 3; Rijkswaterstaat, no year). Moreover, the station-based systems can be distinguished into "roundtrip" or "back to one" systems, where the user has to bring the vehicle back to the original station, and "back to many" systems, where the user can bring back the vehicle at any station of the company (compare to figure 2) (Boyacı et al., 2015, p. 719; Rijkswaterstaat, no year).The systems can further be classified according to whether a reservation is possible or needed or not (Boyacı et al., 2015, p. 719). There is also the peer-to-peer system, which is often functioning like the station-based system, however, the vehicle fleet is owned by private people and the service is facilitated through a third-party operator.


*Figure 2: Different models for shared mobility systems (Rijkswaterstaat, no year)*

Vehicle sharing services typically include opening an account with the respective company and paying for the service either on a monthly / yearly basis, or on a per-use basis (McKenzie, 2020, p. 1). There is a wide range of vehicles that can be used in shared mobility: They include different types of bicycles, from normal bicycles towards cargo bicycles, electric bicycles and special types such as mountain bikes, to (electric) scooters, all other light electric vehicles, such as (e-)steps, all types of (electric) cars and (electric) vans (Barth & Shaheen, 2002, pp. 108–109; Cooper et al., 2019; Expo, 2020; Luca de Tena & Pregger, 2018; McKenzie, 2020; Zipcar, no year). Of decisive importance for the functioning of vehicle sharing is that the vehicles are easily accessible and close to the users' residences (Schreier, H., Grimm, C., Kurz, U., Schwieger, B., Kessler, S., Möser, G., 2018, p. 11).

The biggest car sharing companies today are for example Zipcar and Car2Go, with each over 900.000 members mainly in Europe and the US (Zipcar 2015 in Laporte et al., 2015, p. 342). There are six providers of carsharing services in the Netherlands, who provide their services in over 88 communities (MOMO Car-Sharing, 2010, p. 17). The oldest and biggest Dutch provider is Greenwheels, with over 1,100 vehicles (Metz, 2008, pp. 6–7; MOMO Car-Sharing, 2010, p. 27). The total number of carsharing vehicles in the Netherlands has risen from 1,832 in 2009, serving about 27,000 customers to around 51,000 vehicles in 2019 (Kouwenhoven, 2019; Metz, 2008, pp. 6–7).

With shared (electric) bicycles, there are different models, such as short-term renting (e.g. FlickBike, Urbee, Donkey Republic, Deelfiets Nederland), long-term lease models like Swapfiets, which offer year-long contracts for leasing bicycles, or the OV fiets, the bicycles located at major stations in the Netherlands (Deelfiets nederland, 2020; Donkey Republic, no year; Flickbike, no year; NS, no year; Swapfiets, no year; Urbee, no year). A discussion of how many shared vehicles might be necessary to sufficiently supply a certain group of inhabitants can be found in Appendix 2.

The benefits of shared mobility for the user include, among others, flexibility in time and mode of transportation, increased accessibility without having to own a private vehicle, increased accessibility and mobility for disadvantaged societal groups, no necessity to take care of the vehicle for the user (in terms of maintenance) and reduced personal transportation costs (Anderson et al., 2016; Crane et al., 2012, p. 20; Deelfiets nederland, 2020; Donkey Republic, no year; Duncan, 2011, p. 364; Shaheen & Cohen, 2013, p. 5). Vehicle sharing can also reduce vehicle kilometers traveled, greenhouse gas emissions, and is likely to decrease congestion and space usage of mobility (compare to figure 3) (Crane et al., 2012, pp. 21–24; Martin & Shaheen, 2011, p. 1074; Martin & Shaheen, 2016, p. 3; Shaheen & Cohen, 2013, p. 5; Voet, 1995, p. 32). If inhabitants have sufficient access to alternative modes, e.g. in the form of MaaS, the need for a personal car is reduced. In the future many households might abandon first their second and then their first car because they no longer need it (Smith et al., 2018, p. 596; Yang et al., 2016).

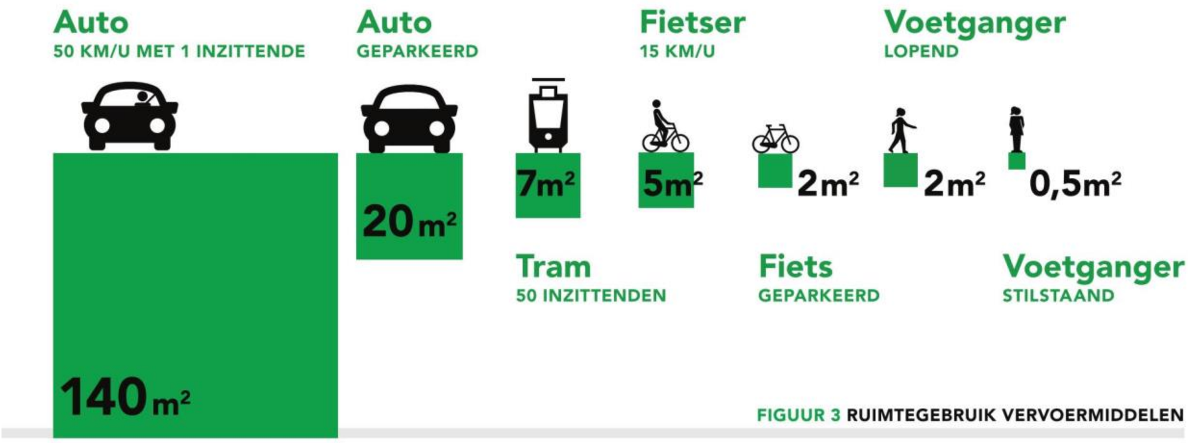


*Figure 3: Space usage different modes (Gemeente Amsterdam, 2017, p. 15)*

One of the main problems that vehicle sharing companies face is to provide sufficient numbers of vehicles at every station (Laporte et al., 2015, p. 342). There are models available that provide insights about the amounts of vehicles needed at specific stations and how the relocation of the vehicles can be planned in the best way (Chow & Sayarshad, 2014; Lin et al., 2013; Nair & Miller-Hooks, 2014, 2016). However, it is beyond the scope of this research to discuss these models in detail.

Important to note is that shared mobility and MaaS services are not supposed to replace well planned Public Transport (PT), but rather to support PT with an often more small-scale network of services. PT routes are still needed to efficiently move high numbers of people around in an urban area, but it can be supported by MaaS e.g. in increasing the accessibility of PT (Smith et al., 2018, p. 596).

### *Chain mobility*

The term chain mobility is closely connected to the concepts of shared mobility and MaaS. Chain mobility describes the increasingly evident fact that each journey by public transport requires the use of several modes of transportation. Chidambara (2019, p. 183) argues, that "[even] with a fairly expanded network of state-of-the-art transit systems criss-crossing the city, it is inconceivable to connect each commuter to his/her doorstep of home, office or elsewhere through it". Resulting from this, each trip with PT normally requires the user to use another mode of transportation, e.g. walking or cycling (Chidambara, 2019, p. 183). Although this has been true since the introduction of public transport, in recent years there has been a trend towards recognizing this fact and trying to improve the integration of different modes of transport (Goudappel Coffeng, 2019, p. 5). Chain mobility in specific then describes the integration of different modes of transport, so that the user can easily switch modes and trips consisting of several modes of transport become easier. In a well-integrated mobility system, the user can easily make use of all transport modes "in a chain". Chain mobility can support individual travel needs and on the other hand can assure that societal costs of mobility remain manageable (Goudappel Coffeng, 2019, p. 5). The term has a lot in common with other concepts discussed above, as it also includes solving the first-and-last mile problem by for example sharing vehicles.

### *The first-and-last mile problem*

The first-and-last mile is described as a "major component of a transit journey, and it determines whether transit service is reachable or not" (Zuo et al., 2020, 2). The accessibility to public transport is influenced by the distance between the user and the location, as well as the willingness of the user to walk or cycle (Mistretta et al., 2009, p. 12). Moreover, the attractiveness of the surrounding, the state of the built environment and the service availability can have a significant influence on whether a location is accessible or not (Chidambara, 2019, pp. 183–184). Acceptable walking and cycling distances are discussed in the literature, and the common idea is that a pedestrian should not have to walk more than 300 to 500 meters and a cyclists should not have to cycle more than five kilometers (Chen et al., 2019, p. 46; Flamm & Rivasplata, 2014; Kim et al., 2005, p. 529; Mistretta et al., 2009, p. 12; Murray, 2001, p. 581; Rietveld, 2000, p. 73). While from public transport stations, a connection with a range of different places within and outside of the city are accessible, the first-and-last mile problem describes the often lacking accessibility of public transport stations themselves starting from the residential places of users and the other way around (Chen et al., 2019, p. 45; Chidambara, 2019, p. 183; Wang, 2019, p. 131). A low accessibility of PT stations can lead to a reduced usage of PT, although the PT itself offers good connections, because of the inaccessibility of the station and the problems with reaching it (Chen et al., 2019, p. 45; Chidambara, 2019, p. 184; Wang, 2019, p. 131). Researchers have focused on this problem in recent years and are trying to find ways of "bridging" the last mile between PT stations and the destinations of PT users (Flamm & Rivasplata, 2014). Methods that are being tried out include offering shared vehicles such as bicycles or scooters, or on-demand bus services, which can increase the speed at which pedestrians move and thus their range within a given time (Adnan et al., 2019, p. 4721; Chen et al., 2019, p. 46; McKenzie, 2020). In order to solve the first-and-last mile problem, it is aimed at increasing the connectivity between PT and other modes of transportation (Adnan et al., 2019, p. 4722).

The first-and-last mile problem is one of the reasons why people keep using their private cars; if the alternative, e.g. the PT, is not accessible from their home, the travel time or inconvenience is increased. At this point, neighborhood hubs that are located in close proximity to the residents and provide access to multiple modes of transport can be a solution to the first-and-last mile problem.

#### *Micro mobility*

The term micro mobility is intricately connected to the first-and-last mile problem and the concepts of shared mobility and MaaS. There is no commonly agreed definition for the term, but micro mobility is often described as the usage of vehicles that enable short-distance mobility, such as shared bicycles, scooters or even cars (Deloitte, 2019; Euronews, no year; Forbes, 2019; McKenzie, 2020, p. 1; SEAT, 2019; Shared-use Mobility Center, no year, p. 3). It is the term used to describe the purpose of the shared vehicles, not the method or system used. For the current research, the term is neglected because of its vagueness, because it is somewhat synonymous to MaaS and because it is not used very often in scientific research, but was rather coined by the private companies providing the services. When it used, it is used as a synonym for describing the shared use of vehicles for short distances, thus as an extension to the shared mobility and MaaS terms at the micro scale.

### Conclusion

The four main concepts that have been discussed in the previous sections all add to the interpretation of the mobility function of a neighborhood hub. As is visible from chapter 1.1. and 2.1, the concept of shared mobility is an integral part of the hub concept. Neighborhood hubs can be the locations where shared vehicles of all kinds could be accessed by the local residents. With the implementation of hubs, the residents of a neighborhood can more easily travel "in a chain" making use of different kinds of modes. The journey can the start with the walk to the hub, where a person selects a shared vehicle or a parked private vehicle, or takes the PT if available, in order to continue the journey. Thereby, the first-and-last mile problem of especially residential neighborhoods can be solved. As the hubs provide easy and close access points to all kinds of transportation possibilities, also the transportation to for example the station is made easier.

Because the neighborhood hub is a "origin" hub, where people can start their journey and come back at the end of the day, as well as the position of the neighborhood hub in the hierarchy of hubs and the urban system, it is expected that there are a lot of small-scale and lighter vehicles needed for the residents in the long run. To come to the neighborhood hub in the morning and get back in the evening, it is expected that if the hubs are accessible enough, the residents will mainly walk to and from the hubs (ANWB, 2016, p. 21). Lighter vehicles in this context include things like (e-)bicycles, (e-)scooters, segways and other smaller vehicles that might be developed in the coming years (ANWB, 2016, p. 21; McKenzie, 2020, p. 1). Moreover, it is expected that people park their private car at the hub, especially in the beginning of the implementation, and would like to make use of shared cars at the hub. An offer of shared vehicles, partly electric, among which also shared cars, is expected to be one of the first functions implemented at a neighborhood hub. The proportion of shared cars can then grow in relation to the private cars. However, the exact mix of vehicles provided at the hub depends both on the needs of the local residents, as well as on the existence of a business case for a shared vehicle provider. The needs of the local residents can be influenced for example by demographic factors, the willingness to be active while travelling (bicycle vs. e-scooter) or the economic possibilities of the residents (McKenzie, 2020, p. 8).

An important potential benefit of neighborhood hubs could be the increased accessibility of goods, services, and everything else the inhabitants need in their neighborhood. This is on the one hand caused by the flexibility the shared mobility services offer, on the other hand the short distances between the neighborhood hubs could result in a higher density of diverse uses and services, which also increases the accessibility of these (Litman, 2020, p. 19; Monteiro & Campos, 2012, p. 643; Noland & DiPetrillo, 2015, p. 45; Wegener & Fürst, 1999, p. 6; Yigitcanlar & Kamruzzaman, 2014, p. 2122). Increasing flexibility of the user today is especially important, as needs and mobility patterns have become more diverse (Litman, 2019, p. 13). As the neighborhood hubs are not supposed to substitute good public transport, they can be organized in such a way that they support the existing public transport system and operate as a supplier of first-and-last mile services (Goudappel Coffeng, 2019, p. 5; Smith et al., 2018, p. 596; Zuo et al., 2020, 1). Moreover, as hubs are supposed to be placed in walkable distances to the residents, they can increase the accessibility of functions especially for groups of people who do not own a car (Koedood, 2020, p. 13). Due to easier transferring between modes, increased quality of stations and improved parking convenience for other modes, the transportation systems could be integrated better and thus accessibility could be increased (Litman, 2020, p. 13; Zaręba et al., 2016, 4). Especially for user groups such as people with disabilities, children, and people carrying heavy loads, neighborhood hubs could increase accessibility as they serve latent demand or make travelling easier (Litman, 2020, p. 13).

With all the concepts discussed above, one of the aims of a neighborhood hub is to provide more space in neighborhoods for other uses than cars. The additional space from a reduction of private cars can be used for other functions, such as UGS, playing grounds and more living space for the residents and therefore can increase quality of live and urban form in the neighborhood (Koedood, 2020, p. 11; MOMO Car-Sharing, 2010, pp. 79–81). Moreover, active mobility can be given more space, so that all user groups can use active modes of transportation such as walking and bicycling (MOMO Car-Sharing, 2010, p. 89). Active mobility is not only a flexible, convenient and healthy way to complete short and medium trips, but it also reduces congestion and air pollution (Adnan et al., 2019, p. 4721). Also the amount of hardened surfaces in the streets can be reduced and replaced by more natural surfaces, which can then for example improve the water runoff, reduce heat stress and increase biodiversity (Daisa, 2004; Lehmann & Mainguy, 2010, p. 6).

In conclusion, it can be said that the main characteristics of the mobility function of the hub include the position and relation to other "hubs" (e.g. big stations) in the transport system, the accessibility of the hub for the local neighborhood, the connectivity among different modes of transportation and the actual transport offerings and services (Bell, 2019, p. 4).

### 2.2.2. The societal function

The societal function of a neighborhood hub as conceptualized in this research mainly entails the presence of amenities and the fostering of social cohesion in the neighborhood. Both aspects are deeply connected to each other; the selection of the amenities present at the hub can have a significant influence on the social cohesion among the residents.

User facilities or societal functions of a hub can be planned in a lot of different forms and sizes, depending on the size and scale of the hub, and are, as Koedood (2020) argues, "context-driven". They generally aim at serving social, cultural and leisure purposes, while making daily trips more convenient (Bell, 2019, p. 4). They can entail all kinds of amenities from supermarkets, restaurants, drug or convenience stores, package delivery points, comfort amenities such as a water tab, a heated waiting room, an information point to community rooms, childcare or elderly care (Bell, 2019, p. 4; Koedood, 2020, p. 23; Monzón et al., 2016, p. 1125; Schutte, 2019, 25, 46-47). Aspects such as mixed use of the area, density and diversity can have a significant influence on the societal functions of a hub.

The statement that the functions at a hub are context-driven is an important one; it means that the functions cannot be chosen on any other basis than the needs of the local residents. This is of course also connected to the societal relevance of the research; if the functions are not chosen on the basis of what is needed in the neighborhood, the residents might not make use of the hub and then the investment into the hub was useless.

A societal benefit of neighborhood hubs could be the facilitation of local identity and the increase of social cohesion between different groups of local inhabitants (Zaręba et al., 2016, 4). In addition to restaurants, cafés and convenience stores, the neighborhood hubs can also provide other premises for local residents. This can turn the hub into a community center with meeting places and jointly organized events and can help to create a strong community (Blijham, 2009; Gehl & Koch, 2006, p. 59; Moussa, 2011, p. 14). In times of strong individualization and deteriorating communities, neutral places for organizing activities are of great importance (Ball & van der Kooij, 2004, pp. 5–7; Bovenhoff & Meier, 2015, 6, 19).

It can be said that the societal function of the hub is somewhat secondary to the mobility function. The mobility function is the main function of a hub, as it entails the basic idea behind the hub concept and it provides one of the main reasons for coming to the hub. However, the societal function is an important one too; if the residents find it useful to make use of the mobility function of the hub, the societal function is actually the function that makes a hub more than a parking place. The existence of all kinds of amenities can bring different people from the neighborhood together and can provide a place for community activities. Therefore, only the inclusion of the societal function into the hub concept can actually provide the neighborhood with the positive benefits for the society.

Therefore, the societal function a neighborhood hub can have, is depending on the presence of amenities at the hub, the social contact among the residents of the neighborhood ("the social structure"), as well as the physical structure of the neighborhood, e.g. in terms of physical and population density, parking pressure etc.

### 2.2.3. The energy function

The energy function of a hub is a twofold one: first, a hub can be not only the place to get a shared vehicle, but also to charge (shared) electric vehicles. Second, a hub can be a place where sustainable energy is generated and used for the neighborhood.

There are several potential benefits in the combination of shared mobility concepts and electric vehicles (EV) at a neighborhood hub. The electrification of cars is considered to be a potential driver for tackling climate change in the future as well as reducing noise and air pollution (Bünger & Michalski, 2018,

p. 113; Cooper et al., 2019, p. 36; Mwasilu et al., 2014, p. 502). Electric vehicles will become more widespread in the coming years and, depending on the development of the technology, charging options, fuel prices and policies, might become a reasonable alternative for many people on a wider scale within the coming decade (Fortune Business Insights, 2020; IEA, 2020; Kah, 2019; Valeri & Danielis, 2015, p. 44; Zhang et al., 2017, pp. 12–13). However, studies estimate that with this, the energy consumption per household might increase by 17-25 % (Mwasilu et al., 2014, p. 504). This increase of energy consumption will also mainly happen in specific peak times, for example in the afternoon when people come home from work. The exhaustion of the infrastructure can be avoided by charging the vehicles in an organized way at the neighborhood hub (Hu et al., 2016). By applying smart charging schemes, the cars could be charged at a time when the electricity network can cope with it (peak load minimization or peak shaving) (Moghaddam et al., 2018; Wirges, 2016, p. 60). Another benefit is that the costs of installing the charging infrastructure in the hub might be significantly lower than installing it in the individual households (Mwasilu et al., 2014, p. 511). However, this depends on the utilization rate of the vehicles and the fees applied (Wirges, 2016, pp. 131–132). Moreover, the possibilities of Vehicle to Grid (V2G) are currently explore in scientific research. V2G means that the EVs are charged, and their batteries are used as a buffer for the energy, which is fed back into the grid at another time. This solution can also be combined with the local generation of energy, which is then stored and fed into the grid at a suitable time, either in terms of capacity or economic advantage (Falvo et al., 2011, p. 2135; Mwasilu et al., 2014, p. 506; Wirges, 2016, p. 60).

The possibilities to generate energy locally, for example by implementing solar panels on the roofs for supplying EVs as well as potentially the neighborhood with sustainable energy, or using geothermal heat for heating of the hub and the neighborhood (Lützenberger et al., 2014, p. 781; Urban Design Studio, 2016; Zaręba et al., 2016, 4). Renewable energy generation is one of the focus areas in the coming years to make our cities more sustainable and thus should be integrated wherever reasonably possible. Also, the local energy grid can become more independent and stable. However, the reason that neighborhood hubs are especially appropriate for the generation of energy is that the parked EVs at the hub can serve as a battery for the neighborhood. Vehicle-to-Grid technology can be used to store the overcapacity of sustainably produced (solar) energy during the day and feed this energy back into the grid in the evening hours when a lot of energy is needed in the neighborhood (Hu et al., 2016; Moghaddam et al., 2018; Mwasilu et al., 2014, p. 502; Yilmaz & Krein, 2013) (more on this in chapter 5.1.2.).

An important aspect of the energy function of a hub is the connection to the energy network. The question is here how the connection to the energy network can be established in the most efficient way, spatially and financially. Spatially, it is for example not desirable to add many additional electrical substations into the residential streets. One idea is also the use the existing substations of the energy network as the starting points for the development of neighborhood hubs. If the charging of electric vehicles is centralized at specific spots within the neighborhood, then these spots need a good connection to the energy grid. The question is whether existing electrical substations can be expanded to serve as neighborhood hubs; whether this is possible in terms of space and whether it is desirable in terms of their locations. Moreover, it is important to find out which locations for neighborhood hubs would be the best for their connection to the energy network, if the electrical substations cannot be expanded to neighborhood hubs. Therefore, the potential of this combination is explored in this research and it is tried to find out how important it is to choose locations in proximity to the energy network in order to reduce the costs for establishing the connection.

The energy function is relatively new to the hub concept. It originates from the trend of the electric vehicles and the necessity to generate sustainable energy locally. It is, like the societal function, secondary to the mobility function, as it is not essential to what a hub in the original idea means. However, the combination can have much potential for the mobility function of the hub as well and might provide a possibility to cope with problems of the energy system in the future. Therefore, both aspects, the charging and electric vehicles and the generation of sustainable energy are included in this research and it is tried to find out what the potentials and problems are of integrating the function with the other two.

### 2.2.4. Conclusion

In conclusion, it can be said that the conceptualization of neighborhood hubs in this research contains three functions: the function of mobility, society and energy. These three functions have different levels of importance to the concept as well as they influence the concept in quite different ways. The mobility function is the most common, as it is the basis of the concept (Schutte, 2019, p. 8). However, it has become clear that connecting different societal and economic functions to the location of hub can significantly increase its success in a city or neighborhood (Bovenhoff & Meier, 2015, p. 5). Therefore, the three functions are used as the basis of the conceptualization and according to them, potential indicators for selecting a location were sought for in the literature.

## 2.3. Potential indicators for the selection of a location for a neighborhood hub

In the previous chapters, the concept of neighborhood hubs was introduced, explained in more detail, the research aim and questions were discussed, and the three functions of neighborhood hubs were explored. In this chapter, the question of which indicators are important for the functioning of a neighborhood hub as conceptualized in this research is answered. The indicators discussed here are derived from the literature review done during the research. The potential indicators that are displayed here are the following ones: (social) amenities, mixed use development, spatial density, the existence of public transport stops, Real Estate Prices, Proximity to new residential housing, Proximity to Heat Stress, Proximity to UGS, Demographic factors and Population density.

Table 1 on the following pages shows the list of the included potential indicators, which were used as a starting point for the expert interviews. The detailed discussion of each indicator can be found in Appendix 3. The indicators were then used as the basis for the development of the expert interviews.

*Table 1: List of included potential indicators*

<table>
<tr><th>Indicator</th><th>Description</th><th>Why is it important for a hub?</th><th>In what way can it be useful to the hub?</th><th>Importance according to literature</th></tr>
<tr><td rowspan="2">Amenities</td><td rowspan="2">Social amenities describe all types of services that inhabitants of an area need on a regular or irregular basis and that have potential to increase the social cohesion. Potential amenities are: Grocery stores, pharmacies, cafés / restaurants, package drop-off, fitness, meeting / conference rooms, community centers, other recreative functions, daycare, elderly care, schools.</td><td rowspan="2">Potential to increase the social inclusion, interaction and participation of inhabitants</td><td>Places with amenities are already visited, increase the usability of the places</td><td rowspan="2">Highly important</td></tr>
<tr><td>Disadvantaged areas with little amenities are better serviced</td></tr>
<tr><td rowspan="2">Mixed use development</td><td rowspan="2">Mixed use describes a type of urban planning that blends residential, commercial, cultural, institutional or entertainment uses into one space, where those functions are to some degree physically and functionally integrated, and that provides pedestrian connections.</td><td rowspan="2">Increased accessibility to different functions, increasing the usability of the places, improved transport options</td><td>Reputation and existing uses in mixed use places invite more people to visit for proximity</td><td rowspan="2">Highly important</td></tr>
<tr><td>Less mixed areas can become more mixed</td></tr>
<tr><td rowspan="2">Spatial density</td><td rowspan="2">Spatial density refers to the quantity of buildings within a certain measuring area.</td><td rowspan="2">More potential users of the hub, economic feasibility, more uses available, invite people to walk or cycle, increase interest in using mobility services of the hub</td><td>Scarce space implies a shortage of parking space, increase in interest in using mobility services</td><td rowspan="2">Highly important</td></tr>
<tr><td>Easier implementation in less dense areas</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| Demographic factors | Demographic data refers to the study of a population based on the factors such as age, race, and sex as well as socio-economic information (e.g. including employment, education, income, marriage rates, birth and death rates). | Place the hub in proximity to specific demographic groups that have the highest interest and / or need in / for a hub | Use representative “types” of people to identify the necessity and willingness to use a hub | Highly important |
| | | | - | |
| Population density | Population density refers to the quantity of inhabitants living within a certain measuring area. | Increase the amount of inhabitants using the hub, reduce attractiveness of car driving, increase attractiveness of walking and cycling | Areas with the highest density have more people to service. | Highly important |
| | | | Disadvantaged less dense areas are serviced more | |
| Public transport stops | There is a stop of a public transport line, e.g. of bus or rail, integrated or located in close proximity (e.g. within 100 meters) to the neighborhood hub. | Increase accessibility by more modes of transport, hub becomes interchange place, increase willingness for walking | Increase effectiveness of hub by adding another mode of transportation to the offer of the hub | Medium important |
| | | | Provide alternative nodes in the network, in order to cover more of the neighborhood in combination | |
| Real estate prices | The price of land and real estate at the location and in the surrounding area. | Indicate where major changes are going on, which areas are of high interest for investors | High prices indicate which areas are developing | Less important |
| | | | Low prices show areas where construction is more affordable | |
| Proximity to new residential housing | Newly constructed residential housing (e.g. apartments, houses) is situated in close proximity to the neighborhood hub. | Easier integration in planning and placement and construction of the hub, inhabitants can be invited based on the hub concept | Easier integration for proximity | Less important |
| | | | Not disadvantaging remaining parts of the neighborhood | |

| | | | | |
|---|---|---|---|---|
| Proximity to heat stress | There are streets or areas that suffer from heat stress within medium proximity (e.g. within 250 meters) of the neighborhood hub. | Potential for reduction of the impact of heat stress in the neighborhood | Reduction of heat stress by measures in the direct environment for proximity | Medium important |
| | | | Distance to heat stress reduces the potential for additional heat stress by the new building | |
| Proximity to Urban Green Spaces | There are urban green spaces such as parks, playgrounds or lawn in close proximity (e.g. within 100 meters) to the neighborhood hub. | Increase the attractiveness of the hub, increase the probability that people stay longer in the surrounding of the hub | Higher attractiveness for proximity | Medium important |
| | | | Potential for making less green areas more green for distance | |

*Note: This table displays the included potential indicators that have been derived from the literature review. The first column shows the name of the indicator, the second displays the chosen description. The third column gives an overview of why the respective indicator is important for the selection of a location of a neighborhood hub and the fourth column shows in what way the respective indicator can be useful to the hub. this column is subdivided for every indicator into whether the indicator as described can be useful, or whether maybe the opposite might be more useful (e.g. proximity vs. distance to heat stress). The fifth column shows the estimated importance of the respective indicator based on the literature review. The detailed discussion can be found in Appendix 3, as well as sources on the single statements.*

As visible from table 1, there were in total 10 potential indicators derived from the literature review. Each of the indicators has a specific reason why and in what way it could be beneficial to a neighborhood hub. The decision on which of these indicators should be included for the selection of a location for a neighborhood hub is taken on the basis of the opinions of the experts. Moreover, it is decided based on the expert interviews how important each of the indicators is and which of the two options of the in what way column is the realistic one. The description of the expert interview method can be found in chapter 3.4., while the results of the expert interviews on the indicators can be found in chapter 4.2.

## 2.4.Conceptual model

Based on all the aspects discussed above, a conceptual model was developed. It provides the theoretical backcloth and rationale for the current research and provides a framework within which the social phenomena can be observed (Bryman, 2012, p. 20). The conceptual model and preliminary indicators together form the theoretical background of this research. A conceptual model uses and explains key concepts and the relationships between them to provide a framework for the research (Singh, 2007b, p. 9).

The conceptual model was developed based on the three functions mobility, energy and society of the neighborhood hub and the derived potential indicators for selection a suitable location for a hub. It was asked which underlying aims lie beneath the discussion of the potential indicators. For the mobility function, the main aim to achieve with the hub is the accessibility for all modes of transportation and all users of the neighborhoods. For the society function, the main aim is the social connection among the residents and the inclusion and participation of all groups of society. For the energy function, the main aim is to connect the hub with the energy network in a way that is sustainable both for the hub, the mobility system and the neighborhood. However, it is not yet visible from the three functions and the underlying aims, how they are connected to the values in society. Based on the literature review, the potential indicators were derived, but it cannot be said until now whether these indicators are perceived as important in society and which ones are the most important based on the societal values. Therefore, an aim of the current research is to find out, how the three functions relate to each other, whether these indicators represent the values in society connected to a neighborhood hub or whether other indicators are added that represent other values. Moreover, it is tried to find out which of the potential and the indicators added by the experts are the most important for displaying the values that are connected to a neighborhood hub by society.

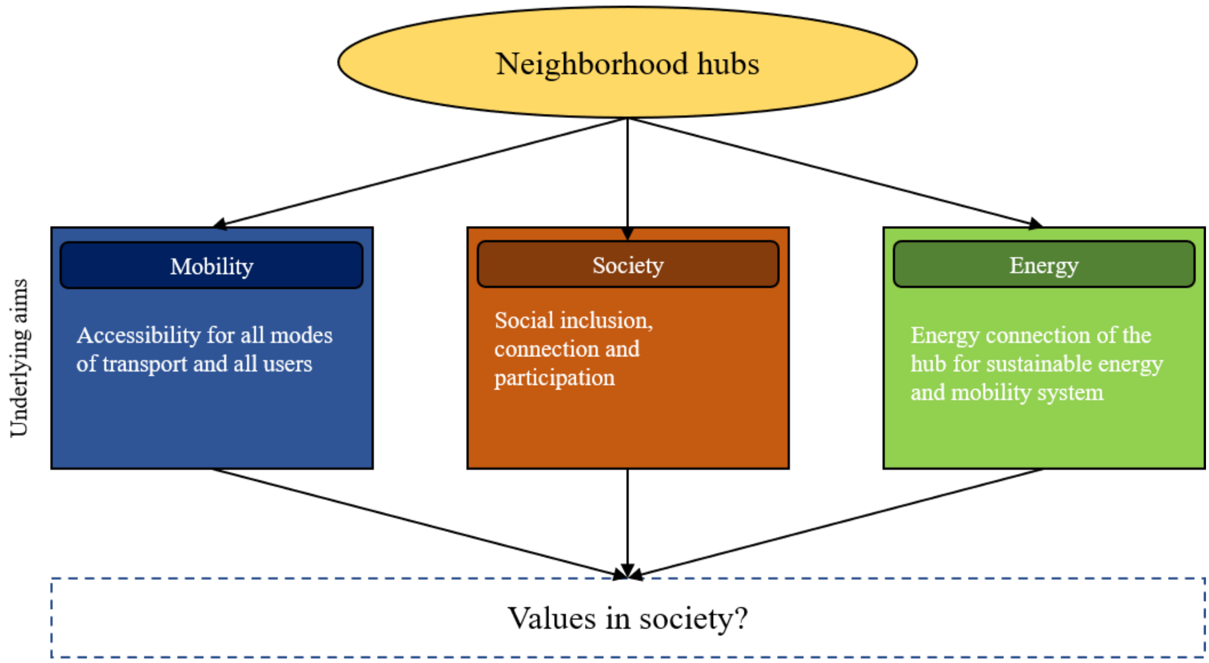


*Figure 4: Conceptual model of the research. Own presentation developed based on the three functions of a neighborhood hub and the potential indicators derived in the literature review phase.*

# 3. Methodology

In this chapter, the applied methods for answering the research questions are discussed. In chapter 3.1., the research strategy is outlined, and the preliminary analytical framework is explained. In chapter 3.2., the case study method is explained, and in chapter 3.3., the document analysis conducted is outlined. Thereafter, the methods of the expert interviews and the ranking are explained (chapter 3.4.). in chapter 3.5., the applied GIS analyses are outlined and finally, the validity and reliability of the applied methods is discussed.

## 3.1.Research Strategy

The research strategy is the overall design or logical procedure that will be followed and outlines how methods and techniques will be applied (van Thiel, 2014, pp. 56–57).

The research strategy of the current research (figure 5) was divided into four phases: The Literature Review phase, the Expert Interview phase, the Data Analysis phase, and the Desk Research on Results phase. The literature review phase was used to collect more information on the topic of neighborhood hubs and to derive preliminary indicators. From the preliminary indicators, a preliminary Analytical Framework was derived. In the Expert Interviews, the experts were asked general questions about the three topics mobility, energy and society in relation to the topic of neighborhood hubs and were asked to choose the most important indicators for selecting a suitable location for a neighborhood hub. Based on the results of the expert interviews, the final Analytical Framework was designed. In the Data Analysis phase, several GIS analyses were conducted to test the application of the method, to measure the five selected indicators and to display potentially suitable locations for neighborhood hubs in the case study. Afterwards, the results of the single GIS analyses for the five selected indicators were compared to the existing space in the neighborhoods and the possible connection to the energy network, in order to further estimate the potential of the selected locations. Finally, conclusions and recommendations were derived.

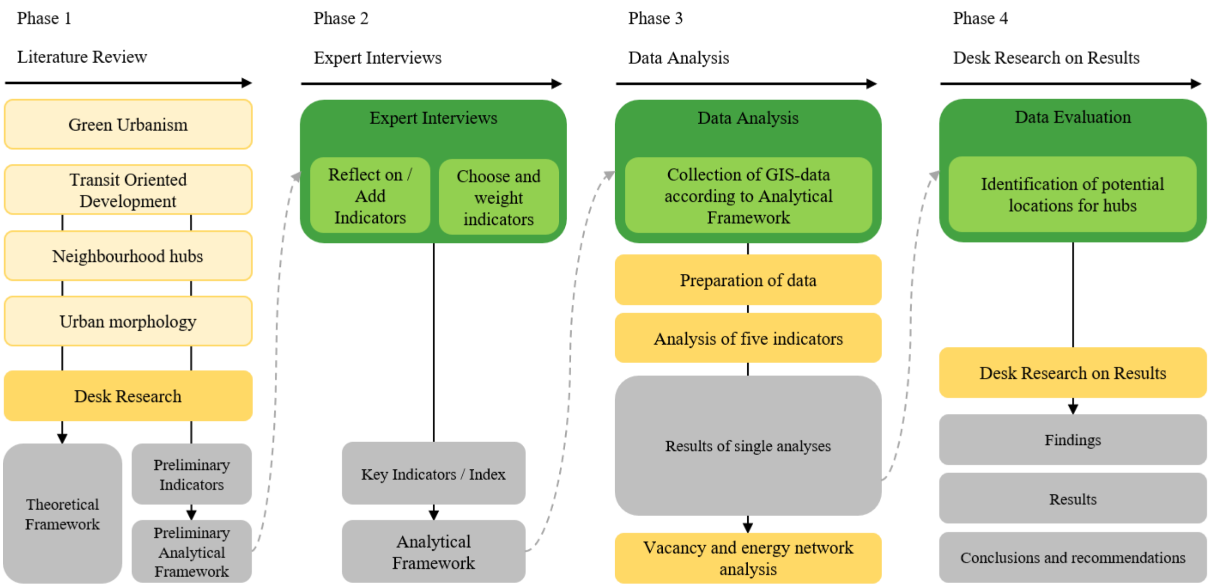


*Figure 5: Research strategy*

Figure 6 shows the analytical framework used in the research. The figure is based on the discussion of the potential indicators in chapter 2.3. and Appendix 3 and the underlying aims of the three functions in chapter 2.4. The figure displays the interpretation of the literature in relation to the indicators and is supposed to give a visual indication of the importance of the indicators and the relationships between them. Moreover, it shows how the underlying aims of the three functions relate to the potential indicators. The three aims are not included as potential indicators for the expert interviews as they represent the three functions of the hub (compare to chapter 2.4.).

As this research is more of the inductive kind in its approach and uses both inductive and deductive methods, this analytical framework can be understood as the starting point for a theory of location selection for neighborhood hubs. It is not intended as a final conceptualization, but as a first indication of the potential connections between the indicators among each other and the indicators and the underlying aims. The analytical framework is further developed, adjusted and added to in chapter 4.2.1. based on the results of the expert interviews.

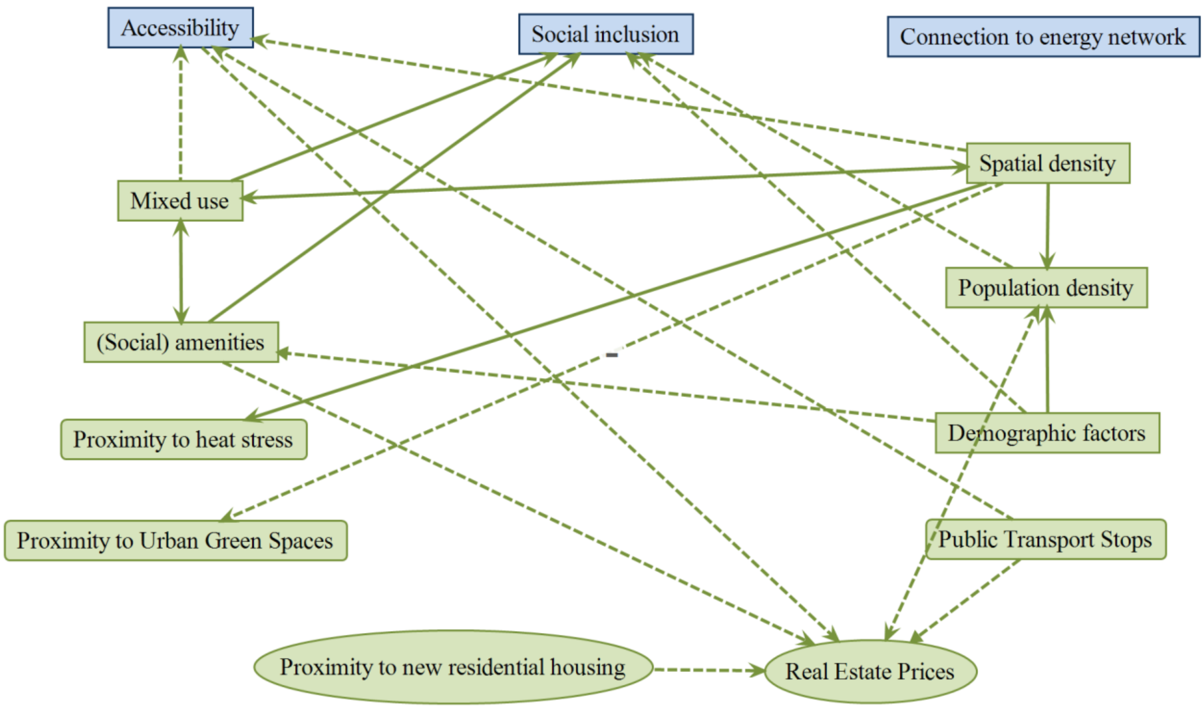


*Figure 6: Preliminary analytical framework of the research (based on own presentation). Visualization of the importance and relationships between the potential indicators according to the literature review. The form of the boxes displays the importance the potential indicator has according to the literature based on the frequency of mentioning and the place in rankings of potential indicators (if available). The square boxes are the most important, the boxes with rounded corners are the middle ones and the round boxes are the least important indicators. The arrows show the relationships between the indicators; the type of arrow shows the strongness of the relationship: the strongest relationships are reflected by a continuous arrow and the middle strong relationships are represented by a dashed arrow (there were no weak relationships found in the literature review). The aspects accessibility, social inclusion and connection to the energy network are not included as preliminary indicators; they are the three underlying aims of the three functions of a hub to which the different indicators relate to (compare to chapter 2.4.). In the course of this research, it is explored how the potential indicators relate to the underlying aims and which ones are the most important.*

## 3.2. Case study

In the current research, the method of case study analysis is applied. “Case study research is consistently described as a versatile form of qualitative inquiry most suitable for a comprehensive, holistic, and in-depth investigation of a complex issue […] in context, where the boundary between the context and issue is unclear and contains many variables” (Harrison et al., 2017, p. 12). However, there are several differing definitions of the case study approach, including more or less the same features but focusing on different aspects (Flyvbjerg, 2006; Merriam & Tisdell, 2016, pp. 37–38; Stake, 1995; Yin, 2014). A case can be defined as the unit of analysis or object of the study (Grogan Putney, 2010, p. 2; Harrison et al., 2017, p. 12). Typically, in a case study a lot of information is gathered about the case, where the focus lies on the depth of the information instead of the breadth (Grogan Putney, 2010, p. 2; Timney Bailey, 1992, 52-53). Also, a distinctive attribute of the case study is that the case study is investigated in context (Yin, 2014, p. 16). Sometimes, also the method of triangulation is applied in case study research, which means that different methods are used to double or triple check the results of the research (van Thiel, 2014, p. 52). With the application of case study research, it is tried to arrive at an explanation of the research subject in question (van Thiel, 2014, p. 87). The current research tests the developed methodology for finding suitable locations for neighborhood hub in the two case neighborhoods Kamperpoort and Assendorp in the city of Zwolle. The method of triangulation is also applied, as the three methods of literature review, expert interviews and GIS analyses are applied for the analysis of the case neighborhoods (Harrison et al., 2017, p. 9; Yin, 2014).

It was chosen for the method of a case study, because it is a very applied form research, where the researcher tries to contribute to the solution of a concrete issue (van Thiel, 2014, p. 86). As the topic of neighborhood hubs is relatively new and scientifically not very explored, the application of a case study is a way of gathering first insights about the topic. The results of the research can then be tested further and verified or falsified at a later stage in the research cycle. Case study research can be both inductive and deductive, which is exactly the mixture that is applied in this research as well (van Thiel, 2014, p. 86). Moreover, it was expected that a case study analysis would provide the researcher with sufficient depth of knowledge about the two case neighborhoods to select suitable locations for neighborhood hubs (Blatter & Haverland, 2012a, p. 5).

For the application of a case study in the context of the current research, a realist approach to case studies was chosen (Harrison et al., 2017, p. 9; Yin, 2014). A realist, or post positive approach was chosen for pragmatic reasons; it was expected to fit best with the research aim. It entails the quest for objectivity and generalizability within the research method, while acknowledging that all measurement is imperfect (Harrison et al., 2017, p. 9). In line with what Harrison et al. (2017, p. 9) state, the qualitative part of the case study research is applied in order to derive data that can be analyzed in a more quantitative way (the GIS analyses).

For the collection of information, both the literature review and the expert interviews were used. In the literature review, general information about the city, the location of the case neighborhoods within the city, the relationships of the neighborhoods with the other neighborhoods, the types of residents and the general climate were analyzed using policy documents. Moreover, it was analyzed which developments are going on currently and which are expected to happen in the future. In the expert interviews, more specific knowledge about the residents, their potential interest and willingness to make use of neighborhood hubs, their needs and wishes were discussed. It has to be noted however, that these aspects were not the focus of the research and were therefore not discussed in as much detail as one might be able to do.

For the case study, the two case neighborhoods Kamperpoort and Assendorp were analyzed. Both neighborhoods lie in close proximity to the city center of Zwolle and are densely built and populated historical neighborhoods. The two case neighborhoods of Zwolle were chosen because of several reasons. The city of Zwolle is an interesting case for the analysis of the mobility transition and the development of hubs. First, the city of Zwolle is one of the major centers in the North of the Netherlands, forming an important node for mobility of all transport modes (Gemeente Zwolle, 2019, p. 6). Moreover, the city is currently in an immense development driven by urbanization, migration, changes in the working market, climate adaptation and other factors (Gemeente Zwolle, 2020a, 34, 99). The two areas are very dense, inner city areas with high parking pressure and not a lot of space to organize parking. In both neighborhoods, there is currently and in the future a lot of development going on, where existing buildings are reconstructed in order to renew the neighborhoods[2] (Gemeente Zwolle, 2008, p. 52, 2020a, 34, 99). This provides an opportunity for testing the possibilities of alternative solutions, of which a neighborhood hub can be one. The case areas are therefore similar and the results can be compared afterwards (Blatter & Haverland, 2012b, 25, 27; Grogan Putney, 2010, p. 4).The development of inner city areas offers high potential for the implementation of the hub concept, as both the necessity of organizing mobility differently (e.g. due to space scarcity) as well as the interest in new solutions come together (Gemeente Zwolle, 2019, 8, 16). The city of Zwolle is interesting for this topic, as the province of Overijssel and the city themselves are especially interested in the combination of the mobility and energy side of the hub concept (Gemeente Zwolle, 2020a, 44, 82, 86; Provincie Overijssel, 2016, p. 2, 2019, p. 5). Connected to this is also the expectation of the municipality, that the two areas are growing more towards the inner city, therefore becoming an extension of the central city (compare to Appendix 11).

A more practical reason for the choice of the two case neighborhoods was that the mobility advisory office &morgen was conducting two projects in the two neighborhoods, with a focus on the restructuring of the mobility system in the neighborhoods. This allowed the researcher to combine the work for the advisory office with the research goals of the current research. Moreover, an intensive involvement with the planning in the areas and the ideas of the municipality was possible. Based on the work of the internship office and supporting their work, the current research was able to add additional information and a scientific view to the choice of locations for neighborhood hubs (van Thiel, 2014, p. 89).

## 3.3.Document Analysis

In the current research, secondary research data was used and recombined in order to answer the first research question. In three of the four phases outlined in the research strategy, document analysis / desk research formed an applied method for the current research. Desk research is an efficient and cost-effective strategy that re-uses existing data sources (van Thiel, 2014, p. 102).

In phase 1, secondary research data was used to theoretically explore the concept of neighborhood hubs, in order to form a conceptualization and understand the three functions of mobility, energy and society of a neighborhood hub, and to identify preliminary indicators for the selection of a location for neighborhood hubs. A review strategy was applied, which defined the goals of the review and helped the researcher to identify important keywords for the search for literature (compare to Appendix 4). The review question was: How are societal, mobility-related and energy-related functions represented by indicators in the public space in western cities? The review question was translated into search terms, which were used to find suitable literature both in scientific literature and in policy documents, last of which specifically in the Dutch context. The results of the search were collected in a search protocol, putting each title into a category (Appendix 5). Afterwards, the categories were screened for their relevance to the review question (Appendix 6). Of the screened sources, those were selected to be read that include information about at least one of the three chosen functions of hubs to identify which indicators are applied most frequently and why (van Thiel, 2014, p. 106).

The data of the desk research in phase 1 was processed using a modified form of content analysis. This method is used to establish facts and opinions about a topic. Based on the deductive structure of the three topics mobility, energy and society, codes were assigned inductively to the different contents in the three topics (compare to figure 7) (van Thiel, 2014, 108, 110). These were used to identify potential indicators for the selection of neighborhood hubs. The coding function of the literature management program Citavi was used for the coding (figure 7).

[2] A detailed description of the two case neighborhoods can be found in Appendix 11.

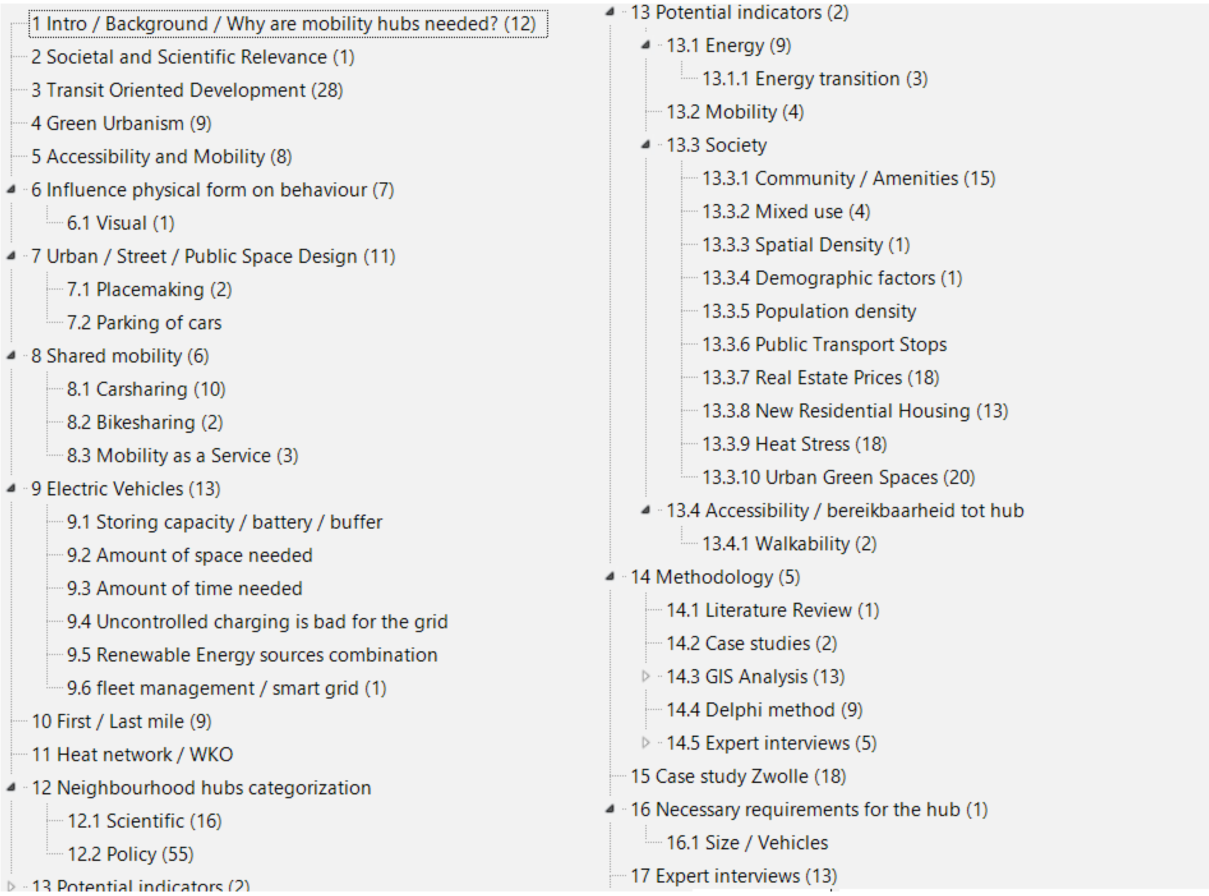


*Figure 7: Codes applied during the literature review in phase 1 (program: Citavi)*

Moreover, the results of the literature review were used to answer the question of what the size of an average neighborhood hub as conceptualized in this research is. This is important to know in order to evaluate the results of the GIS analyses as well as to base the search for the physical space in the neighborhoods on. The average size was determined analyzing the three topics mobility, society and energy according to their space request. For the mobility function of the hub, this was addressed on the lines of the following three key questions: Which types of vehicles will be needed?, how many shared vehicles are needed to sufficiently supply the inhabitants?, How much space is required for the parking and charging of the shared vehicles? For the society function, it was based on the estimated space requirements of small shops and on the opinions of the experts on the topic. For the energy function, it was determined on the space requirements of charging EVs and generating sustainable energy using PV panels on the roof.

In phase 3, desk research was applied by scanning scientific literature on information about the five selected indicators. Relevant information and data were gathered about the neighborhoods Kamerpoort and Assendorp according to the indicators. This information was used to identify a suitable method to measure the respective indicators in GIS (compare to chapter 3.5.). This analysis was done less systematic and the methods were selected based on their easiness of application, demand for accessible data and possibilities of the programs at hand. A more detailed description of the selected methods for the GIS analyses can be found in chapter 3.5.

In phase 4, desk research was applied to interpret the results of the GIS analysis and understand the feasibility of the methodology for finding suitable locations for a neighborhood hub. For this, additional background information as well as research to compare the results to was analysed in order to interpret the results of the GIS analysis.

## 3.4. Expert interviews

This sub chapter is structured along the lines of the data collection and the data analysis in the course of the expert interviews.

An interview as a research method is “a conversation during which the researcher gathers information by questioning one or more people (respondents)” (van Thiel, 2014, p. 93). Expert interviews are a qualitative research method often applied in case study research (van Thiel, 2014, pp. 93–94).

**Data collection**

Semi-structured qualitative expert interviews were conducted in phase 2 of the research and applied in order to gather more general information about the three topics in the case study areas, to receive feedback on the potential indicators derived from the literature review, obtain new indicators and select five indicators for selecting a suitable location for a neighborhood hub. expert interviews provide the researcher with the possibility to gain knowledge about a topic where only little systematic knowledge is available (Kallio et al., 2016, p. 2959). It was chosen for semi-structured interviews, because this interview-style allows for addressing both aims of the expert interviews, while still assuring comparability between the interviews, as well as enough flexibility for new ideas from the experts (Corbetta, 2003, pp. 7–8; McNamara, 2009; Turner, 2010, p. 755; van Thiel, 2014, p. 94). An expert is defined as someone with specific knowledge in the respective field (van Thiel, 2014, p. 178). Experts were selected using the method of purposive / quota sampling (non-probability sampling) on the basis of the following list of non-compulsory criteria: working in spatial planning or a similar field, specific knowledge in the field of one of the three topics (mobility-related, energy-related and / or societal functions), specific knowledge on the selected neighborhoods (having worked on at least one project concerning the neighborhood) or working at the municipality (Corbetta, 2003, 3, 6; Flyvbjerg, 2006, p. 231; van Thiel, 2014, pp. 45–46). Nevertheless, the contact to the interviewed expert was established by the supervisor of the researcher at the internship office, who has contact to a suitable range of possible experts due to the collaboration with the municipality of the case neighborhoods. There were twelve experts interviewed for this research, accounting for at least four experts for every topic. An overview of the characteristics of the interviewed experts can be seen in table 6 in chapter 4.1.

The interviews were done using video platforms like Zoom and Microsoft Teams and one time partly using the telephone. The interviews were recorded using the integrated recording tool within Zoom or the recording function of the phone of the interviewer. Afterwards, the interviews were transcribed by hand. The result of the transcription were interview reports for each of the expert interviews (compare to Appendix 12 to 34).

The expert interviews were structured in three parts: First, there was an introduction of about 15 minutes, in which the interviewer introduced herself and the research topic, questions and methods, as well as her conceptualization of neighborhood hubs. The presentation used for this can be found in Appendix 7. Moreover, in this part, the expert was asked to introduce him or herself to the interviewer and explain their job and relation of the job to the research topic. In the second part of the interview, the expert was asked a list of open-ended questions about the three topics mobility, energy and society. In the third part, the experts were first shown a MURAL board via screensharing and were asked to collect answers for a question that the interviewer did write down. Afterwards, the expert was invited to open a link to the MURAL board him or herself and was displayed a list of potential indicators and their definitions with the task to rank them in the order of their importance for selecting a location of a neighborhood hub. In total, the expert interviews were expected to last about one hour, which was only exceeded seldomly.

For the second part of the expert interviews, an interview guide was developed, containing a similar number of open-ended questions for each of the three topics mobility, energy and society (Corbetta, 2003, pp. 9–10; Turner, 2010, p. 756; van Thiel, 2014, p. 94). The interview guide was developed with the help of the interview guide development framework of Kallio et al. (2016, p. 2962) and with Turner (2010, pp. 757–758). The guide was developed in English and translated to Dutch for two of the expert interviews. The questions were asked in the three blocks of the three topics. It was chosen to move the block with the questions about the focus topic of the expert to the end of the first part of the interviews, in order to increase the interest of the experts, and to insure that despite the time constraints, the experts would be asked about each topic. It was expected that the questions on the two topics the expert would know less about would be discussed in less time, and that therefore more time would remain for the questions on the focus topic of the expert. However, in some cases the experts did start talking of one specific topic directly within their own introduction and it was therefore started with questions concerning this topic instead in order to make the interview as convenient as possible for the experts. Moreover, the wording of the questions was slightly different in the interviews, as they were adapted in the course of the respective meeting to the respective expert (Corbetta, 2003, p. 9). It was aimed for to ask all experts all questions, regardless of their focus topic, with different amounts of time spent with the different topic blocks. However, it was not possible to do that due to time constraints. Therefore, some experts were only asked about their focus topic and another topic block, but the third had to be neglected in order to conduct the MURAL board task. In total, the interview guides contained 9 to 15 questions for the second part of the interview, depending on the focus of the expert. Especially for the experts who were interviewed focusing on the energy side of a neighborhood hub, there were several additional questions on the topic of energy. Three examples of the interview guides for experts with the focus on the three topics can be found in Appendix 8 to 10.

For the third part of the expert interviews, the experts were asked about which indicators they find important for the selection of a location for a neighborhood hub without showing any keywords or answers (van Thiel, 2014, p. 106). After a list of potential indicators was collected by the expert, the expert was asked to open the link to the MURAL board him or herself. On the lower half of the MURAL board, the expert was shown the list of potential indicators collected from the literature review and from the earlier expert interviews and definitions of the potential indicators. The expert was asked to read the list of potential indicators and their definitions and afterwards select and rank five of the potential indicators according to their importance for selecting a location of a neighborhood hub. The expert was also allowed to use his or her own collected potential indicators in the ranking. After or while the expert was selecting the indicators for the ranking, he or she was asked to explain why he or she chose to select the respective indicators and why he or she chose to put them on the respective place in the ranking. An example of the MURAL board before the first expert interview is displayed in figure 8, while figure 9 shows the MURAL board after the method was slightly changed (more on this below). The filled in MURAL boards of all experts can be found in Appendices 13 to 35. The additional indicators that were named by the experts were included in the blank MURAL board for the following expert. Therefore, the list of potential indicators grew within the course of the interviews (see chapter 5.2.1. for the final MURAL board). All adjustments to the MURAL board in the course of the research, for example the addition of the new indicators, were noted down in the Expert Interview Adjustment Log, which can be found in Appendix 36.

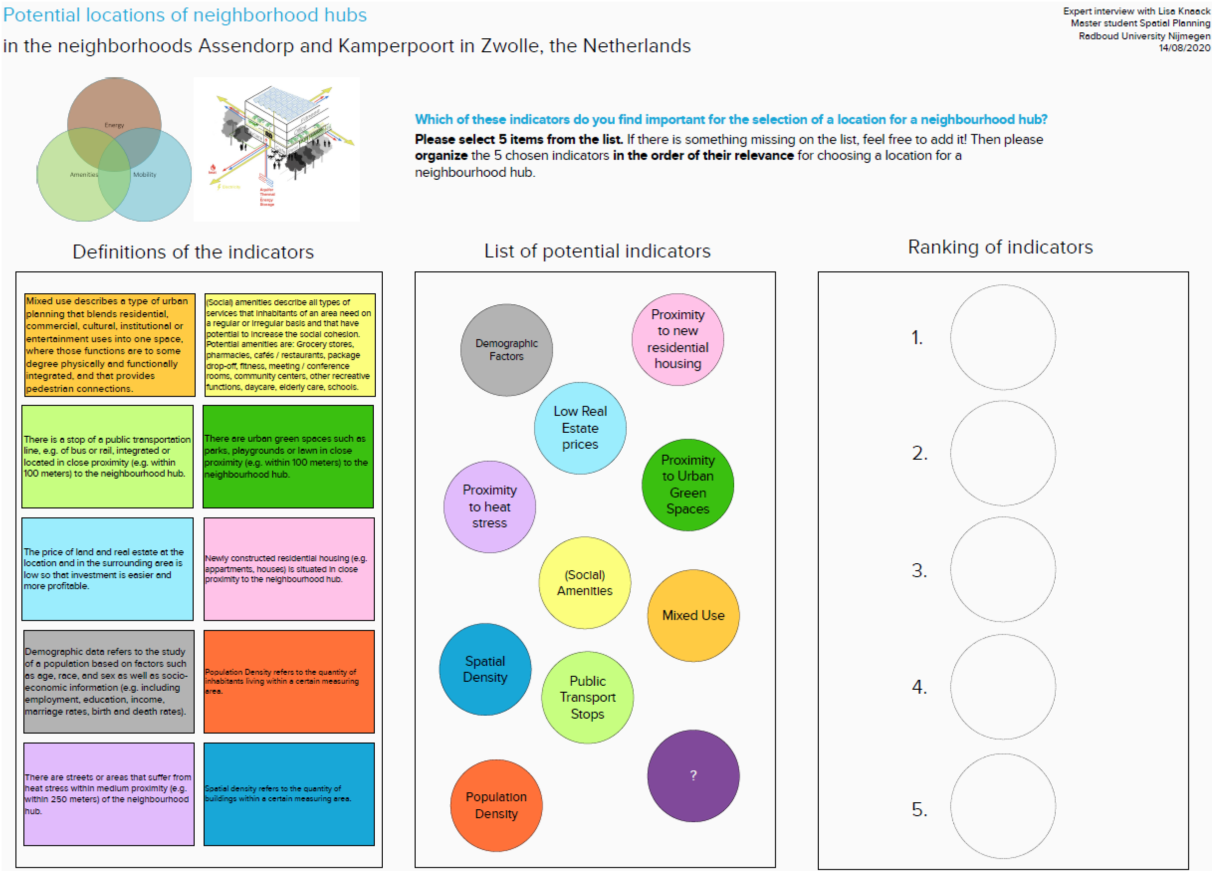


*Figure 8: MURAL bord before the first expert interview showing the list of potential indicators, the definitions of these indicators and the opportunity to rank the indicators.*

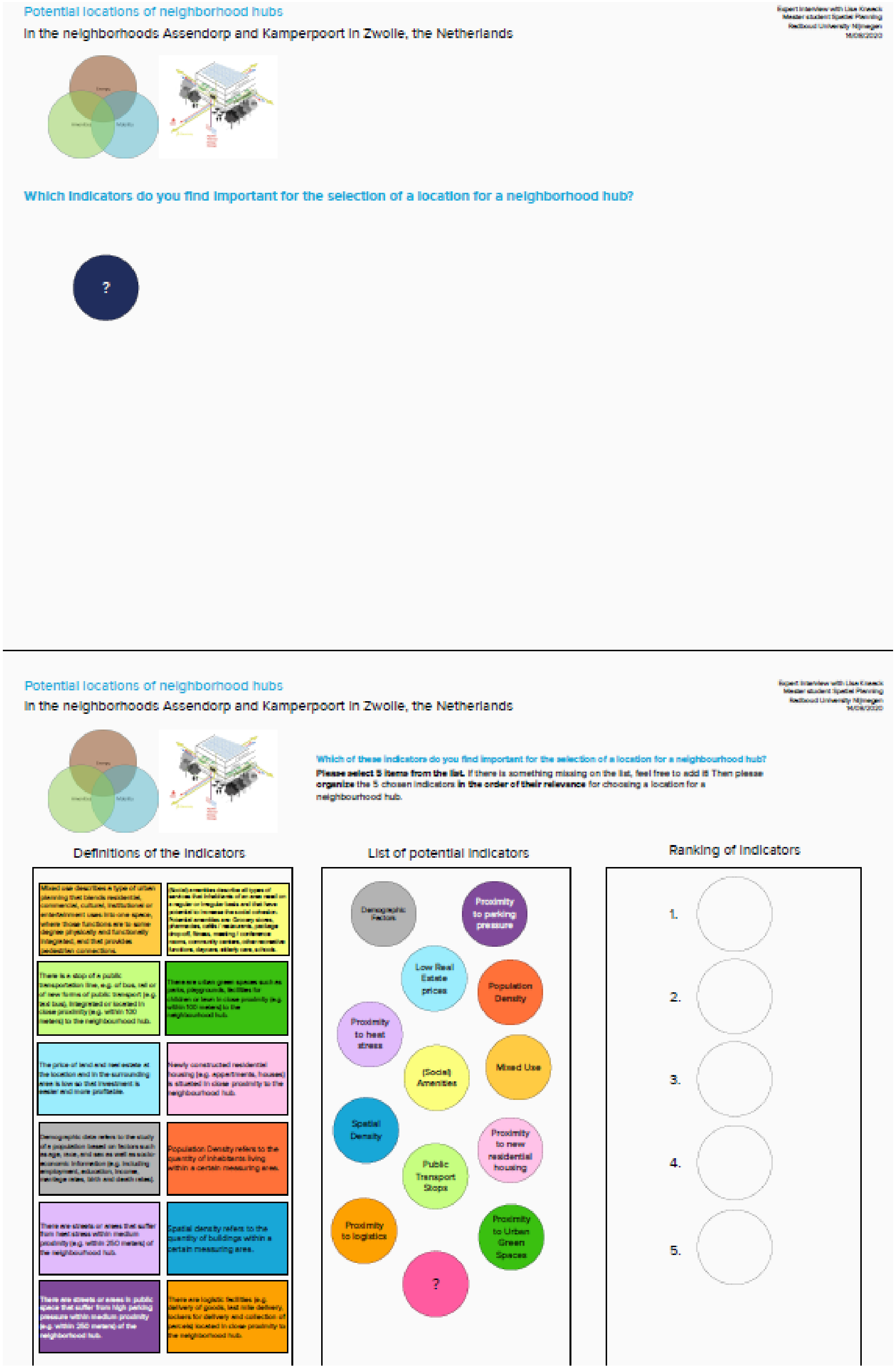


*Figure 9: MURAL board after the second expert. The method has been changed here At the beginning of the third part of the interview, only the upper part of the MURAL board was shown to the expert. When the question was answered, the expert was invited to open the link to the MURAL board and work together with the researcher.*

The method for the MURAL board is based on an adjusted Delphi method, trying to find out what the expert him or herself finds important without influence from other experts. The idea is that the expert first has to make up his or her mind him or herself about what he or she finds important and can afterwards compare his or her ideas with the list of potential indicators.

The Delphi method is a technique for interviewing a group of experts on a certain subject (van Thiel, 2014, p. 97). There is a range of different formats and ways to structure a Delphi based interview, but they all have some common characteristics (Linstone & Turoff, 2002, pp. 9–10; McMillan et al., 2016, p. 659). The method is only suitable for working with experts and is typically applied for trend analysis, scenario development or making prognoses (van Thiel, 2014, p. 98). In the standard written Delphi technique, the experts are sent a list of questions either by post or nowadays by email[3] which they are asked to answer and send back to the interviewer in the first round (Avery et al., 2005, pp. 4–5; van Thiel, 2014, p. 97). Sometimes, the experts are asked to answer open-ended questions, sometimes to choose between alternatives (Bayasari et al., 2013, p. 9; Cassar Flores et al., 2014, p. 1182). The interviewer then compares the answers and writes down for every expert for every answer, how he or she diverts from the opinion of the other experts. The document is then sent back to the expert, with the task of reading and potentially adjusting his or her own answers, if one is convinced by the argumentation of the other experts. This is repeated until a consensus has been reached. Sometimes, the study is finished with a group discussion or workshop on the topic (Linstone & Turoff, 2002, pp. 8–9; van Thiel, 2014, p. 97). Important in this method is that the experts never get to talk to each other about the questions in real life and stay anonymous in the process of finding consensus (Linstone & Turoff, 2002, p. 22). This method is often preferred above group discussions, because they reduce the effects dominant experts may have on less dominant parts of the group (Jay & Williams, 1966). The opinion of each participant is equally important in the discussion, without personal or character aspects interfering with the research.

The first question in the third part with the collection of indicators without any influence from a list of indicators, has only been adapted after the first two interviews had been conducted. Moreover, the addition of the new potential indicators named by the experts after each interview for the following expert has also been added after the first two interviews. The first two interviews were more explorative in their approach and after conducting them, the conclusion was drawn that a slight change of method would add to the depth of knowledge on the topic and would reduce the bias of the potential indicators on the experts. The changes were made despite the bias in mind, that a change of method can have on the research data. The two main reasons for the change are the following: First, a fuller range of indicators could be collected by always adding the new potential indicators to the list. It was hoped for that the list of potential indicators would grow to a bigger size than in the beginning, including all aspects that were important in the interviews. It was not expected that the list would be exclusive; however, it was hoped that with the list, a good overview can be reached of all the aspects that might be important to think of when searching for a location of a neighborhood hub. Also, the experts were confronted with indicators they did not think about themselves and could evaluate whether they think these are important. The second reason for changing the method is that the question before the expert is shown the list of potential indicators should reduce the bias from the opinion of other experts. The first two experts were directly shown the list of potential indicators from literature, which might have influenced their thinking. By changing the method, the opinion of the expert in question was asked before any other influence could happened from the side of the interview. With this, it was hoped to conduct the expert interviews as unbiased as possible.

**Data analysis**

The data analysis of the expert interviews was conducted in two parts: The open-ended questions of the second part of the interview were analyzed applying codes and analyzing the opinions of the experts according to the three different topics mobility, energy and society and the potential indicators already discussed in this part of the interview (van Thiel, 2014, p. 138). The ranking of the indicators from the third part of the interviews was analyzed using the coding scheme as well and calculating the most selected indicators and their order of relevance in Excel. Both methods, the coding and the ranking are explained in this chapter.

[3] The Delphi method is currently developing towards real time collection and presentation of the answers with the use of poll apps and other computer programs Aengenheyster et al. (2017); Linstone and Turoff (2002, p. 483).

***Expert interviews – Coding***

Applying codes to the interviews is a way of ordering the data for the analysis. A code is a brief summary of the main attributes or features of the unit [of information]" (van Thiel, 2014, p. 143). Codes can be deductive and inductive in nature, meaning that the deductive codes are based on the operationalization of the research question, while inductive codes are derived from the interview material (van Thiel, 2014, pp. 142–143). The method of coding is applied in order to structure the collected information according to the research question and to make it comparable for the analysis (van Thiel, 2014, p. 139). In contrast to what is stated in Corbetta (2003, p. 21), the analysis of the interviews is mainly variable based instead of case based. This is the case because the focus of the research are the indicators for finding a suitable location, not the experts who are used as a source of information on this topic. However, it has to be noted that each expert interview is still treated as a unity, meaning that the different quotes are analyzed in relation to the other things the respective expert said.

The coding scheme was developed partly deductive and partly inductive. A deductive coding scheme was developed on the basis of the second research question, which of the indicators can be selected as relevant for the research? Based on the codes used in the literature review (compare figure 7) and the interview questions (compare to Appendices 8 to 10), the list of deductive codes was organized according to the three topics mobility, energy and society and on the preliminary indicators derived from the literature review (Miles & Huberman, 1994, p. 9; Robson, 2002, p. 456). Additional codes were derived from the interview data in the course of the coding process, based on additional indicators that the experts named (van Thiel, 2014, 140, 143, 145). The coding scheme is displayed in Appendix 37, showing both the deductive and inductive codes used.

The codes were then used to describe the opinions of the experts on the inclusion of the three functions of mobility, energy and society within the concept of neighborhood hubs, and its application in the case study neighborhoods. Moreover, the codes on the indicators were used to adjust the analytical framework according to the opinions of the experts and to describe the reasons for choosing the five selected indicators in detail.

***Expert interviews – Ranking***

The outcome of the MURAL board task was, besides the transcribed text of the expert interviews, the ranking of the five most important indicators for each expert (compare to appendices 13 to 35). These rankings were transferred to an Excel table, assigning a different number of points to each of the ranks. The assigned points are displayed in table 2.

*Table 2: Assigned points for the ranks of the indicators*

| Rank | Points |
|---|---|
| 1 | 5 |
| 2 | 4 |
| 3 | 3 |
| 4 | 2 |
| 5 | 1 |

In several rankings, the experts chose more than one indicator per rank (compare to Appendices 15, 19, 23, 25, 33). These additional indicators were taken into account in the Excel table but were marked in orange to display their "double" status. Moreover, while adding the ranks of the selected indicators into the table, several decisions about which indicators to add and which to neglect if there were more than one indicator chosen for the rank had to be taken. These decisions are explained in the Expert Interview Adjustment Log in full detail (Appendix 36). The Excel table is displayed in table 3.

*Table 3: Excel table displaying the calculation of the final ranks of the indicators*

| Indicator | Expert 1 | Expert 2 | Expert 3 | Expert 4 | Expert 5 | Expert 6 | Expert 7 | Expert 8 | Expert 9 | Expert 10 | Expert 11 | Expert 12 | Sum | Sum clean | Standard d | Standard d |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Accessibility for all modes of transport | | | | 4 | | 3 | 5 | 3 | 5 | 2 | | 1 | 23 | 20 | 1,38505139 | 1,49071198 |
| Prox to parking pressure | | 5 | 3 | | | 1 | 1 | 5 | | | 1 | 3 | 19 | 18 | 1,66598626 | 1,63299316 |
| Mixed use | 3 | 2 | | | 5 | | 2 | | | 5 | | | 17 | 17 | 1,356466 | 1,356466 |
| (Social) Amen | 4 | | | | | 4 | 1 | 5 | | 3 | | | 17 | 16 | 1,356466 | 0,70710678 |
| Population De | 2 | 3 | 2 | | | 2 | 3 | | | | 5 | 4 | 21 | 14 | 1,06904497 | 1,16619038 |
| Draagvlak | | | | | | 5 | 4 | 4 | | | 4 | 5 | 22 | 13 | 0,48989795 | 0,47140452 |
| Demographic | 1 | | 4 | | | 5 | | | | | 5 | 5 | 20 | 10 | 1,54919334 | 1,69967317 |
| Ownership location | | | | 1 | 4 | | | | 2 | | 3 | | 10 | 10 | 1,11803399 | 1,11803399 |
| Public Transpo | 5 | | | | | | 4 | | 3 | 1 | | | 13 | 9 | 1,47901995 | 1,63299316 |
| Prox to new residential hous | | 1 | 1 | | 3 | | | | | | | 4 | 9 | 9 | 1,29903811 | 1,29903811 |
| Spatial Density | | | 5 | | | | 3 | | | | | | 8 | 8 | 1 | 1 |
| Prox to UGS | | 4 | | 2 | | | | | 4 | | | | 10 | 8 | 0,94280904 | 0 |
| Available space (vacancy) | | | | | | | | | | 4 | 3 | 2 | 9 | 6 | 0,81649658 | 1 |
| Prox to logistics | | | | | 2 | 3 | 1 | | | | | | 6 | 5 | 0,81649658 | 0,5 |
| Conciousness of necessity | | | | 5 | | | | | | | | | 5 | 5 | 0 | 0 |
| Proximity to electrical substations | | | | 3 | 1 | | 1 | 2 | 1 | | | | 8 | 4 | 0,8 | 0,47140452 |
| Interest of mobility companies | | | | | | | 4 | | | | | | 4 | 4 | 0 | 0 |
| Attractiveness of the hub itself | | | | 3 | | | | | | | | | 3 | 3 | 0 | 0 |
| Attractiveness of surrounding and route | | | | | | | 5 | | | | 2 | | 7 | 2 | 1,5 | 0 |
| Prox to heat stress | | | | 2 | | 1 | | | | | | | 3 | 2 | 0,5 | 0 |
| Safety | | | | | | 4 | | | | | | | 4 | 0 | 0 | #DIV/0! |
| Real Estate Prices | | | | | | | | | | | | | 0 | 0 | #DIV/0! | #DIV/0! |
| | | | | | | | | | | | | | | | | |
| "double" indicators | | | | | | | | | | | | | | | | |

*Note: The displayed numbers per indicators and expert show the assigned points, not the rank, the expert has given to the indicator.*

After adding the ranks to the Excel sheet, the sum of points per indicator was calculated. This method was chosen, as it both displays the importance of the indicator and the frequency of it being chosen. The highest number an indicator could possibly receive was 60, if all experts chose the respective indicator as the most important one. As visible in table 3, the sum was both calculated with and without taking the "double" indicators into account, in order to see what the difference would be (see: "sum" and "sum cleaned"). Moreover, the standard deviation per indicators was calculated, both including and excluding the "double" indicators. The standard deviation is a statistical method that displays the dispersion of a dataset relative to its mean (Singh, 2007a, p. 26). With this, in quantitative data analysis it is typically checked in how far the values differ from the mean value, therefore displaying how mixed the results are (Singh, 2007a, p. 26). Although the sample is not at all big enough to reach statistically significant conclusions, the calculation of the standard deviation was used to show in how far the experts agreed on the final ranks per indicator. Same as with the sum, the standard deviation was calculated both with and without taking the "double" indicators into account.

The result of this is a list of indicators sorted according to their relevance (both in terms of high rank and frequency of being chosen) for finding a location for a neighborhood hub, which is analyzed in chapter 5.2.

## 3.5.GIS analyses

Based on the results of the expert interviews and the ranking, the five key indicators were analyzed in a GIS system in order to select a suitable location for a neighborhood hub. For each of the indicators, it is explained in the following which data was used and how the analysis was applied. For this analysis, the version 10.7.1. of the program ArcMap was used. The data that was used is specifically outlined in the subchapters on the indicators, but the main sources were the Basisregistratie Adressen en Gebouwen (BAG), the basic registration system for addresses and buildings in the Netherlands, as well as the statistics of the year 2016 from the Centraal Bureau voor de Statistiek (CBS) of the Netherlands. Moreover, the information about the indicator parking pressure was provided to the researcher by the municipality of Zwolle.

In the following, the overall strategy used to analyze the indicators in the GIS system is outlined. The strategy applied is based on the selection strategy of locations for wind energy plants in the Netherlands and Germany (Aan de slag met de omgevingswet, no year; Agatz, 2018, 146, 261). There, inclusion / exclusion criteria for the placement of wind energy plants are defined by the legislation system (in the Netherlands for example the “regionale energiestrategien” (the regional energy strategies) or the “Besluit kwaliteit leefomgeving” (Decision on the quality of the living environment) (Aan de slag met de omgevingswet, no year) , and are respectively applied in order to select the areas where no exclusion criteria are present and therefore the locations for building the plants there can be further investigated.

For each of the five selected indicators, data that could be used to represent the respective indicator was gathered and displayed in ArcMap. For each of the key indicators, the criteria for the inclusion of an area were defined. This means that on the basis of the literature review and the expert interviews, it was possible to decide for each indicator on a range of values, above, below or between which the respective area would be suitable for locating a neighborhood hub. The features that fulfilled the inclusion criteria were then selected and saved in a new feature class. Then, for each of the indicators, a Euclidean buffer was created using the “Buffer” tool in ArcMap. For the buffer, a distance of 100 meters from the features was applied. This number was based on the expectation, that everything that should support the placement of a neighborhood hub would need to be in close proximity to it (compare to chapter 2.3.). The buffer zones display the areas with high potential for the placement of a neighborhood hub based on the respective indicator. Then the buffer zones of the four indicators were combined using the tool “Intersect” in ArcMap, which computes a geometric intersection of features or proportions of features which overlap in all layers (compare to figure 10) (ESRI, no year). This was done in order to show only the areas which were expected to be suitable for the placement of neighborhood hubs on the basis of the expert interviews.

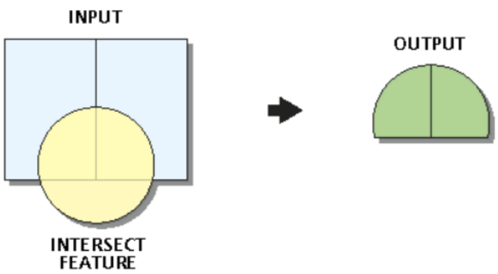


*Figure 10: Visual explanation of the GIS tool "Intersect". Modified after ESRI (no year)*

The remaining features displayed the potential areas for locating neighborhood hubs in the two case neighborhoods based on the key indicators. These areas were then analyzed concerning their potential for hubs in terms of vacancy and the connection to the energy network. The specific explanations of this can be found in the respective subchapters.

It has to be noted that the chosen strategy and methods for the single indicators were chosen on the basis of the easiness of application and the availability of the data. Except for the indicator parking pressure, all of the key indicators could be modelled using publicly available data or policy documents. The analysis strategy could as well be applied using more complex datasets or methods for the single indicators, which could increase the accuracy of the results. This GIS analysis is therefore only a first test of the analysis strategy.

**Indicator accessibility for all modes of transport**

The indicator accessibility for all modes of transport was selected as the most important indicator to take into account when searching for a suitable location for a neighborhood hub. According to the experts, it is important, that all modes can easily reach the hub, and also the hub should be located along strategic routes of the different modes of transport (Expert 10, 2020, p. 13; Expert 3, 2020, p. 13; Expert 4, 2020, 10, 13; Expert 5, 2020, p. 13; Expert 6, 2020, p. 5). Moreover, the hubs could be located at the crossroads, where different modes come together (Litman, 2020, p. 17). By this, the hub should be more visible for the users and would therefore have more use for them.

There are of course a lot of different methods to analyze the accessibility of a location, especially because it is conceptualized as consisting of other indicators as well (e.g. (network) connectivity, walkability, density, design, etc.) (Agampatian, 2014; Ewing, 1996; Geurs, 2018; Litman, 2020, pp. 16–21; Monteiro & Campos, 2012, p. 640; Rabiei-Dastjerdi et al., 2018; Rattan et al., 2012; Zuo et al., 2018; Zuo et al., 2020, 4). Most methods taken into account various modes and land use factors (Adnan et al., 2019, p. 4729; Coolbaugh, 2016, p. 56; Dong et al., 2006; Geurs & van Wee, 2004; Kaufman et al., 2014). The available methods can be differentiated e.g. by degree of detail, approach or format of the result. Moreover, different methods are often appropriate for different goals (Litman, 2020, p. 34). However, it was searched for an analysis method that would be relatively easy to apply and to combine with the analysis strategy for the other key indicators. As a lot of the methods available required a lot of data, computing skills, time or require a starting point, it was decided to use the very basic method of searching for the strategic routes of the four modes of transport in current policy documents and available datasets. Therefore, for each of the transport modes, the main routes within, to and from the two case neighborhoods were identified and labeled accordingly in the “Nationaal Wegen Bestand” (NWB), a dataset containing all roads within the Netherlands (PDOK, 2020).

For displaying the accessibility for all modes of transport, the main routes within the neighborhoods of the four modes of transport were derived from different sources and displayed. The current status of the routes was used, not including the planning for the coming years. This was done, because the planning or the visions are often not yet decided upon and therefore the analysis on the basis of the current situation appears to be the most sensible. In future applications of the method, also the plans for the future could be taken into account and it could be checked what the plans mean for the placement of neighborhood hubs. For the pedestrian, the strategic routes were derived from Gemeente Zwolle (2017, p. 97), Gemeente Zwolle (2020a, p. 77), as well as a presentation for internal use about the development of Assendorp provided to &morgen by the municipality of Zwolle. The strategic routes for cyclists were derived from Gemeente Zwolle (2020a, p. 77) and from a dataset about the regional bicycle routes available via PDOK Viewer (no year). For public transport, only the stops were included, as they form the access points to the public transport network. They were accessed via Gemeente Zwolle (2017, p. 99) and BISON (2018). And for the car, the main routes were derived from Gemeente Zwolle (2017, p. 97) and Gemeente Zwolle (2020a, p. 73).

For each of the four modes, a buffer of 100 meters was applied and afterwards the buffers were intersected, in order to find out at which locations the routes for the four modes come together.

### Indicator proximity to parking pressure

For the analysis of the proximity to parking pressure, the information was provided by the Municipality of Zwolle in the form of two maps of the case neighborhoods with an indication of the parking pressure (compare to Appendix 41). The map for Kamperpoort displayed the parking pressure in the neighborhood at different times of a weekday (Thursday), and at one time on the weekend (Saturday). The map for Assendorp that was provided only displayed the parking pressure without an indication of differences within the week or a day. This information was manually transferred to a file containing all roads within Zwolle, which was derived from the NWB (PDOK, 2020). For Kamperpoort, the parking pressure at a weekday (Thursday) in the time 23.00 hours to 01.00 hours was used, because this was expected to display the parking pressure due to the residents of the neighborhoods. Other time slots, like in the morning or afternoon, were expected to display parking pressure due to workers of the companies in the surrounding. From the expert interviews it was derived that the indicator parking pressure was chosen because of the residential parking pressure, not because of the parking pressure due to work (Expert 2, 2020, p. 10; Expert 3, 2020, p. 15; Expert 7, 2020, p. 14).

### Indicator mixed use

The indicator mixed use was selected as the third most important indicator for selecting a suitable location for a neighborhood hub. Neighborhood hubs should, according to the experts, be located in close proximity to existing mixed use areas (compare to chapter 5.2.3).

There is a range of different methods to measure and analyze, in how far an area has mixed land uses. Among others, the diversity of land use can be measured using the land use parceling, the proximity of residence and services, convenience, the connectivity from origin to destination point, urban zoning and the characteristics of urban density, services within the influence area or the number of shops within the surrounding area and the dissimilarity of the shops (Monteiro & Campos, 2012, 639-640, 643-644). Also, the diversity of an area can be measured as the “percentage of residents within walking distance of defined diverse uses” (Rattan et al., 2012, p. 30). There is a wide variety of research and policy documents focusing on how this indicator could be measured (Atlanta Regional Commission, 2011; Raman & Roy, 2019; Rowley, 1996).

In order to display the mixed use areas, the Mixed Use Index, originally developed by van den Hoek (2008), was applied. The MUI displays the share of residential use (“wonen”) in relation to the total space (“bruttooppervlakte”) of a building (PBL Planbureau voor de Leefomgeving, 2019, p. 13). The analysis of the MUI was conducted for the whole of the Netherlands by the Planbureau voor de Leefomgeving (PBL) in 2019 (PBL Planbureau voor de Leefomgeving, 2019, 2020). The data for the MUI provided by the PBL was displayed with different colors in ArcMap. A low MUI implicates a low share of living and a high share of other functions, while a high MUI implicates a high share of living and a low share of other functions (PBL Planbureau voor de Leefomgeving, 2019, pp. 31–32). Therefore, both high and low MUI display monofunctional areas. For displaying mixed use areas, a MUI between 0.45 and 0.55 was chosen (PBL Planbureau voor de Leefomgeving, 2019, pp. 31–32).

### Indicator (social) amenities

The indicator (social) amenities was selected as the fourth most important indicator for selecting a location for a neighborhood hub. Neighborhood hubs should be located in close proximity to (social) amenities according to the experts (compare to chapter 5.2.3.). Therefore, the more amenities are located in close distance to the preliminary spots, the better this spot is suited as a hub location. In order to display the (social) amenities, the data provided on the function of a building in the BAG was used. The BAG includes a whole range of functions in the category “gebruiksdoel” of the layer “verblijfsobject” (compare to Appendix 42). These were defined by the Dutch government in the Catalogus BAG and the

Bouwbesluit 2012 article 1.1 paragraph 2 (Bouwbesluit, 2012; Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2018, p. 126). On the basis of the discussion in chapter 2.3 on the indicator (social) amenities and the opinions of the experts, the following functions were included for the analysis of the amenities. A detailed discussion of the choice of the functions can be found in Appendix 43.

*Table 4: Included functions from the BAG for the analysis of (social) amenities*

| Function | Meaning | Examples |
|---|---|---|
| Meeting function (“bijeenkomstfunctie”) | Usage function for meeting people for art, culture, religion, communication, child care, providing refreshments for on-site use or watching sports. | Culture / community center, recreation, crematorium / cemetery, religious building, day care center, district / community center, auditorium, theater, casino, convention center, museum, exhibition / event hall, cinema, library, other cultural, cafeteria / snack bar, cafe, bar, restaurant, discotheque, other catering, stadium, grandstand, clubhouse, canteen. |
| Healthcare function “gezondheidszorgfunctie”) | Use function for medical examination, nursing, care or treatment. | Health care, hospital, outpatient clinic, medical day care, rehabilitation center, cross building, practice room for a doctor or therapist, other medical, nursing home, care home, institution for the mentally handicapped, psychiatric institution. |
| Educational function (“onderwijsfunctie”) | User function for teaching. | Educational institution, classrooms, lecture halls, course rooms. |
| Sport function (“sportfunctie”) | Usage function for practicing sport. | Sports hall, dressing (and toilet) building, recreation / sports center, indoor tennis court / ice rink / pool, sauna, other sports and recreation. |
| Shopping function (“winkelfunctie”) | Use function for merchandising materials, goods or services. | Department store, supermarket, travel agency, store, bank, gas station, prostitution, sex establishment, showroom, wholesale, showroom, kiosk, other retail, post office, hairdressing salon, pedicure, tanning salon. |

*Note: Based on Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2018, p. 126), article 1.1 paragraph 2 of the (Bouwbesluit, 2012) and Gemeente Amsterdam (no year).*

The chosen amenities were then displayed according to the size of their location in the map. This was done in order to show which amenities might invite more inhabitants to visit them than the others. It was thought about also using different buffer sizes for the different sizes of amenities. However, it was decided against doing this, because in the discussion of the indicator in chapter 2.3. and in the expert interviews, the focus was on a big number of diverse amenities, meaning that the more amenities of different types were there, the better. The size of the amenities could however also be an important factor, and it could be included in future research.

It must also be discussed how realistic and usable the category “gebruiksdoel” of the layer “verblijfsobject” from the BAG is for the analysis of amenities generally and in the two case neighborhoods. The function that is assigned to the respective building in the BAG is based on the function that the building has according to the environmental permit (“omgevingsvergunning”) (Kadaster, 2020). Thereby, only the interior rooms of the building are important, not the outside. There are several amenities for which it is not directly clear into which of the categories they belong, for example a veterinary clinic (healthcare vs. industry function) or a pharmacy (healthcare vs. shopping function) (Helpdesk Bouwregeling, 2015, 2017). Due to this, it might be the case that there are some amenities, which would have a positive impact on the social interaction, in categories that are excluded, and the other way around (e.g. the sex establishment in the category shopping). The categorization of the BAG is not as detailed as it would be useful for the analysis of the amenities. It would for example be useful if the shopping function or the meeting function could be split into different groups of shops or places. However, a more detailed analysis of the amenities would require immense work to gather the needed data, which was not possible within the scope of this research. Moreover, the current analysis is more of a test of the method and is not expected to be applied exactly like this in coming projects. Based on this discussion, it can be said that the data from the BAG has to be treated with caution, but it provides a good basis for the analysis of amenities in the process testing the method of finding suitable locations for neighborhood hubs.

**Indicator population density**

The indicator population density was selected as the fifth most important indicator for the selection of suitable locations for neighborhood hubs. Neighborhood hubs should be located in close proximity to areas with high population density (compare to chapter 5.2.3.). The population density can easily be calculated by dividing the number of inhabitants by the space they inhabit, possibly provided in square kilometers or hectares (Monteiro & Campos, 2012, p. 643). In order to display the population density, the full postcode statistics from the year 2016 about the Dutch population of the CBS was used (CBS, 2016b). The data is available at different scale levels, which differ in their degree of detail (municipality, neighborhood, area, block) (CBS, 2016b). In the dataset on block level, the category "inwoners_totaal" was used as a basis for the population density, as it displays the total amount of inhabitants living in the respective area (CBS, 2016a, p. 9). In the datasets, blocks with no values available or with a too small amount of inhabitants (privacy) had the value -99997 and were left uncolored in the map (CBS, 2016a, p. 7). The population density was calculated by dividing the number of inhabitants by the size of the land plots in square kilometers.

There are no reliable numbers available to decide from which density onwards a hub as conceptualized in this research might be economically viable. In the expert interviews, it was mainly discussed that the density must be high enough, without concrete numbers. Only one of the experts said that if there were only 500 people living around one of the hubs, that this would be too little for the functioning of a café at the hub (Expert 11, 2020, p. 5). According to Metrolinx (2011, p. 7), in the American context, population densities between 50 and 400 inhabitants per hectare are advised, depending on the size of the node (with 50 to 150 / 200 inhabitants per hectare for bus and regional rail nodes, which are the smallest in this categorization). In the study on mobility hubs of Burlington, a measure of 50 inhabitants per hectare for gateway hubs and a measure of 400 inhabitants per hectare for anchor hubs is used, as well as the 200 inhabitants per hectare measure of the Metrolinx (City of Burlington, 2014, p. 6). Although these numbers cannot be expected to be the same for the Dutch context, they can give a first indication. If these figures are converted to square kilometers, the result is 5,000, 20,000 and 40,000 inhabitants per square kilometer.

The statistics agency of the Dutch government uses the address density for displaying the urban character of an area (CBS, 2016a, p. 29). However, the categories applied there cannot easily be transferred to the population density, as the household size can vary within a neighborhood. In the "knooppuntenboek" of the province of Noord-Brabant, different measures are used for the categorization of the amount of inhabitants, occupational and apprenticeships, in the area within 1200 meters radius from the node (Provincie Noord-Brabant, 2018, p. 25). Converting these numbers to square kilometers, this would mean that for the second smallest node[4], the regional node, around 5526

[4] Only for the second smallest node, the regional node, they provide a number for the density. For the smallest node, the local node, they do not provide a number because they expect denitrification to be very difficult to achieve there Provincie Noord-Brabant (2018, p. 25).

inhabitants, occupational and apprenticeships per square kilometer would be sufficiently dense for the placement of a regional node.

As visible from the discussion above, there are no commonly agreed population density numbers for the placement of a neighborhood hub. This is of course the case because there is no commonly agreed definition of what a neighborhood hub entails; some categorizations do not even include the scale level of neighborhood hubs. As there are only the two mentioned estimates available, the value of at least 5000 inhabitants per square kilometer was chosen as the inclusion criterium for this analysis. This number was respectively applied in the analysis in order to define areas that have a high enough density for a neighborhood hub[5]. Whether this is a density actually applicable in the Dutch context has to be further explored in coming research.

**Presentation of the selected locations after the analysis of the five indicators**

After the buffer features of the five key indicators were intersected, the results of the analysis were displayed (compare to chapter 5.3). The legend shows the suitability for locating a neighborhood hub on the basis of the expert interviews and the GIS analysis in five scales: very high, high, medium, low and very low. From table 5 it is visible, how suitable which combinations of indicators are; the most suitable areas are the ones where all five indicators are present, while the areas where only four of the indicators are present are also still highly suitable. From this onward, the suitability is reduced with the exclusion of the indicators, resulting in the least suitable areas where only one of the indicators is present.

*Table 5: Measurement of suitability - explanation of the legend*

| Suitability | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Very high | x | x | x | x | x |
| High | x | x | x | x | |
| High | | x | x | x | x |
| Medium | x | x | x | | |
| Medium | | x | x | x | |
| Medium | | | x | x | x |
| Low | x | x | | | |
| Low | | x | x | | |
| Low | | | | x | x |
| Very low | x | | | | |
| Very low | | x | | | |
| Very low | | | x | | |
| Very low | | | | x | |
| Very low | | | | | x |

*Note: This table was developed by the researcher. On the basis of the ranking from the expert interviews, it is deducted that the five chosen indicators are ordered according to their relevance for selecting a location for a neighborhood hub. Therefore, combinations that include higher ranked indicators (e.g. indicator one, two and three) are expected to display a higher suitability than combinations that only include lower ranked indicators (e.g. indicator three, four and five).*

[5] Some of the selected plots based on the inclusion criterium were manually excluded from the selection, as the selected plots were cut into pieces by the selection process of selecting all plots within the two case neighborhoods. Because not all of the plots were fully lying in the area of the case neighborhoods, these were divided. However, after the division, the value for the number of inhabitants was still the same, while the area was significantly reduced. Therefore, these areas had a much higher population density than the original areas.

**Other aspects**

In the course of the expert interviews, two further aspects were discussed that were included for the further analysis of the areas with high potential for the placement of neighborhood hubs. These two aspects are the vacancy of the land and the connection to the energy network. Both were named as potential indicators during the expert interviews but were not ranked very high (compare to chapter 4.2. and Appendix 40). The reasons for their inclusion are outlined here. Vacancy was included because although it was not included as one of the very important indicators, it was discussed a lot in the expert interviews as a prerequisite of being able to place a hub. if there is not enough space available or can be made available, no hub can be placed there. The connection to the energy network is discussed for the areas with high potential for placing a hub, because the energy function is not represented very much in the selected indicators and it is expected that by searching for the best way of connecting the hub to the energy network, a lot of costs can be prevented.

These two aspects are however only included after the analysis of the five selected indicators, because they are in some way secondary; vacancy is of primary importance in so far as that if there is no space, then no hub can be placed there, but it is secondary in a way too, because there might be possibilities to create space where the most suitable locations are according to the indicators. The connection to the energy network is also secondary to the suitability of the hub, because the hub needs to have a position where it is functioning for the local residents, while the connection to the energy network is also important, but "only" costs more if the position of the hub is not ideal for it (Expert 9, 2020, p. 17).

***Vacancy***

For the analysis of the selected locations in terms of vacancy, the information from the BAG on the age of the buildings was used as well as the information available on Ruimtelijkeplannen.nl. The analysis for vacancy was conducted along two lines: First, the age of the buildings was displayed, as it was argued by the experts that very old buildings that might have to be renovated or rebuild in the near future might have potential for locating hubs (Expert 5, 2020, p. 13). Instead of rebuilding the plots to new houses, they could be rebuilt to house a neighborhood hub. Of course, the age of the houses alone cannot indicate the status of the houses. Also, older houses have a higher chance of having historical value for the city. Because of this, the cultural history map of the municipality of Zwolle was taken into account (Appendix 50), as well as the information from the "bestemmingsplannen" (the zoning plan) for the areas (Appendix 51) (Ruimtelijkeplannen, 2020). It was checked in the plans which functions the areas have, that are not fully built. Moreover, the areas were checked in Google Street View, where it was tried to evaluate the current status and function of the location (Google Maps, 2020).

Based on the vacancy evaluation of the areas with high potential, several areas could be selected that also provided enough space or where it would be possible to change the current use towards the placement of a neighborhood hub.

***Connection to the electricity network***

For the connection to the electricity network, a lot of information was collected in the course of the expert interviews (compare to Appendix 39). Moreover, a map was acquired displaying the high and middle voltage stations as well as the cables in between within the municipality of Zwolle (compare to Appendix 52). This map was provided to &morgen by the municipality. Unfortunately, no information could be found about the low voltage stations.

The map was used to evaluate the distance of the selected areas with high potential for the placement of hubs based on their potential for an easy connection with the energy network. For this, the distances between the selected high potential areas and the different middle voltage stations were compared.

## 3.6. Validity and reliability of the research

Reliability and validity are important aspects that influence the quality of the research and are generally more difficult to achieve with qualitative research (van Thiel, 2014, p. 51). Reliability is a combination of the accuracy and the consistency with which the variables are measured (van Thiel, 2014, p. 48). Accuracy refers to the measurement instruments, while consistency refers to repeatability of the study (van Thiel, 2014, p. 48). Validity can be distinguished into internal (cogency of the study itself) and external validity (extent to which the study can be generalized) (Gorard, 2013, p. 2). It mainly depends on sound measurement instruments and choosing the right sample.

**Case study**

Because the case study strategy focusses on only two cases, the added value of the strategy lies mainly in the wealth of empirical information instead of statistical testing of hypotheses (van Thiel, 2014, p. 92). Thus, the reliability and internal validity of case studies is high and the external validity and transferability is low (van Thiel, 2014, p. 86). Findings cannot be generalized easily, because the case is either unique or the results only apply to the specific context (van Thiel, 2014, p. 87). However, the findings of a case study can be "regarded as representative for other situations in the same research domain" (van Thiel, 2014, p. 89), if balancing measures are taken. Triangulation and keeping a research protocol to document the decisions that were made were applied in order to increase the generalizability of the case studies (Miles & Huberman, 1994; Timney Bailey, 1992, 52-53; Yin, 2014). Moreover, Flyvbjerg argues that the formal generalizability of research might be overestimated and that the detailed analysis of case studies leading to theoretical generalizations has had a significant influence on scientific research (Flyvbjerg, 2006, pp. 227–228).

**Desk research**

The desk research was applied based on the first research question and the derived review question. Moreover, the development of a review strategy, which provided the inclusion criteria for the literature, and the application of both a search protocol and a screening protocol in the course of the literature review was done to increase the reliability and validity of the method (Gorard, 2013, p. 8). It is expected that the literature review is reliable and internally valid, because the methods used in the literature review were documented and could be replicated by other researchers. However, the reviewed documents were not selected on the basis of a statistical selection, which means that the research might not be externally valid.

**Expert interviews**

For the evaluation of the validity and reliability of the expert interviews, different aspects have to be analyzed: First, the open-ended questions of the expert interviews, then the ranking, and also the adjustment of the method with the ranking in the third part of the interviews.

***Open-ended questions***

The method of expert interviews is generally high in accuracy, and thus in reliability, because it measures a lot of detail. In order to arrive at reliable and replicable results of the expert interviews, the interview guide was developed, which allowed the researcher to ask the same questions to the experts. The conducted expert interviews are however not always high in consistency, as not all experts were always asked all questions, and the experts were allowed to include the potential indicators listed by the other experts in their ranking, therefore changing the board that every expert saw (Turner, 2010, p. 755).

For addressing this issue, the experts were first asked about their personal list of potential indicators before showing them the list derived from literature and prior expert interviews. This was however only done after the first two expert interviews.

Expert interviews are generally high in internal validity, because a lot of information is collected, and low in external validity, because the number of interviewed experts is too low for statistically significant conclusions and the non-probability sample method is not representative of all comparable cases (Corbetta, 2003, pp. 5–6; van Thiel, 2014, p. 100). In this research, the expert interviews function as a verification of the preliminary indicators and thus it is important that they have a lot of internal validity. The conducted expert interviews have relatively high internal validity, as the questions for the interviews are based on the first research question, the theoretical framework and the literature review (van Thiel, 2014, p. 49). Therefore, the exploration of the potential indicators was based on theoretical discussions of the three topics mobility, energy and society and the concept of neighborhood hubs. However, it has to be noted that the internal validity also displays whether the research design is able to only measure what it is supposed to measure, and nothing is getting in the way (van Thiel, 2014, p. 49). It can be said that because of the semi-structured interviews, the verbal adjusting of the questions to the respective expert and sometimes leaving out questions due to time constraints, the internal validity is reduced (van Thiel, 2014, p. 52). Moreover, it has to be noted that the method of expert interviews altogether can become biased by the influence of socially desirable answers to the questions, instead of the real opinions of the experts (van Thiel, 2014, p. 52). Interestingly, this was even stated by one of the experts (Expert 12, 2020, p. 7). Although this bias could not be avoided, it is expected that the conducted expert interviews provide a relatively realistic picture of the indicators, as the experts were chosen on the basis of their experience in the field and their knowledge about the case neighborhoods.

***Delphi method***

As has been discussed in chapter 3.4., the Delphi method was adapted to the application in the expert interviews. How reliable and valid the method is, what the critique of the method is and why it is nevertheless chosen for this research is discussed in this section.

There is a wide range of critics on the Delphi method, of which not all are also applicable to the adapted version used in this research. The applicable critiques of the method are discussed in the following. An important critique of the Delphi method is also criticizing the expert interviews: it is the discussion about whether experts do have knowledge that goes beyond the average and whether they are therefore suitable as a source of information for predicting the future development of for example a trend[6] (Murray, 1979, p. 155; Welty, 1972, pp. 122–123). While this critique cannot completely be disproved, the experts interviewed in the course of this research are expected to be suitable sources of information as they have experience in the field of spatial planning and know the case study neighborhoods well. Moreover, they are not actually interviewed in order to give their opinion on a trend, but rather to select aspects that are important to be taken into account when searching for a location. Moreover, another critique is how the experts for the Delphi method are selected (Welty, 1972). The selection of experts can seriously bias the result towards a respective direction, which can render the research as non-scientific in the eyes of critics (Keeney et al., 2006, p. 208; Murray, 1979, p. 155). This critique can also not be completely disproved, as the experts were purposefully selected instead of a random selection. However, as discussed in the expert interview section, it is expected that the selection criteria ensure that the experts have enough knowledge about the topic and the case neighborhoods and represent the three topics mobility, energy and society. Another critique of the Delphi method is that the experts bias each other by reading the opinion of other experts, which also might reduce the quality of the results ; however, the idea of the method is to engage the experts in an anonymous debate on the topic and reach consensus exactly by

[6] Another critique connected to this is the question whether the questions within the method are not too ambiguous and whether they are interpreted in the same way by all experts Murray (1979, p. 154).

that (Powell, 2002, pp. 377–378; Salkind, 2010, p. 4). Moreover, as in this research the experts only see the other potential indicators named by the experts, but not the ranking of the other experts, they are not influenced in their decision as much as they would be otherwise. Another bias that is discussed in the literature is the danger that the researcher may misinterpret the opinions and statements of the experts (Keeney et al., 2006, p. 210; Murray, 1979, p. 156). The danger of this is tried to reduce in this research by having a virtual meeting with the experts, where they can explain their decision for the rank of each indicator. However, misinterpretation is a general problem of expert interviews and the Delphi method that cannot be completely prevented and can therefore reduce the internal validity of the research (Salkind, 2010, p. 4).

Having discussed the possible critiques of the Delphi method, it is explained why it is nevertheless chosen to make use of this method for the current research. The Delphi method is applied in an adjusted form, giving the experts the opportunity to react to the indicators collected both from the literature review and from the other experts. First, it provides the researcher with the possibility of collecting the unbiased opinions of the experts as well as making use of their common argumentation towards specific indicators. It is adapted because the experts stay anonymous, do not get to know what the opinion of the other specific experts on the topic or indicator is and still can be inspired by the ideas of the other experts. Second, the method allows for a result (the ranking) that can be used as a basis for the GIS analysis. The ranking provides the researcher with an indication of where to focus the analysis out of the multiple possible ways to analyze the case study areas. Moreover, the adjusted Delphi method could be conducted using separated online expert meetings, while methods such as group discussions would have made it more complicated to find a suitable time and date and this method would also not have kept the experts anonymous. The last point to discuss on the expert interviews is the question of how sensitive the results of the ranking are to mistakes that could alter the research findings (Gorard, 2013, p. 9). As displayed in table 2 in chapter 3.4, the results of the ranking differed between the version with and without the "double" indicators. Moreover, the relatively low number of experts means that each expert had a relatively big influence on the result of the ranking (Corbetta, 2003, p. 3). Therefore, it can be said that the ranking was very sensitive to change and additional experts might have changed the ranking into another order, which reduces the internal validity (Gorard, 2013, p. 9). In order to overcome this, it would have been needed to include more experts in the ranking task and leave out the in-depth open-ended questions.

***Change of the method with the MURAL board***

It has to be discussed moreover, which issues exist because of the change of the methodology. First, it can be said that the changing of the method towards the addition of the new indicators to the list after each expert interview is not expected to be a bias. This is because the first expert only selected indicators from the existing list and did not want to add new ones. The second expert did add new indicators to the list, but the method was changed after his interview and the third expert was then shown the new indicators from the second expert (Appendix 36). Second, it can be said that the addition of the question about which indicators the expert would find important first without showing the expert the list of potential indicators, is partly biasing the results of the expert interviews. The interviews are not completely comparable, because not every expert has been asked this question about his or her unbiased opinion before getting to see the list. However, it should not be such a problem, as at least both experts saw the same list of indicators, which was derived from literature. This list was unbiased still from opinions of other experts. The only bias happening is then that the first two experts might have been biased by the list of indicators shown to them and their "pure" opinion was not asked before. However, as long as the inductive research in its pure form is not conducted, there is always something forming the bottom line from where it is started. And, the list of indicators is based on the literature review (chapter 2.3.), which means that the first two experts are at least biased by scientifically proven aspects.

However, due to the change in method with the MURAL board, the consistency of the expert interviews is slightly reduced, therefore reducing the comparability of the third part of the expert interviews. This issue is discussed in more detail in the Expert Interview Adjustment Log (Appendix 36), but it is important to note that due to the general questions asked to the expert before showing the MURAL board and due to the fact that the MURAL board only showed indicators derived from literature and not yet from prior expert interviews, the bias of the first two interviews is reduced to a minimum.

Based on the discussion above, it can be concluded that the adapted Delphi method is relatively valid, but that there are several aspects that need to be taken into account when interpreting the results (Powell, 2002, p. 380; Salkind, 2010, p. 4). The reliability of the ranking is high, as the method of selecting was clear and consistent. Moreover, there is not such a high chance of bias as in the open-ended questions part of the interviews, because the ranking is very unambiguous. It is however important to see the ranking as a first exploration, which should be followed by a large-scale statistical evaluation of the opinions of, for example, citizens.

**GIS analyses**

The applied GIS analyses were conducted as an easy test of the results of the ranking in the two case neighborhoods. The validity and reliability of the method differs between the five indicators. For some, very easy but common methods based on research were applied, while for others, the available information from policy documents was used. For the first ones, the indicators mixed use and population density, high internal validity, generalizability and reliability are given, as the same method would achieve the same results when applied again and could also be transferred to other contexts. Moreover, both methods can be said to measure what they were supposed to measure. Especially for the indicators accessibility and amenities, the internal validity is reduced, because it cannot be said with complete certainty that the GIS methods measured what they should measure. As the information for the accessibility was derived from policy documents and manually transferred to the GIS dataset, the method is also not completely reliable. The researcher could have made mistakes or have interpreted the information differently than another researcher would. For the amenities, the information from the BAG was used, and it was already discussed that it is questionable in how far the information shows a realistic picture of the available amenities. Therefore, the internal validity is reduced for amenities, but the indicator has a high reliability and generalizability, because the method could be reapplied and achieve the same result, as well in other context. The validity and reliability of the indicator parking pressure is questionable, because it is not clear how exactly the information was collected by the municipality. Therefore, no assessment of the validity and reliability can be made.

The reliability of the buffer method of the analysis strategy is partly given, as the method could be easily repeated or transferred to another context. However, the accuracy is partly questionable, because there could for example be spatial obstacles in the way that were not taken into account in the analysis, that could bias the results. Moreover, the internal validity of the method could be reduced; the inclusion criteria for the indicators were based on scientific and policy documents, but sometimes there was just not enough information available on which criteria should be chosen. Therefore, it remains to question whether the buffer method actually showed the suitable locations. In general it can be said that the GIS analyses would need to be improved in order to arrive at overall generalizability and reliability.

**Conclusion**

In conclusion, it can be said that the current research does not offer external generalizability and validity as a statistical analysis would, but it does offer relatively high internal validity and reliability of an in-depth study of the search for suitable locations for a neighborhood hubs in the case neighborhoods. Through triangulation and keeping a research protocol, the quality, reliability and internal validity of the research was assured as much as possible. Moreover, it offers a starting point and a long list of potential indicators for the further development of theories about neighborhood hubs as well as the practical implications for choosing a location for hubs. Therefore, some general conclusions can be drawn for cities and neighborhoods with similar contexts.

# 4. Results

In this chapter, the results of the current research are displayed, discussed and concluded. First, the general results of the expert interviews[7] are outlined (chapter 4.1.), then the results on the ranking of the indicators are displayed (chapter 4.2.). Afterwards, the results of the applied GIS analyses are shown (chapter 4.3.). In chapter 4.4., the results of the research are discussed in the context of the research questions and the conceptual model, recommendations for future research and practice are formulated and conclusions are drawn from the research.

## 4.1.General results of the expert interviews

For the expert interviews, there were in total twelve experts interviewed, most of them working for or being rented in at the municipality of Zwolle. In table 6, the background of the experts as well as their focus topic within the scope of the research is indicated.

*Table 6: Information about the interviewed experts and their focus topic*

| Expert | Background / Position | Focus topic |
|---|---|---|
| Expert 1 | Electricity network expert, working at an energy provider | Energy |
| Expert 2 | Mobility strategist, Municipality of Zwolle | Mobility |
| Expert 3 | Advisor for mobility, Municipality of Zwolle | Mobility |
| Expert 4 | Mobility agent, self-employed | Society |
| Expert 5 | Energy advisor for the energy transition, Municipality of Zwolle | Energy |
| Expert 6 | Mobility and inclusivity planner | Society / Mobility |
| Expert 7 | Mobility strategist, Province of Overijssel | Mobility |
| Expert 8 | Advisor climate adaptation and energy, Municipality of Zwolle | Society / Energy |
| Expert 9 | Electricity network expert, working at an energy provider | Energy |
| Expert 10 | Neighborhood manager | Society / Mobility |
| Expert 11 | Board member of the societal organization 50 Tinten Groen | Society |
| Expert 12 | Manager Innovation at an ICT company | Mobility / Energy |

It is visible from the table that most of the experts were in some way associated with the Municipality of Zwolle. As discussed in the methods chapter, this is a bias that needs to be taken into account when determining the reliability of the results of this research. It was however tried to bring the perspective of other groups into the picture as well. For this reason, expert 4 and 12 were interviewed, as a representation of the wishes and needs of the inhabitants of the neighborhood. Expert 10 was also included in order to give a fuller picture of the local circumstances of the two neighborhoods. Furthermore, several of the other experts stated that they are living in Zwolle and partly even in one of the neighborhoods.

One of the results of the expert interviews is that after changing the method (compare to chapter 3.4.) and asking the experts their "unbiased" list of indicators first and showing the list derived from the

[7] The results on the open questions of the expert interviews can be found in Appendix 39.

literature review afterwards, some of the experts did not choose their own indicators anymore. It can be said that three of the remaining ten experts used most of their own indicators, while five used some of their indicators and two used none of their own indicators. These mixed results show that there is a range of aspects that might be important for determining the location for a hub, but that sometimes even one person is not consistent in his or her opinion on the relevance of the aspects. This was further shown by several of the experts hesitating to choose one indicator over the other or by a general difficulty of ranking the indicators in the order of their relevance (Expert 1, 2020, p. 13; Expert 4, 2020, p. 13; Expert 7, 2020, p. 14).

Moreover, there were several general aspects that were discussed in the course of the expert interviews and that will be discussed in short here.

First, it was discussed that the experts see the potential in the combination of the three topics mobility, energy and society. Although the combination between mobility and society seemed to still be relatively new, it was seen as quite "normal" to the hub concept in the perception of the experts. Several of the experts stated that they only see the hubs working as actual "hubs", if there are enough (social) amenities and meeting points present (Expert 10, 2020, 7-8, 13; Expert 4, 2020, p. 8). Expert 12 stated:

*"I really think it is a social point, it should be. Else it is not a hub, then it is a parking garage. If you want to make it a hub, different functions should intervene, so that you get a mix" (Expert 12, 2020, p. 9).*

However, the combination of the topics mobility and energy at the hub seemed to be relatively new to the experts and aroused interest and enthusiasm among them, despite several of the experts being doubtful about the implementation of the charging and loading with sustainably generated energy in the near future (Expert 10, 2020, p. 12; Expert 7, 2020, p. 4; Expert 8, 2020, pp. 3–4).

Secondly, it became clear during the interviews, that there is a specific hierarchy of the three topics mobility, energy and society for the experts. It was made clear that the mobility function is the central function of a neighborhood hub, and all other functions that could be added to it are secondary (Expert 7, 2020, 7, 10, 12). This also became apparent even if experts did not state it explicitly, as they often named the accessibility for all modes of transport as one of the first indicators to take into account, as well as discussing that their needs to be a demand for a hub for implementing it (Expert 11, 2020, p. 7; Expert 4, 2020, pp. 8–9; Expert 5, 2020, p. 13; Expert 7, 2020, 8-9; 11).

Thirdly, it was discussed by several of the experts that the hub should be no goal by itself, but that it should rather serve as a solution for specific problems in a neighborhood (Expert 8, 2020, p. 3). According to expert 12, a hub should be discussed as a potential solution like other solutions and the decision to implement a hub should be based on the problems and needs in place (Expert 12, 2020, p. 9).

The message of the experts seems to be that the focus should be at the solutions a hub can offer to the local residents, as an answer to the problems in the neighborhoods today. It is warned to follow the "hype" of the hub concept too much and forget about the original ideas and wishes with the concept. It was discussed in the interviews that the users' side is very important and has to be the ultimate focus area for developing a hub (Expert 12, 2020, p. 15).

Fourthly, one of the results of the expert interviews is that according to the experts, there is no "one size fits all" method for building a hub, but that for each location, a tailor-made solution of a hub must be put together (Expert 2, 2020, p. 5; Expert 7, 2020, p. 10; Expert 8, 2020, p. 16). It was often discussed that it does not have to be the same offer of shared mobility for example at a hub, and that there does not need to be a café at every hub. Sometimes, it would be sufficient to add smaller stations of shared bicycles to the neighborhoods, or make it a green space, or a community garden, depending on the needs and wishes of the local residents (Expert 10, 2020, pp. 6–7; Expert 11, 2020, p. 5).

Finally, the fifth general result is that the experts agree that there should be a kind of "grow concept" for the hubs in a city, in order to make them work and also grow to the vision that is created for them now. It was explained that one should start with very basic ingredients of a hub, such as shared mobility, in a small quantity, and then take little steps towards increasing the offer at the hubs (Expert 1, 2020, pp. 10–11; Expert 10, 2020, pp. 8–9). With this method, it is expected that one can see which amenities and functions work in that specific neighborhood and build upon these experiences. Moreover, this allows to nurture the inhabitants of a neighborhood or city to slowly adapt the new behavior of the sharing economy (Expert 10, 2020, p. 9).

There is however also a point where the experts do not agree: the perception of what exactly it is, that makes a hub. Some of the experts think that the connection with public transport is essential to the neighborhood hub, while others see them as secondary, and some experts think that including parking spots for the private vehicles of the residents is important, while others see them more as an addition or even a issue that can reduce active mobility (Expert 1, 2020, p. 14; Expert 2, 2020, p. 12; Expert 3, 2020, p. 15; Expert 6, 2020, p. 8; Expert 9, 2020, p. 22). Moreover, some experts neglect the energy function of the hub relatively much, which can also be the case because the technology needed for this is not commonplace and there are uncertainties about its application (Expert 10, 2020, p. 12).

A topic that was also discussed in the course of the expert interviews was the difficulty of implementing the hubs. The experts stated that due to the novelty of the concept, most municipalities did not do anything like this before and it is therefore a struggle of finding ways to engage with stakeholders, search for business cases and find out how to finance the hub (Expert 4, 2020, p. 16; Expert 6, 2020, 7-8, 10; Expert 7, 2020, 4, 5, 9-10; Expert 8, 2020, pp. 3–4). The experts think that the way of acting of the municipality has typically been reaction, thus reacting to a request or problem that occurred. However, the planning of hubs requires proactive action and this is not normal work for the municipality and does also not work well in the current structures (Expert 5, 2020, pp. 9–10). Moreover, it is not actually expected by some of the experts that the municipality themselves implements the hubs, but rather that they provide the space for it and organize the process with the stakeholders (Expert 8, 2020, pp. 3–4). It was discussed that with more stakeholders, it becomes more difficult to get everyone on board and to reach a compromise that is pleasing everyone (Expert 3, 2020, pp. 3–4). However, with all the stakeholders, the question is how the hub can actually be implemented, who is taking the lead, what is the role of the municipality and the province (Expert 7, 2020, pp. 9–10; Expert 8, 2020, 3-4, 6, 14). Moreover, the difficulty of implementing the hub also depends on the insecurities concerning the development of technology such as EVs and V2G, the planning of the energy providers and the willingness to participate in the changes of the inhabitants (Expert 5, 2020, 6, 9). The experts also displayed differing opinions and knowledge about the current development status of concepts such as V2G or charging with PV panels, ranging from thinking it is not possible yet to thinking it is technically possible, but that it lacks the organizational structures to be implemented (Expert 10, 2020, p. 12; Expert 12, 2020, p. 10). Especially for the engagement and the *draagvlak* of the local residents, it is important to the experts that a clear vision is provided for the future of the neighborhoods and the role of the hubs in the neighborhoods (Expert 4, 2020, p. 11).

## 4.2. Results of the ranking of the indicators

In this chapter, the results of the ranking of the indicators are displayed and discussed. First, in chapter 4.2.1., the full list of the potential indicators is discussed. In chapter 4.2.2., the results on the five selected indicators are discussed in detail. A detailed discussion of the other indicators can be found in Appendix 40.

### 4.2.1. Full list of the potential indicators

In this subchapter, the results of the ranking of the indicators by the experts are displayed and discussed. The experts were allowed to choose from the list of potential indicators as well as add new indicators to the list and also select them for their ranking. The final list after all expert interviews is displayed in figure 11. The final list of all indicators with the respective definitions can be found in Appendix 38. In figure 12, an example of the MURAL board of one of the experts is displayed. All filled MURAL boards can be found in the Appendices 13 to 35. In figure 13, the results of the cleaned ranking are displayed.


*Figure 11: Final list of potential indicators. The list is based on the preliminary indicators derived from the literature review and was added to in the course of the expert interviews.*

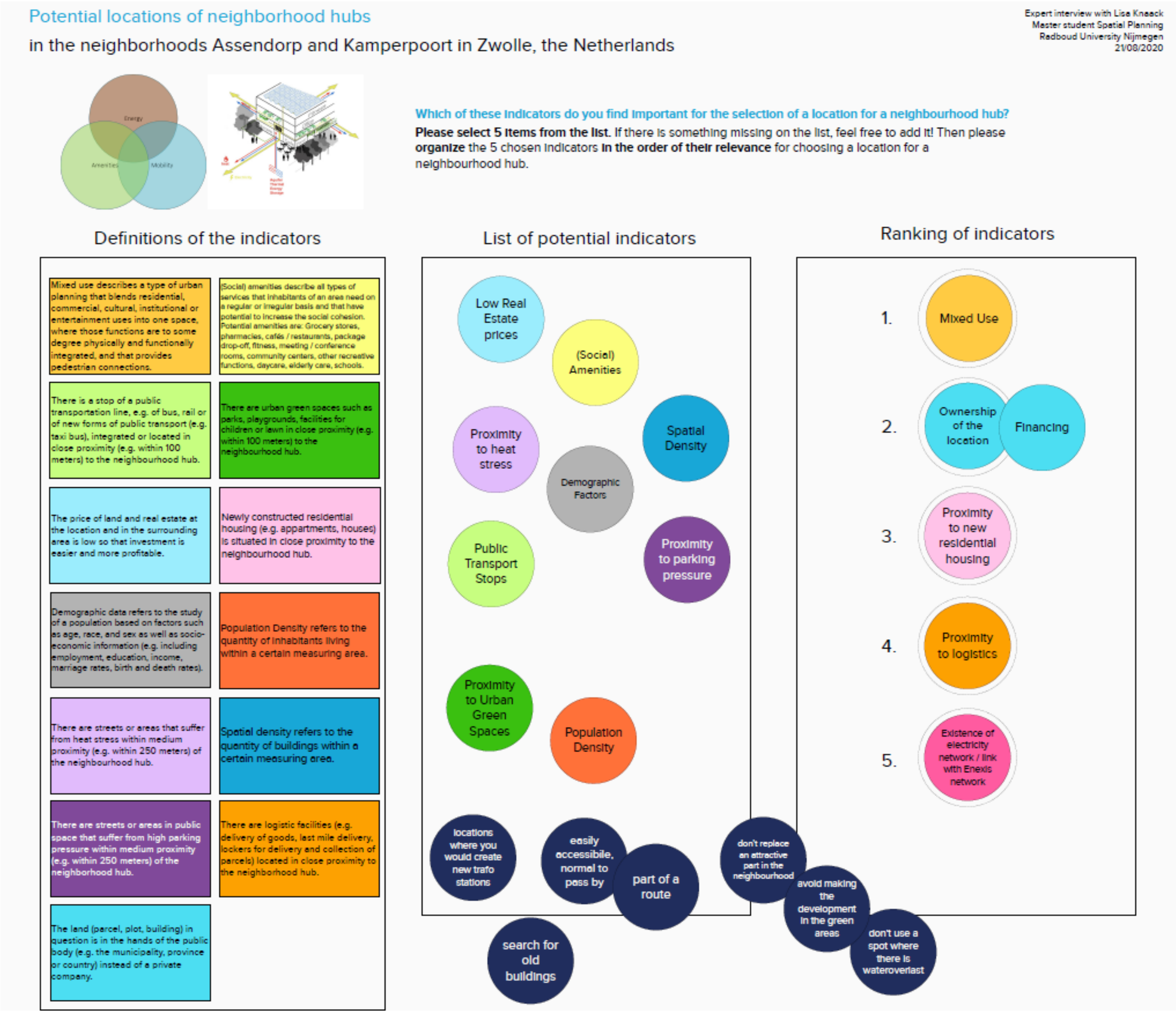


*Figure 12: Lower part of the MURAL board with the ranking of expert 5*

First, it can be said that according to the ranking of the interviewed experts, the five indicators Accessibility by all modes of transport, Proximity to parking pressure, Mixed use, (Social) amenities and Population density in this order are the most important indicators to take into account when searching for a suitable location for a neighborhood hub. Moreover, it is directly visible from figure 13 that the selection of these five indicators is not a clear-cutting selection by all experts that distinctively shows the major difference in importance between the indicators. The final ranking rather displays a picture of a lot of aspects that were relevant to the experts to different degrees instead of distinctive single winners. This can mean that besides the higher importance of the five highest ranking indicators, the other indicators are not to be neglected as influence factors for selecting a suitable location. It was stated by several of the experts, that the ranking would display the most important indicators in their opinion, but that the other indicators were as well important to have a look at when searching for a location for a neighborhood hub (Expert 1, 2020, p. 13; Expert 2, 2020, p. 12; Expert 9, 2020, p. 22). The experts wanted to make clear that they did not neglect these topics, but rather that the ranking is a selection of the most important aspects. Those experts also claimed that for a proper selection process, almost all of the indicators would need to be taken into account (Expert 11, 2020, p. 8).

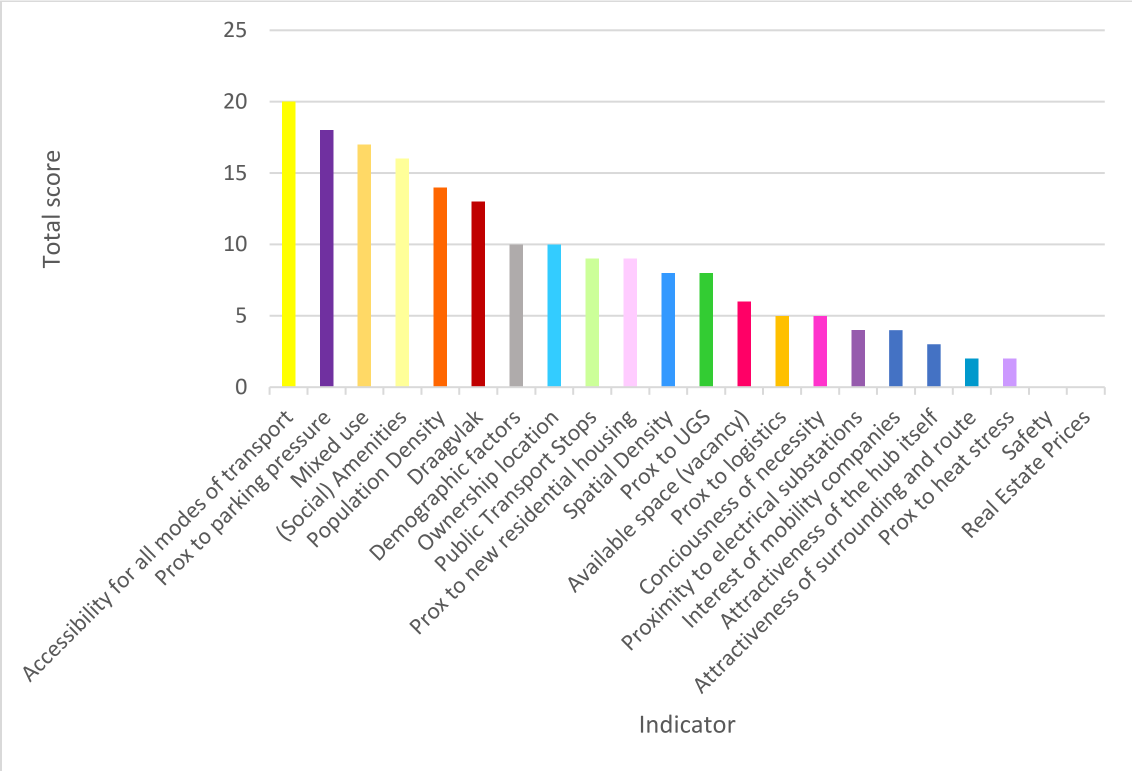


*Figure 13: Results of the ranking of the preliminary indicators displaying the total score per indictator. The ranking displayed here is based on the cleaned results from the Excel calculation, not taking the "double" indicators into account. The colors have been chosen to match the colors from the MURAL board and have no further informational value.*

In table 8, the total scores and the standard deviation of the five selected indicators is displayed. The results for all indicators can be seen in table 3 in Chapter 3.4.. The standard deviation is used here not to come to statistically significant results, but to get an indication of how much the views differ on the respective indicator. As a comparison, the values for the Proximity to electrical substations are displayed, as it is the indicator with the lowest standard deviation that is not zero. Especially in comparison with the indicator Proximity to electrical substations, it can be said that the five most highly ranked indicators have a relative high standard deviation, implying that the experts have different opinions on the importance of these five indicators. The indicator with the highest standard deviation is Proximity to parking pressure, showing that despite of their agreement on the indicators' importance, the experts disagree on its level of importance. The indicator with the lowest standard deviation is (social) amenities, showing that it is generally more agreed by the experts on the rank of the indicator on the fourth rank.

*Table 7: Total scores and standard deviation of the five selected indicators*

| Indicator | Total score | Standard deviation |
|---|---|---|
| Accessibility for all modes of transport | 20 | 1.491 |
| Proximity to parking pressure | 18 | 1.633 |
| Mixed use | 17 | 1.356 |
| (Social) amenities | 16 | 0.707 |
| Population Density | 14 | 1.166 |
| … | … | … |
| Proximity to electrical substations | 4 | 0.471 |

**Adjustments of the analytical framework according to the experts**

In the following section, the results on the indicators are compared to the results expected after the literature review (compare to table 9 and figure 14). In figure 14, the form of the boxes displays the importance the potential indicator has according to the experts based on the ranking. The square boxes are the most important, the boxes with rounded corners are the middle ones and the round boxes are the least important indicators. The different colors show the status of the indicators: The green boxes show the indicators derived from the literature (compare to figure 6 in chapter 3.1.), the blue boxes show the three underlying aims of the three functions of a neighborhood hub, and the orange boxes show the additional indicators collected in the course of the expert interviews. The red boxes show the indicators that have been added but not selected by the experts and two aspects that were mentioned as being influenced but not being indicators themselves (necessity of the hub and financing of the hub). The arrows show the relationships between the indicators; the type of arrow shows the strongness of the relationship: the strongest relationships are reflected by a continuous arrow and the middle strong relationships are represented by a dashed arrow (there were no weak relationships found in the literature review). The green arrows display relationships that were detected in the literature review, while the orange arrows display relationships that were detected in the expert interviews.

It is interesting to see that a lot of indicators were thought to be as important as the literature review suggested, and the others were thought to be less important. The indicators (social) amenities, mixed use and population density were ranked as important as expected after the literature review, while the indicators spatial density, demographic factors and proximity to heat stress were ranked less important than expected. The indicator real estate prices was discussed in the qualitative part of the interviews, and also discussed as a potential influence factor for the choice of a location of a neighborhood hub, but it was not selected by the experts for the ranking (Expert 1, 2020, p. 15). It is ranked less important by the experts than expected after the literature review.

Moreover, it is interesting to note that there were no indicators ranked more important by the experts than by the literature review. This may however also be a result of the ranking method, as the experts were only allowed to rank until five. These five ranks were counted as the “highly important” group, which might exclude surplus aspects that have been ranked as highly important in the literature review.

*Table 8: Importance of the indicators according to the literature review and the expert interviews*

| Indicator | Importance according to literature | Importance according to the experts |
|---|---|---|
| Amenities | Highly important | Highly important |
| Mixed use development | Highly important | Highly important |
| Spatial density | Highly important | Medium important |
| Demographic factors | Highly important | Medium important |
| Population density | Highly important | Highly important |
| Public transport stops | Medium important | Medium important |
| Real estate prices | Less important | Not important |
| Proximity to new residential housing | Less important | Medium important |
| Proximity to heat stress | Medium important | Less important |
| Proximity to Urban Green Spaces | Medium important | Medium important |
| Proximity to parking pressure | - | Highly important |
| Proximity to logistics | - | Less important |
| Ownership of the location | - | Medium important |
| Proximity to electrical substations (trafostations) | - | |
| Draagvlak (societal support base) | - | Medium important |
| Proximity to existing parking areas | - | Not important |
| Accessibility for all modes of transport | - | Highly important |

| | | |
|---|---|---|
| Attractiveness of the surrounding and the route | - | Less important |
| Available space (e.g. vacant lots) | - | Medium important |
| Capacity of the electricity network | - | Less important |
| Proximity to demand for gas within the neighborhood | - | Less important |
| Safety | - | Not important |
| Attractiveness of the hub itself | - | Less important |
| Consciousness of necessity | - | Less important |
| Interest of mobility companies | - | Less important |

*Note: The table shows the importance of the indicator according to the literature review in comparison* to *the importance according to the expert interviews.* The green fields show the indicators that have been ranked highly (in the top 5 ranking), the yellow fields show the indicators with medium importance and the orange fields show the indicators with low or no importance (not selected in the ranking for the third row). For the indicators added in the course of the interviews, no information is available on the importance according to the literature. The four indicators marked in grey at the end of the table are indicators that have been chosen by some of the experts in the course of the ranking, but which were not included as potential indicators for the following experts, because they did not fit the search for indicators that have an influence on the selection of a location for a hub. More information on this can be found in the Expert Interview Adjustment Log in Appendix 36.

According to the aspects and relationships discussed in the expert interviews, the visualization of the connection of the indicators was adjusted. A lot of additional relationships were added to the visualization.

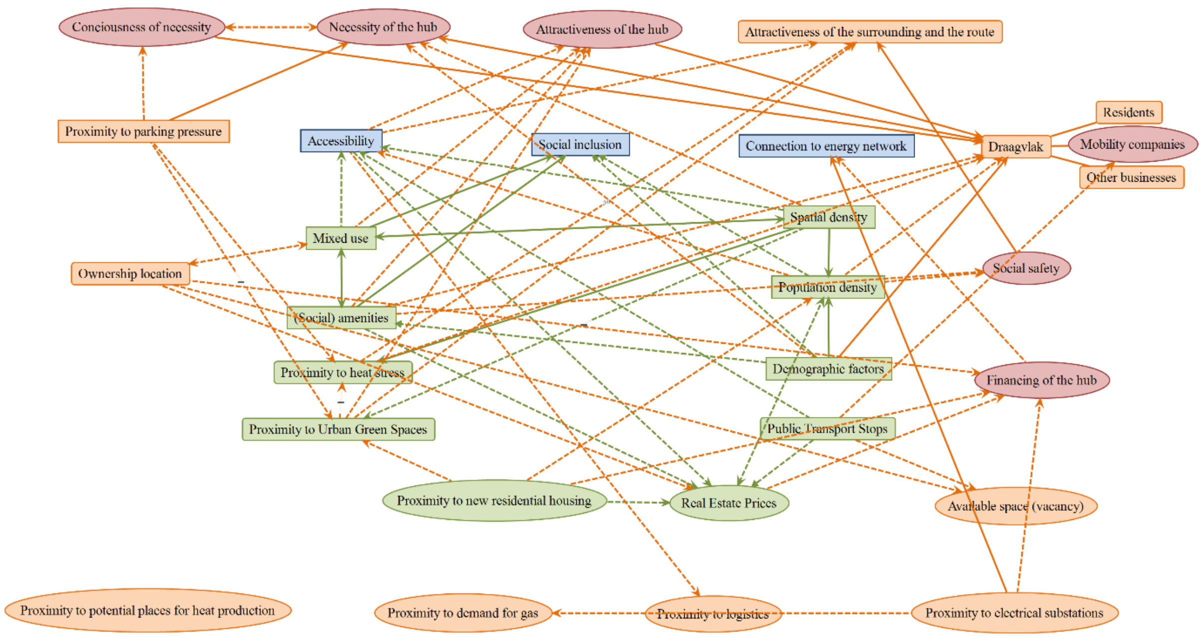


*Figure 14: Adjusted visualization of the importance and relationships between the indicators based on the expert interviews.*

### 4.2.2. Results on the selected indicators

In this subchapter, the five selected indicators are discussed in detail. It is discussed why the experts selected these five indicators, how they relate to the other indicators and what the opinion of the experts is about the indicators. The discussion of the results of the remaining indicators can be found in Appendix 40.

**Indicator 1 – Accessibility for all modes of transport**

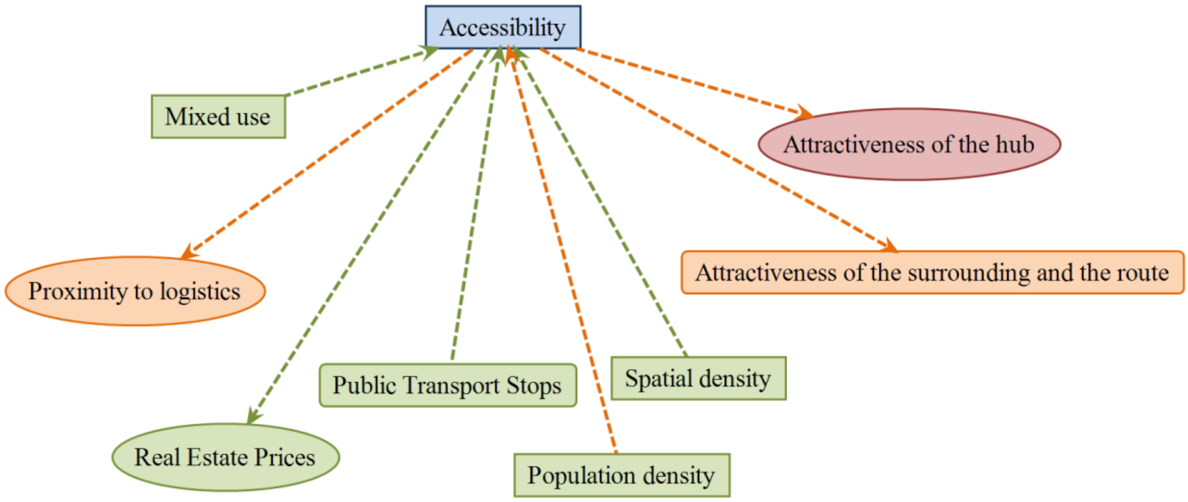


*Figure 15: Relationships of the indicator Accessibility for all modes of transport*

Figure 15 shows the direct relationships of the indicator accessibility. The indicator accessibility for all modes of transportation was selected as the most important aspect to be taken into account when selecting the location for a neighborhood hub. It was named in most of the interviews as one of the leading factors and selected in the ranking by six of the experts. Two experts selected it as the most important indicator, while one expert selected it for rank two, one for rank three, one for rank four and one for rank five (compare to table 3).

As has been discussed in chapter 2, the concept of accessibility has several layers to it. The accessibility of all modes of transport has a significant influence on other indicators, such as the attractiveness of the hub, but is also influenced by a range of different aspects. Most experts discussed that the potential location for a neighborhood hub needs to be easily and safely accessibility by all modes of transportation (Expert 4, 2020, p. 10). The hubs need to be located at strategic points on the main roads, which are logical to use (Expert 11, 2020, p. 6). The routes to and from the neighborhood hub need to be clear, the hubs need to be visible and it is positive for the hub if it can be connected to already existing routes that are used by the residents on a regular basis (Expert 4, 2020, 10, 13; Expert 5, 2020, p. 13). Expert 5 said on this topic:

*"The second I think what is important is that the location is for the people who live in that area, a location where it is normal to pass by. So close to their house, part of a route for walking or biking. To go to a shopping center or near to a park. So, the location must be part of this route system" (Expert 5, 2020, p. 13).*

The hub must be accessible by all modes of transportation, thus walking, cycling, maybe the public transport and the car, which means that there must be (differing) routes for the different modes of transport (Expert 10, 2020, p. 13; Expert 3, 2020, p. 13; Expert 6, 2020, p. 9; Expert 8, 2020, p. 10).

The cyclist requires safe and direct cycling routes to and from the hub, which are connected to other routes that lead to important destinations within the city (Expert 11, 2020, p. 7; Expert 3, 2020, p. 7; Expert 4, 2020, 11, 13). The public transport user needs easy access to the respective public transport in place, while the car driver requires quick and direct access to and from the main roads (Expert 3, 2020, p. 13). For reaching accessibility for the car driver, it was suggested from several experts to place the hubs on the edges of the neighborhood (Expert 11, 2020, p. 5; Expert 3, 2020, p. 13). The placing of the hubs on the edges of the neighborhoods was also suggested due to the space needed for the hub, which is hard to acquire in the dense neighborhoods, and the reduced traffic within the neighborhood that is expected from pushing the cars to the edges (Expert 11, 2020, p. 5; Expert 7, 2020, pp. 7–8).

Accessibility in small scale and dense neighborhoods such as the two case areas Assendorp and Kamperpoort is often understood as pedestrian friendliness (Expert 6, 2020, p. 5). As Expert 6 argues:

*"The difficulty I think is planning them in the right spot. So, they should be walkable, bicycle, not only walkable, but the route to, should be comfortable and attractive" (Expert 6, 2020, p. 5).*

Especially for the pedestrian and also for the cyclist, the attractiveness of the route to and from the neighborhood hub influences the accessibility, as it makes it more convenient to use the route (Expert 3, 2020, p. 13; Expert 4, 2020, p. 13). The attractiveness of the route is influenced, among others, by the quality of the pavement, the existence of shading, social surveillance and security (Expert 4, 2020, p. 13).

Part of the accessibility of a hub, especially for the pedestrian, is the travel distance to and from the hub. The experts agree that the walking distance should not be too high and not exceed a range of 250 to 400 meters (Expert 10, 2020, p. 13; Expert 7, 2020, p. 7; Expert 9, 2020, p. 23). However, it was also discussed that the actual distance is not as important if the route is attractive (Expert 7, 2020, p. 13). The actual distance to and from the hub can feel different depending on the attractiveness of the surrounding (Expert 6, 2020, p. 6; Expert 7, 2020, p. 7). Basically, if there is a lot to look at and the routes are interesting to walk, people are expected to be willing to walk longer than if the routes are unattractive.

Another aspect that was discussed as part of the accessibility of a hub is the interchange between different modes of transport. It must be easily possible to change the mode of transportation for example from bicycle to public transport or from the car to walking or cycling (Expert 7, 2020, p. 13; Expert 8, 2020, p. 11).

Moreover, as part of the accessibility of the hub it was discussed that opening hours of the hub itself are important; if it is for example not possible to get the personal bicycle after a certain hour, it is not convenient to use the hub for residents (Expert 3, 2020, p. 7).

**Indicator 2 – Proximity to parking pressure**

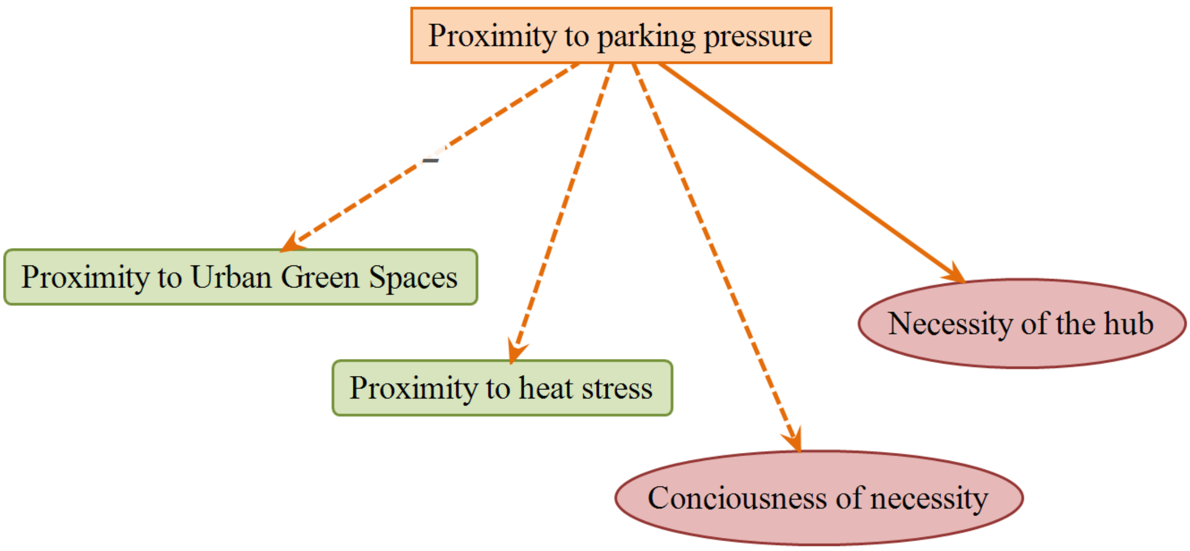


*Figure 16: Relationships of the indicator proximity to parking pressure*

Figure 16 shows the direct relationships of the indicator proximity to parking pressure. The indicator proximity to parking pressure was selected as the second important aspect to be taken into account when selecting the location for a neighborhood hub. It was named in seven of the interviews as one of the leading factors and selected in the ranking by six of the experts. Two experts selected it as the most important indicator, while two experts selected it for rank 4, and two for rank 5 (compare to table 3).

The indicator proximity to parking pressure was selected mostly, because it is expected to both show the places where it is needed the most to place a neighborhood hub for reducing the parking pressure and because it was expected that the parking pressure could increase the willingness of residents to make use of the hub (Expert 2, 2020, p. 10; Expert 3, 2020, p. 15; Expert 7, 2020, p. 14). Expert 12 said about this:

*"Parking pressure [..] is more or less the creator of the necessity" (Expert 12, 2020, p. 16).*

Where the parking pressure is the highest, the people have the most problems of finding a spot for their car as well as little space for their children to play or green areas (Expert 2, 2020, p. 10). Moreover, the experts said that if there are a lot of parking spots in the neighborhood, the people would normally park their car in close proximity to their house (Expert 3, 2020, p. 15). According to the experts, the possibility of seeing and surveilling the private car in front of the house is something most residents like to have as an opportunity (Expert 11, 2020, p. 4; Expert 4, 2020, p. 12; Expert 5, 2020, p. 11). Residents also typically like to have the freedom of using their car whenever they want (Expert 10, 2020, p. 7; Expert 4, 2020, p. 6). Due to these reasons, high parking pressure can reduce the advantages people get from their private car and can increase the willingness to park the private car at a hub or use a shared vehicle from the hub.

A negative relationship between the proximity to parking pressure and proximity to urban green spaces was therefore also expected.

Moreover, the indicator proximity to parking pressure is expected to have a reinforcing relationship with the proximity to heat stress, because of the hardened surfaces needed for the parking of cars (Expert 2, 2020, p. 11; Expert 6, 2020, p. 12). The existence of heat stress because of high amounts of parking spots might also increase the willingness of residents to bring their vehicles to the hub or use vehicles from the hub (Expert 6, 2020, p. 12). However, it was discussed that the residents do not see heat stress as a major problem in their daily life, while parking pressure is really a problem for a lot of people in cities (Expert 2, 2020, p. 10).

**Indicator 3 – Mixed use**

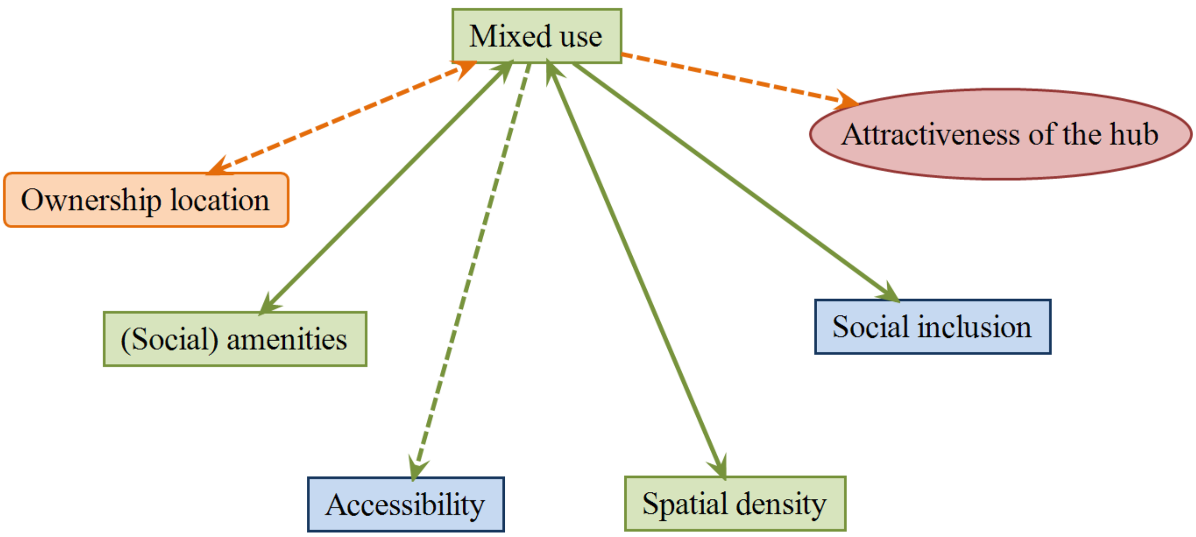


*Figure 17: Relationships of the indicator mixed use*

Figure 17 shows the direct relationships of the indicator mixed use. The indicator mixed use was selected as the third important aspect to be taken into account when selecting the location for a neighborhood hub. It was named in five of the interviews as one of the leading factors and selected in the ranking by five of the experts. Two experts selected it as the most important indicator, while one expert selected it for rank 3, and two for rank 4 (compare to table 3).

The indicator mixed use was chosen by most of the experts because it increases the attractiveness of an area if it has several uses (Expert 2, 2020, p. 12; Expert 3, 2020, p. 6). Typically, in mixed use areas, everything is close by and can be accessed easily (Expert 1, 2020, p. 7). The more uses are mixed in an area, the better it is for a hub, according to the experts (Expert 7, 2020, p. 14). Moreover, already existing mixed use parts of a neighborhood are places people already make use of, which makes it easier to implement a neighborhood hub there. The potential customers of the additional services that the hub can offer are already visiting the area on a regular basis. The hub can add the functions that are still lacking and even increase the use of visiting the place for the residents (Expert 10, 2020, p. 13; Expert 12, 2020, p. 9). Expert 2 said about this:

*"If you have two or three reasons to go there, instead of just picking up your shared car, then there is more reason as well to use it" (Expert 2, 2020, p. 6).*

Moreover, if there is a mix of functions in the surrounding of the neighborhood hub, then normally also a mix of different people make use of the area, increasing the potential user group of the neighborhood hub (Expert 1, 2020, p. 13; Expert 12, 2020, p. 9). Expert 7 puts it like this:

*"If there is lots of things to do around, then it is better to have a point, a hub, in that kind of dense areas" (Expert 7, 2020, p. 14).*

The indicator has a close relationship with the indicator (social) amenities, as amenities are a part of the mixed uses in a neighborhood (Expert 1, 2020, p. 13; Expert 10, 2020, p. 16). It was also explained, that typically very dense areas have more and mixed uses than less dense areas (Expert 10, 2020, p. 14). The mix of uses can increase the accessibility for most modes of transport, as more functions are available in shorter distances.

**Indicator 4 – (Social) amenities**

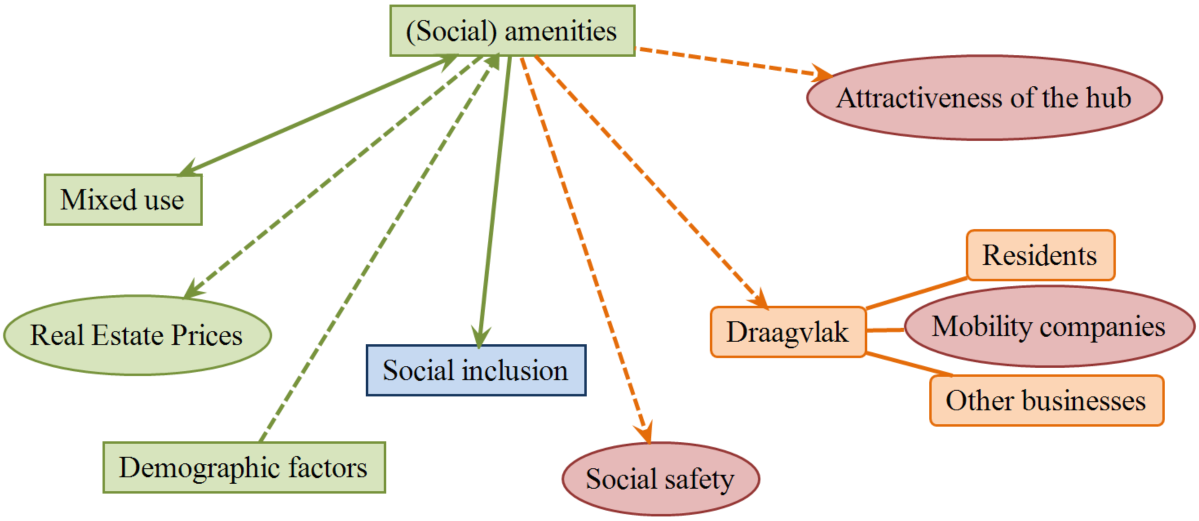


*Figure 18: Relationships of the indicator (social) amenities*

Figure 18 shows the direct relationships of the indicator (social) amenities. The indicator social amenities was selected as the fourth important aspect to be taken into account when selecting the location for a neighborhood hub. It was named in five of the interviews as one of the leading factors and selected in the ranking by four of the experts. One expert selected it as the most important indicator, while two experts selected it for rank 2, and one for rank 3 (compare to table 3).

The indicator (social) amenities was often chosen in combination with the indicator mixed use, or at least a similar explanation was provided for choosing it as an indicator (Expert 1, 2020, p. 13; Expert 10, 2020, p. 16). This is not surprising as the amount of amenities within a neighborhood can have a significant influence on the mixed use-status of the neighborhood. It was also discussed by the experts that the existence of different amenities at the hub, but also in the surrounding area, would increase the attractiveness of the hub (Expert 1, 2020, p. 7; Expert 4, 2020, p. 14; Expert 6, 2020, p. 12). As with the mixed use, if there are more things a user can do in the area, the area has more benefits for the user (Expert 1, 2020, p. 14). Moreover, it was discussed by the experts that the existence of amenities in proximity to the potential location can be a significantly important reason to choose the place as a location for a neighborhood hub (Expert 12, 2020, p. 9). Expert 7 said about this:

*"Sometimes you can also search for, is there any possibility to make a neighborhood hub near an existing coffee shop or other function? Like you try to combine with the energy network, to combine with logistics, also to combine with other stores that are already existing. So, you do not have to organize it again. You can use the existing business there" (Expert 10, 2020, p. 12).*

Expert 10 concluded on this matter:

*It must also fit in with what the environment of such a hub actually needs. So, the user side. What do people want. I think that it also makes a difference whether there are facilities nearby, such as shops, or other places where more people come. That that can also be a reason to set up a hub nearby*[8] *(Expert 8, 2020, pp. 10–11).*

There is moreover a relationship between the indicators amenities, attractiveness of the hub and *draagvlak*, because a mixture of existing amenities at the hub and in the surrounding area, as well as the overall attractiveness of the hub all influence the willingness of people to go there and make use of the hub (Expert 12, 2020, p. 9; Expert 7, 2020, p. 6; Expert 8, 2020, p. 15).

It was also discussed by the experts, that the amenities already existing in the surrounding of the potential location for a hub can be taken as a basis for the planning of which amenities should be added at the hub. the idea is to thereby add missing amenities for the neighborhood, that will also be used (Expert 11, 2020, p. 7). One expert said that the demographic profile of the neighborhood has to be taken into account when deciding for specific amenities, as for example older people need different amenities than younger people (Expert 11, 2020, p. 7).

Moreover, it was discussed for the social amenities at a hub, that these would significantly increase the probability that people also stay at the hub and not only use it for a single specific purpose and then leave again (Expert 10, 2020, pp. 13–14). This applies as well for more social amenities in the surrounding area of the hub, as they can increase the range of possible destinations for a user (Expert 2, 2020, p. 6).

[8] Translated from Dutch

**Indicator 5 – Population density**

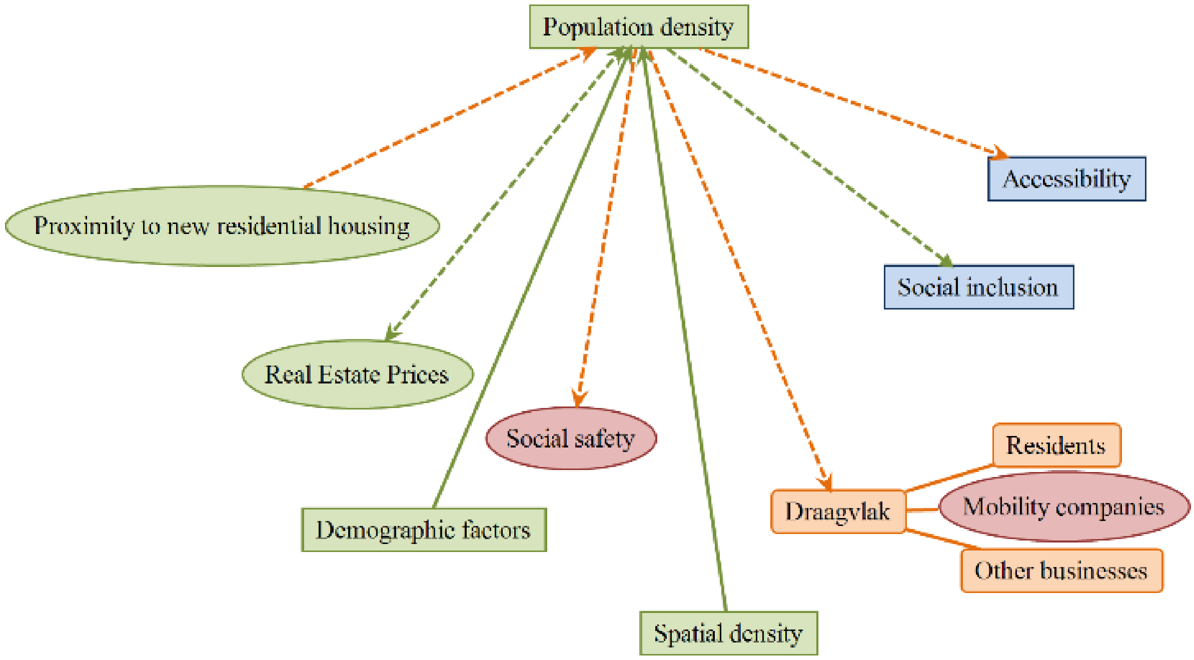


*Figure 19: Relationships of the indicator population density*

Figure 19 shows the direct relationships of the indicator population density. The indicator population density was selected as the fifth important aspect to be taken into account when selecting the location for a neighborhood hub. It was named in seven of the interviews as one of the leading factors and selected in the ranking by five of the experts. One expert selected it as the most important indicator, while one expert selected it for rank 3, and three for rank 4 (compare to table 3).

The indicator was selected mainly by the experts, because they agreed that there is a certain threshold of inhabitants that need to be living in an area in order for the hub to work (Expert 1, 2020, p. 13; Expert 5, 2020, p. 15; Expert 7, 2020, p. 13). This was said to have both economic as well as capacity reasons. If the hub includes all kinds of amenities, such as a café, these need enough visitors to be rentable, otherwise they will not thrive (Expert 1, 2020, p. 14; Expert 11, 2020, 5, 7; Expert 3, 2020, p. 15). And on the other hand, it is more attractive for shop owners and other stakeholders to rent space in a neighborhood hub, if there is a bigger customer basis around (Expert 7, 2020, p. 14). Moreover, it was argued by one expert that a high population density might be a prerequisite for planning a hub altogether, as the concept might not work for lower densities and there also could be other solutions in low density areas (Expert 12, 2020, p. 15).

Expert 3 put it like this:

*"[…] I think that is also important, because you need to have some population, it has to be again feasible for shops or parking places to be used. Or else, you will start a hub and two or three years later it will be bankrupt and will not be used again" (Expert 3, 2020, p. 15).*

Expert 7 said about this:

*"I think population density has also something to do with the distance. You can maybe combine it with the first one. It has something to do with travel distance but also more people, density. It gives more market for your hub, if there is more people living around your hub in an acceptable distance" (Expert 7, 2020, p. 13).*

Expert 11 put it even more concrete, when he explained:

"This has to do with rentability of the hubs. For a café, you need a certain amount of people that make use of it. If you are talking about maybe 500 people using one of the hubs in the upset used in your conceptualization, they are not rentable. So, it might be useful to make one or two of the bigger ones on the outer edges, to also have an additional place for community activity" (Expert 11, 2020, p. 5)[9].

Moreover, with more inhabitants in a certain area, there are more people that can make use of the hub and the hub is therefore useful to more residents of the neighborhood than if it was located at a less dense area (Expert 2, 2020, p. 11). The close link between spatial and population density was acknowledged by the experts, stating that each of these indicators could be used to indicate the direction for the other (Expert 1, 2020, p. 13; Expert 3, 2020, p. 14; Expert 7, 2020, p. 15; Expert 9, 2020, p. 17). It was also discussed that a higher population density would typically also increase the accessibility for all modes of transport, as a high population density generally implies a high spatial density. One expert explained, that the higher the population (and also spatial) density is, the higher the interest and the draagvlak of the residents should be, as with parking pressure and scarcity of space in general, they would see the advantages for themselves more easily (Expert 6, 2020, p. 12).

## 4.3. Results of the GIS Analysis

The goal of the GIS analysis was to display the five selected indicators and to test whether the applied methodology has potential for the selection of locations for neighborhood hubs. In this chapter, the results of the GIS analysis of the five key indicators are displayed (chapter 4.3.1.), the map displaying the suitability of the locations within the two case neighborhoods is shown and the areas with high potential for the placement of neighborhood hubs are further evaluated on the basis of the vacancy, cultural historical value, current use of the location and the connection to the energy network.

### 4.3.1. Results of the five single indicators

In this section, for each of the five indicators, the results of the single analyses are displayed and discussed.

**Indicator 1: Accessibility for all modes of transport**

The strategic routes for the pedestrian, the cyclist and the car as well as the public transport stops of the two case neighborhoods were collected (Appendix 44). In Appendix 45, the buffer areas for all four modes of transportation are displayed and the result of the analysis for indicator one is visible in figure 20.

As visible from Appendix 44, the strategic routes of the pedestrian often overlap with the routes of the bicycle and sometimes of the car. Moreover, the public transport stops are often located along one or many of the strategic routes of the other modes of transportation. Also, the public transport stops are not equally distributed everywhere, so that there is a shortage of public transport stops in the east of Assendorp and in the middle of Kamperpoort.

In Appendix 45, the buffer zones of the strategic routes of all modes of transport are displayed. It is visible from the map, that it is possible almost everywhere to reach a pedestrian route within 100 meters, except for the east of Assendorp. Cycling routes are not directly accessible everywhere. In the east of Assendorp and in the center of Kamperpoort the inhabitants have to cycle a wider distance to access a strategic route. The strategic car routes can mainly be found on the edges of the neighborhoods, which

[9] Due to problems with the recording software, this interview was not recorded fully. However, the aspects discussed with the expert were written down in detail directly after the interview. More information can be found in Appendix 36.

is in line with the statement by some of the experts that the hubs should be located on the edges of the neighborhoods in order to provide accessibility for car users (compare to chapter 4.2.).

Figure 20 displays the high potential areas for locating neighborhood hubs in the two case neighborhoods on the basis of the first indicator accessibility. In comparison with Appendix 45, it is visible that the areas are mainly located where the buffer of the public transport stops were. It is directly visible that the public transport stops had a big impact on the analysis; therefore, it is important to keep in mind that the method of displaying the public transport was by choosing the stops instead of the lines. Moreover, most of the areas are rather located at the edges of the neighborhood than in the small streets within, and rather along the lines of the major streets. This is of course a result of the car routes that were included, which are mainly located on the edges of the neighborhoods.

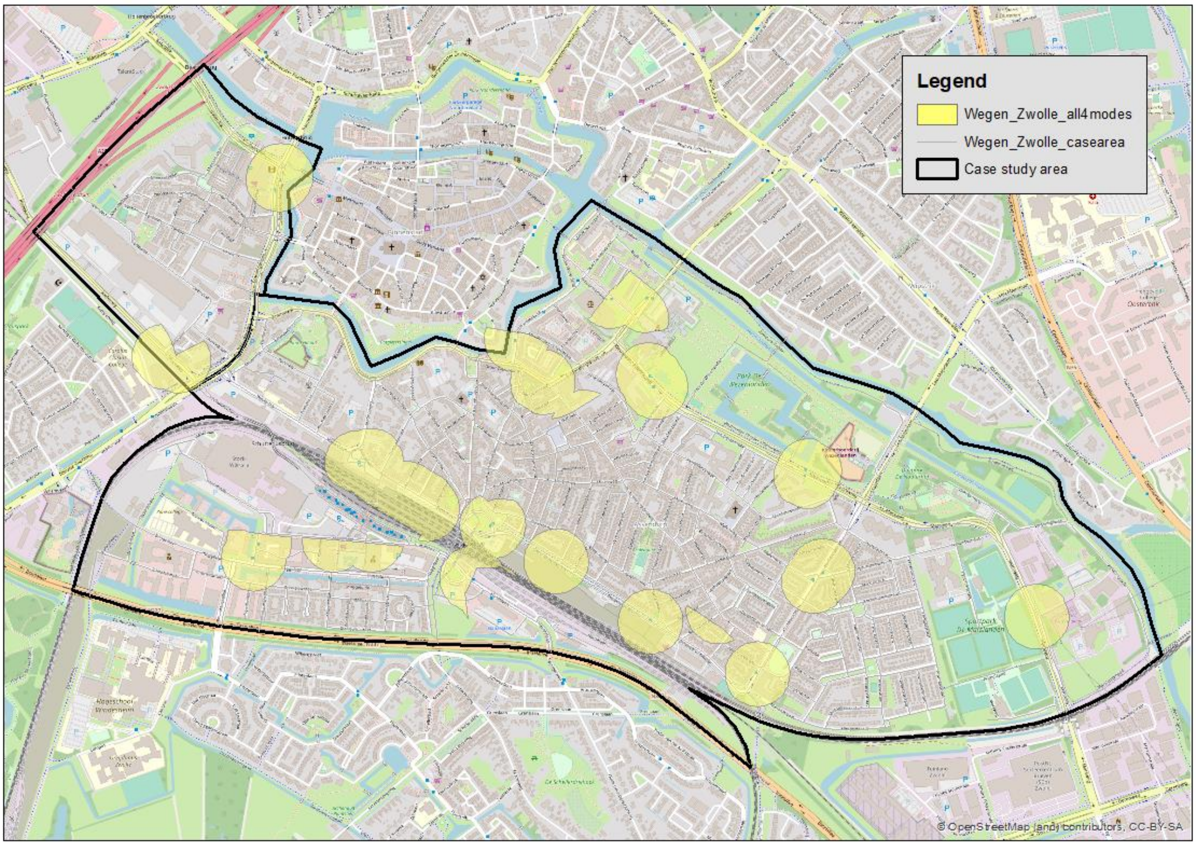


*Figure 20: High potential areas for locating neighborhood hubs based on indicator one. Own presentation.*

**Indicator 2: Proximity to parking pressure**

In Appendix 46, the amount of parking pressure in the two case neighborhoods is displayed and in figure 21, the areas with high potential for locating a neighborhood hub based on the indicator parking pressure are displayed. It is visible from the figure, that high parking pressure (above 80 %) occurs mainly in the small side streets of Assendorp, but also on some of the major routes, such as the Hortensiastraat. In Kamperpoort, high parking pressure also occurs mainly in the smaller streets within the neighborhood and only partly on the major roads, such as the Harm Smeengekade. Moreover, in both neighborhoods, the parking pressure occurs almost exclusively where the major parts of the population live (compare to indicator 5)[10]. Moreover, it means that based on the indicator parking pressure, a big part of both

[10] The high parking pressure is expected to arise from the high number of private cars that are owned in the neighborhood in relation to the very dense structure which does not offer a lot of space for parking. As visible

neighborhoods is suitable for placing a hub there. It is expected that it will be very difficult to find a place within the range of the parking pressure where there is enough space for placing a neighborhood hub.

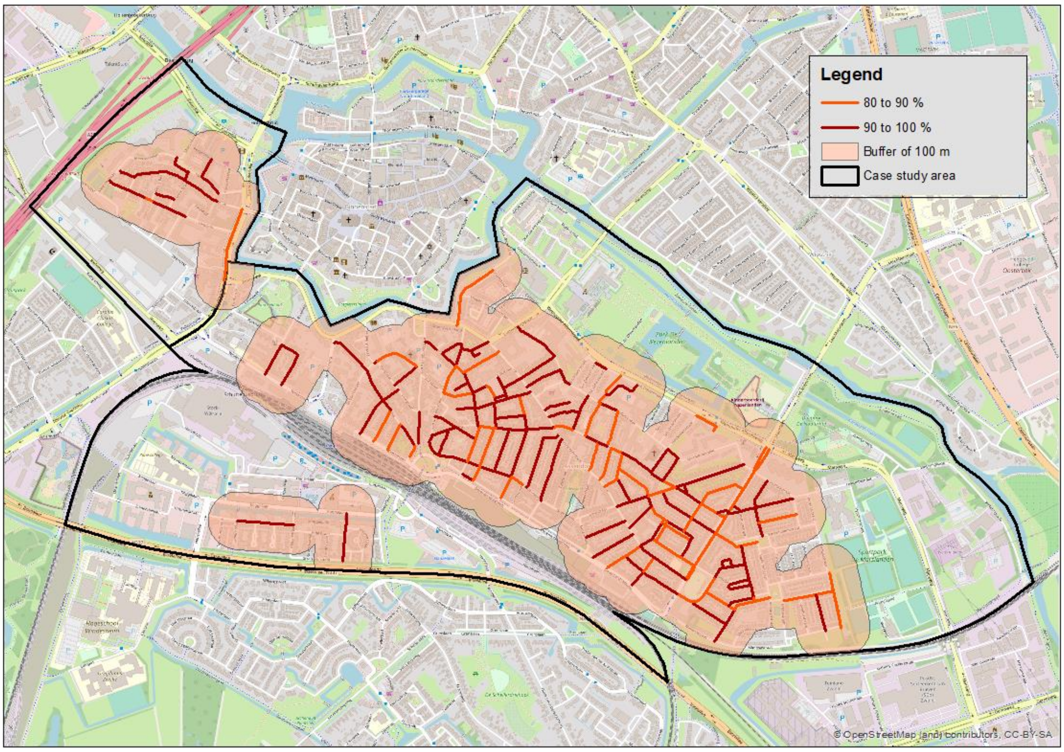


*Figure 21: High potential areas for locating neighborhood hubs based on indicator two. Own presentation.*

**Indicator 3: Mixed Use – Mixed Use Index**

In Appendix 47, the assessment of the two neighborhoods based on the mixed-use index is displayed. The mixed-use index shows how big the share of residential uses is from the total use of the block. The mixture of uses is the highest in the areas with a score between 0.45 and 0.55. Based on this, it is visible from figure 22 that the center of Assendorp and Kamperpoort are mainly used for living, while the north, east and southwest of Assendorp and the northwest, northeast and south of Kamperpoort are mainly used for other uses, such as commercial. Moreover, towards the city center, the areas with the highest mixture of uses can be found.

from chapter 3.5., where possible the information for the late evening / middle of the night was used, in order to display the places where parking pressure occurs due to the parking of the local residents.

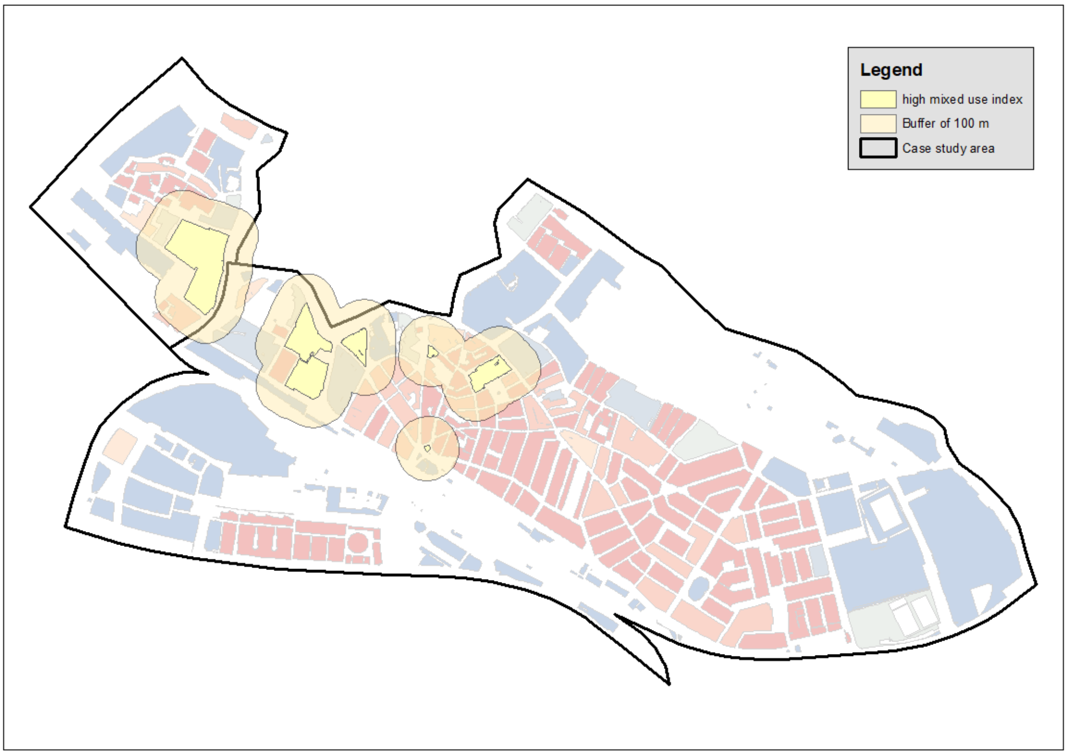


*Figure 22: High potential areas for locating neighborhood hubs based on indicator three. Own presentation*

**Indicator 4: (Social) amenities**

In Appendix 48, the different types of amenities are displayed that are present in the case neighborhoods. The displayed amenities all can support the development of a community feeling and it is therefore useful if a neighborhood hub is located in proximity to areas where many amenities are present.

The main areas with a lot of amenities are the north of Kamperpoort and along the Harm Smeengekade and the Pannekoekendijk, where a sort of business and recreational area is developed in the last years. It is visible that most of the amenities in Assendorp and Kamperpoort are for shopping or meeting. In Assendorp, many amenities, especially shopping, are located along the Assendorperstraat, which is a shopping street. It is moreover visible that amenities with the sport function are located in the center of Assendorp, and that there are no sport amenities in Kamperpoort. The educational amenities are more or less equally distributed in Assendorp and also not present in Kamperpoort. And the healthcare amenities are also more or less equally distributed in Assendorp and often in some distance to the Assendorperstraat, while they are only located in the east of Kamperpoort.

In figure 23, the buffer areas of the amenities are displayed, which show the areas with high potential for placing a neighborhood hub in close proximity. It is visible that most of the space of the neighborhoods belongs to the high potential areas, while only the northwest and southeast of Kamperpoort and the far east and part of the area south to the railway lines as well as parts of the park in Assendorp are not included.

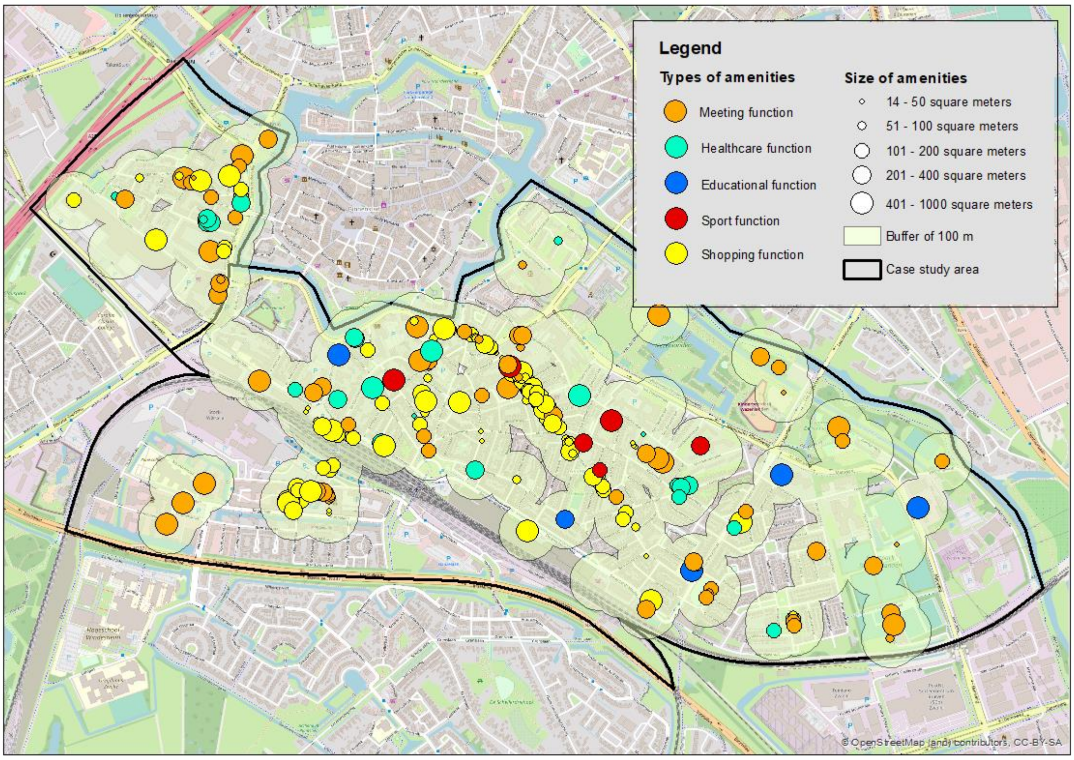


*Figure 23: High potential areas for locating neighborhood hubs based on indicator four. Own presentation.*

**Indicator 5: Population density**

Appendix 49 displays the population density (inhabitants per square kilometer) in the two case neighborhoods. It is directly visible that the areas can be divided into densely populated centers and less densely populated edges. Only to the north and to the south of Assendorp there are some areas that have a higher density than the surrounding low-density areas. The center of Assendorp is relatively homogenous in its population density, however there are some parcels where the density is very high and some where the density is a big lower. Kamperpoort has a similar structure, although it has in relation less high-density areas.

Figure 24 displays the selected areas with a high enough population density of at least 5000 inhabitants per square kilometer and the applied buffer area. As visible from the figure, most of the center parts of both neighborhoods are included in the selection. Based on indicator five, it is therefore possible to locate a neighborhood hub in most parts of the neighborhoods, except for the edges.

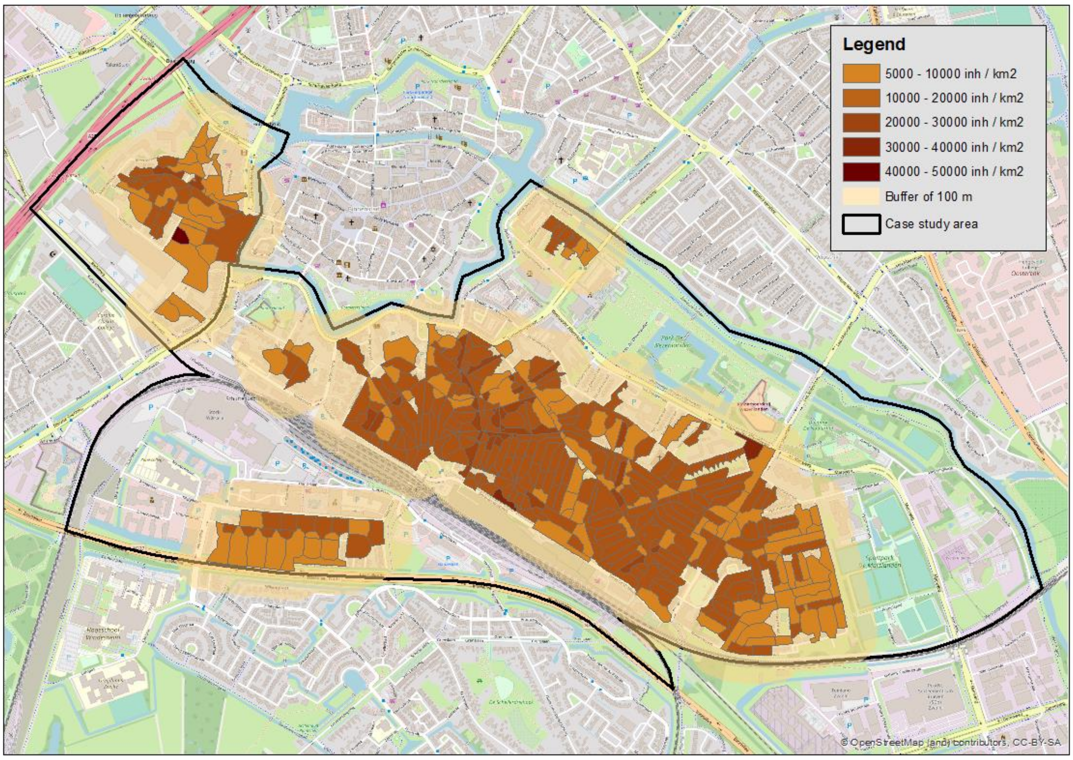


*Figure 24: High potential areas for locating neighborhood hubs based on indicator five. Own presentation.*

### 4.3.2. Results after the five indicators

The combination of the five indicators can be seen in figure 25; the map displays the suitability of the different locations in the two case neighborhoods. The dark green and green areas are the ones, where

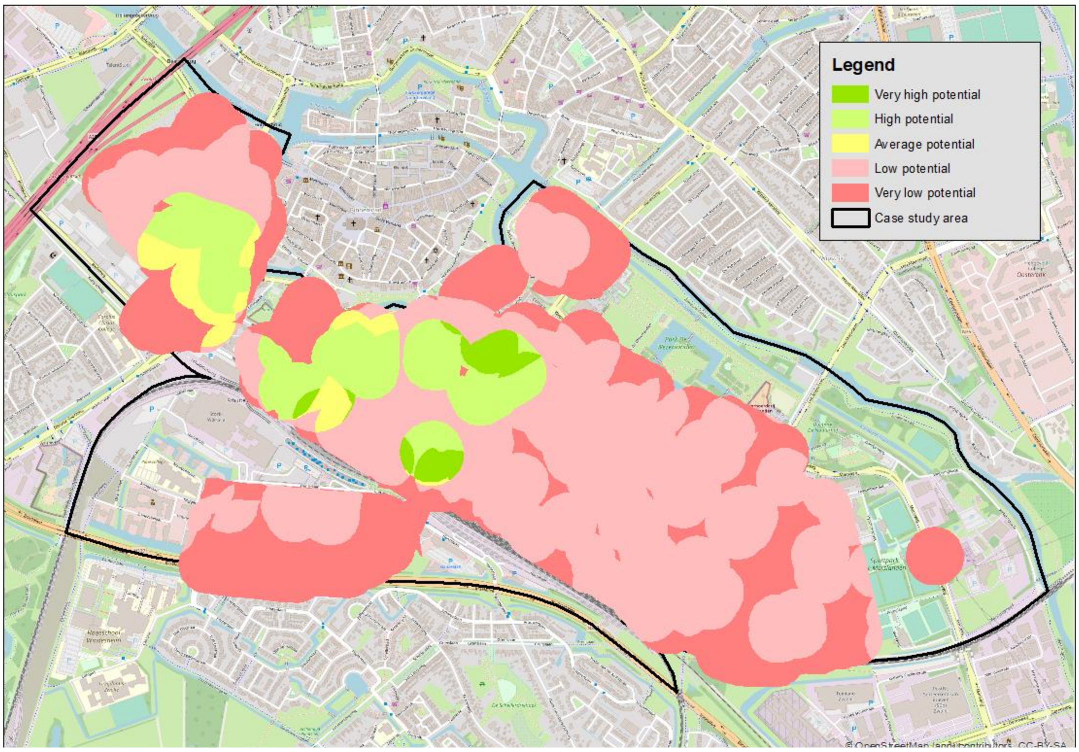


*Figure 25: Suitability map for locating neighborhood hubs. Own presentation, design based on Coolbaugh (2016, p. 76).*

all five or four of the indicators are present in order to provide suitability for the placement of a neighborhood hub.

It is directly visible from the map, that based on the five selected indicators, only some areas in close proximity to the city center have high potential for the placement of a neighborhood hub according to the indicators. Only areas in the east of Kamperpoort and in the north-west of Assendorp are fulfilling four of the five indicators, while there are no areas in Kamperpoort that fulfill all five indicators. In Assendorp on the other hand are four smaller areas that fulfill all five indicators.

Based on the single indicators discussed above, it can be said that some of them oppose each other in the areas of the neighborhoods that are selected as having high potential for placing a hub. For example, the indicators proximity to parking pressure and population density require that the hubs should be placed in the dense center areas of the neighborhoods, while the indicators accessibility for all modes of transport rather requires that the hubs should be placed at the edges of the neighborhood. The indicator mixed use requires proximity to the city center, while the indicator amenities is relatively indifferent except for some excluded areas.

The measuring methods need to be taken into account of course, and it is visible for example for indicator four that the analysis could be more detailed. The analysis included all selected amenities, redundant of the size, and the areas with more different amenities were not more important than areas with many amenities but if the same type.

Figure 26 shows only the areas with very high and high potential for the placement of a neighborhood hub and the building and street structure is visible. These areas are the result of the applied methodology and were further analyzed in the following subchapters, where they are assessed in terms of vacancy and the possibilities for connecting them with the energy network.

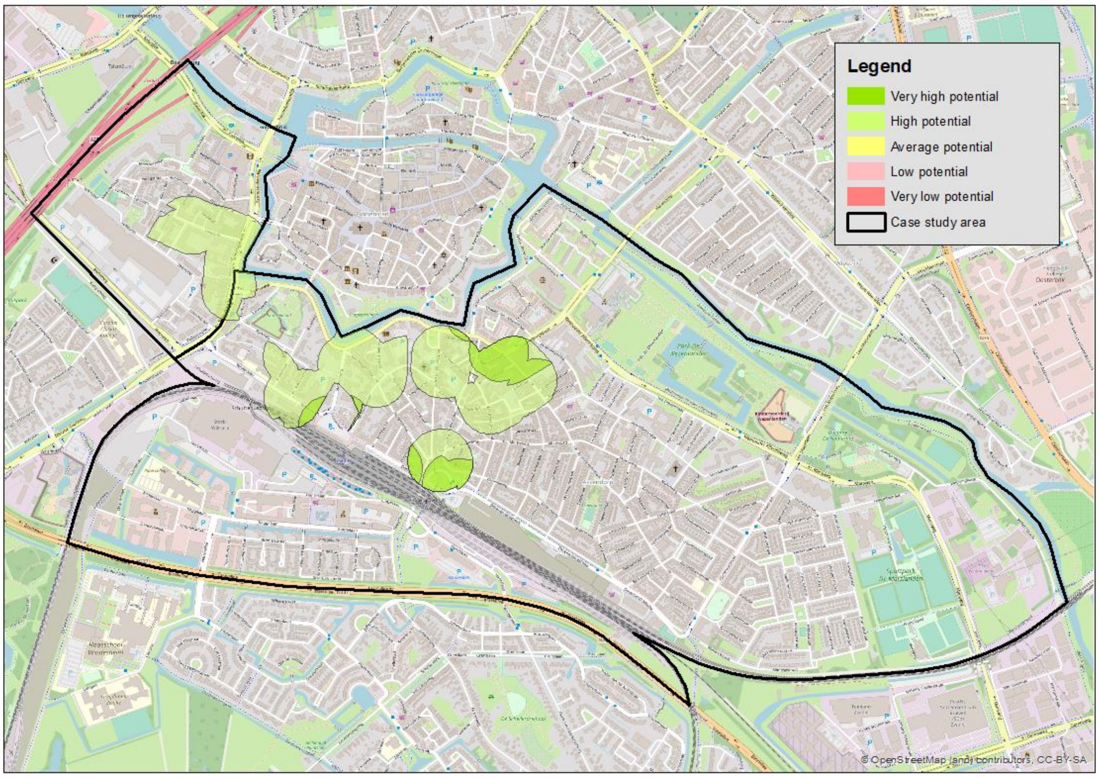


*Figure 26: Potential locations with high potential for neighborhood hubs. Own presentation.*

### 4.3.3. Further evaluation of the high potential areas

As discussed in chapter 3.4. and in Appendix 40, it is important to have enough space for the placement of neighborhood hubs. Based on the results of the analysis along the lines of the five selected indicators, the question is where in these areas there is enough space. For this, both the age of the buildings, the historical value of the area and the current function according to the zoning plan were taken into account.

Figure 27 shows the selected areas with very high and high potential for the placement of neighborhood hubs and the age of the buildings within the selected areas. On the basis of the age of the buildings in the selected areas, it can be said that there are many rather old buildings (built from 1800 to 1940) in the case neighborhood of Assendorp, while there are more rather recently built buildings (built from 2000 onwards) in the case neighborhood Kamperpoort. This is the case because the neighborhood Kamperpoort and especially this selected part of it have been under reconstruction in the last years. Moreover, it is visible that not a lot of free space is included in the selected areas. Furthermore, parts of the theatre Buitensoos as well as the Dominican monastery lie within the selected areas. The unbuilt areas are then e.g. a major traffic junction in the south of Assendorp (1) or a parking area that only available for people parking in a distance (3).

In Appendix 50, the areas in the two case neighborhoods that have cultural historical value are visible. Due to their proximity to the city center and their age, a lot of the selected areas in the two case neighborhoods are historically valuable. It is expected that in these areas, it might be more difficult to restructure existing buildings to house a neighborhood hub. in Appendix 51, all the functions of the zoning plan of the two case neighborhoods and the city center are displayed. With the use of both of the plans, the eight potential locations were evaluated in table 10.

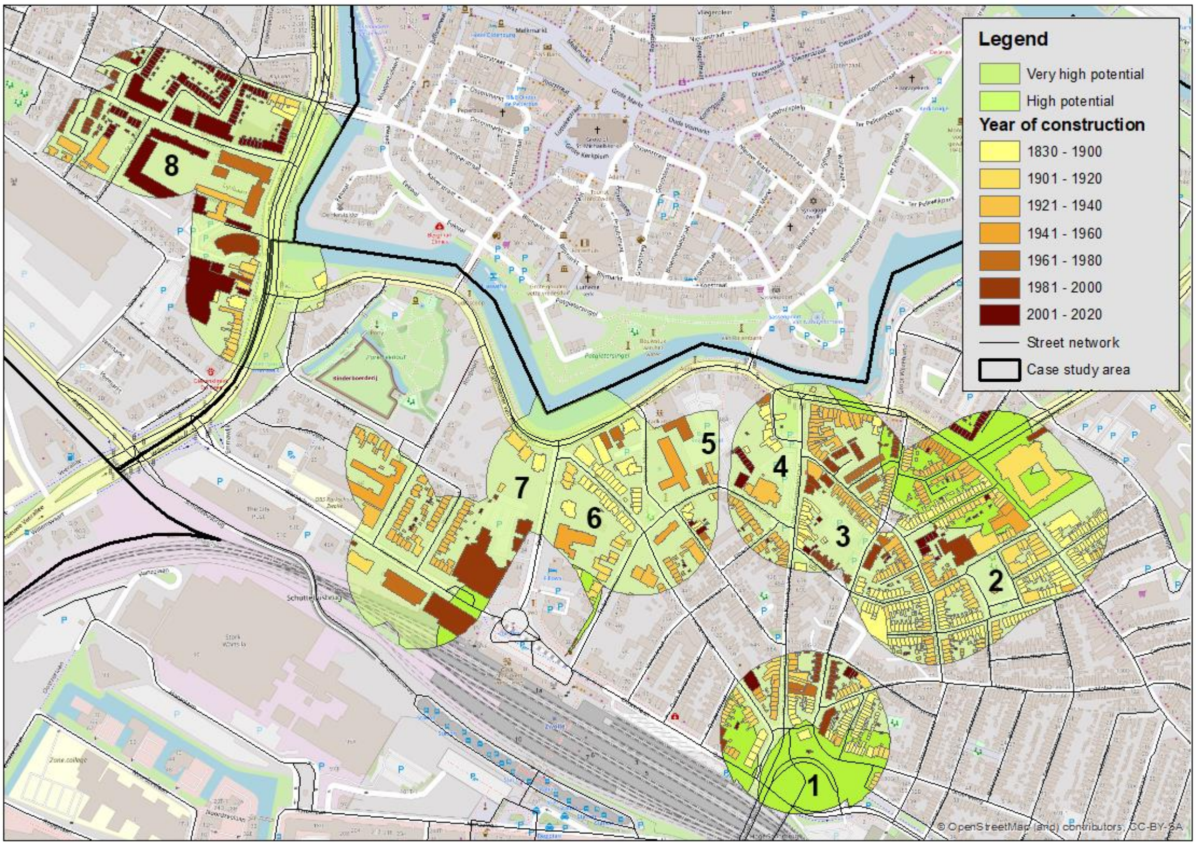


*Figure 27: Age of the buildings in the selected areas. Own presentation based on PDOK (2020a).*

Most of the areas with very high potential according to the five selected indicators are either fully occupied or are not suitable as a location for a hub due to other reasons. For example, for number 1, which is at the traffic junction in the south of Assendorp (Google Maps, 2020; Ruimtelijkeplannen, 2020), it could be thought about transferring the green isle of the junction into a hub and try to make it more accessible by foot (and bicycle) from all sides, but it is questionable whether a neighborhood hub has a lot of utility in so close proximity to the central station. The area with very high potential in the north-east of the figure is fully built with either houses or the monastery. Therefore, the areas not fully built on the remaining high potential areas are analyzed in the following, taking into account the historical value (Appendix 50) and the current function according to the zoning plan of the places (Appendix 51).

*Table 9: Evaluation of the locations with very high and high potential for the placement of a neighborhood hubs*

| Number | Actual use | Current function ("bestemming") | Cultural value |
|---|---|---|---|
| 1 | Traffic junction, green | Green | No |
| 2 | Assendorperplein, public meeting space | Green | Partly |
| 3 | Parking space for remote parking | Traffic - access road | No |
| 4 | Parking space of the NGK Zuiderkerk Zwolle | Traffic - access road | No |
| 5 | Parking space of several shops | Office | No |
| 6 | Courtyard of a building block | Office | Yes |
| 7 | Parking space of a cultural area, including the theatre and the neighborhood association | Mixed | No |
| 8 | Courtyard of a care home | Societal | No |

*Note: This table displays the evaluation of the locations with very high and high potential for the placement of neighborhood hubs in the two case neighborhoods Kamperpoort and Assendorp. The colours display the suitability of the high potential areas on the basis of the historical value, the zoning plan and the actual function seen in Google Street view. Green are the areas that have also high potential according to these other aspects, yellow are the middle suitable areas and the red ones are those that are not suitable based on these other aspects. The table is based on Ruimtelijkeplannen (2020) and Google Maps (2020).*

As visible from table 10, most of the potential locations do not have cultural historical value. Therefore, an exclusion of most of the places based on cultural historical value is not necessary. Three of the potential locations can be excluded based on their current function (number 2, 6 and 8). For example, location 2 is an important public place in Assendorp for meeting and children to play. Number 6 and 8 are both courtyards of private or semi-private spaces. Number 1 is excluded because it might be too close to the central station, as discussed before. The four remaining of the potential locations are existing parking spaces either available to the public, or available for the visitors of shops, the church or a cultural site. These parking spaces are in general expected to have a higher potential for the placement of a neighborhood hub than the other potential locations, because they are on public land and are provided by the municipality. If the policies of the municipality of Zwolle are implemented in the coming years, one of the goals is the reduction of parking places. Therefore, it would be a possibility to transform space that is already used for parking into more multifunctional neighborhood hubs, including parking for different modes of transport. Of the parking spaces, number 3 is seen as the location with the highest potential, because it is not serving as parking space for already existing amenities. On the other hand, it could be argued that based on the expert interviews, those places with existing amenities directly around it could have a higher potential. Then, also the locations 5 and 7 are suitable, while location 4 might be less suitable because it only provides the church function, and the church might also suffer more from the nuisance created by the hub.

Based on the energy network plan of the municipality of Zwolle (Appendix 52), it can be concluded that if it is aimed at establishing a connection to the middle voltage stations, the station in the south-east of the city center is the most suitable station in terms of distance (and therefore costs for the connection). If an energy network solution is established that captures a part of the energy produced at the hub, and it is therefore possible to connect the hub to a low voltage station, suitable stations of these should be searched for in the direct surrounding. Alternatively, it could also be searched for suitable locations to place new low voltage stations, as discussed in Appendix 39.

A further evaluation of these potential locations would be needed according to a lot of the indicators collected by the experts, such as the ownership of the location, the accessibility by all modes of transport (in detail), demographic factors, the societal support base and a lot of other things. Moreover, aspects like the amount of people already making use of the existing amenities around it and the detailed plans for the respective areas for the coming years could be taken into account. However, this further evaluation is beyond the scope of this research and could for example be conducted by the municipality.

# 5. Discussion of results and conclusions

In this chapter, the results of the research are discussed along the lines of the research questions, the conceptual model, the limitations of the research and the recommendations for future research and practice. Moreover, the conclusions are drawn from the discussion.

### Answer to the research questions

First, it can be concluded that the four sub questions could be answered in the course of the research to answer the main research questions. The answer to the first sub question is the list of potential indicators derived from the literature review. The answer to the second sub question is the ranking of the potential and the added indicators by the experts. The answer to the third sub question is the discussion of the methods in chapter 3 and the answer to the fourth sub question is partly discussed in chapter 4.3. and partly in this chapter. The main research question, ***how can suitable locations for neighborhood hubs be identified to combine societal, mobility-related and energy-related functions in the case of the neighborhoods Assendorp and Kamperpoort in the Dutch city of Zwolle?***, can be answered as well. It was possible to derive locations with high potential for the placement of neighborhood hubs from the applied methodology in the case neighborhoods. Moreover, these locations were further analyzed, and it could be concluded that some of them could actually be further analyzed in detail for their potential, because they are not fully built and have current uses that could be changed towards a neighborhood hub. The answer to the main research question is therefore, that suitable locations for neighborhood hubs that combine societal, mobility-related and energy-related functions can be identified by identifying and ranking potential indicators.

### Conceptual model

In chapter 2.4., the conceptual model of the research was introduced. Based on the results discussed in chapter 4.1., Appendix 39 and chapter 4.2., it can be concluded that there is a hierarchy visible in the framing of the functions by the experts and the result of the ranking: the mobility function of a neighborhood hub seems to be the most important, followed by the societal function, and the energy function is the least important. Moreover, based on the discussion in Appendix 39, it can be concluded that the underlying aims of the three functions resonate with the opinions of the experts about the three functions. The topic accessibility was discussed a lot and seemed to be the most important aim to be reached by improving the mobility function, while the social inclusion and connection among the residents seemed to be the main goal the experts saw for the hub from the social side. As was often discussed, the hub should not only have a functional (e.g. mobility) function, but should also provide a social place for the residents and add something to the neighborhood. The underlying aim of the energy function of achieving a sustainable energy and mobility system by providing a smart energy connection to the hub also seemed to resonate with the opinions of the energy experts. Moreover, these experts were motivated to use the energy side of the hub to support the neighborhood, also in terms of space reduction of the energy demand.

It can also be said that the potential indicators derived from the literature review represent the values in society, as many of them scored relatively high in the ranking of the indicators (compare to chapter 4.2.). However, some of the values expressed by the experts were not ranked very high in the ranking; an example of this is the safety for all societal groups. As discussed in Appendix 39, the indicator was perceived as very important in general by the experts, but it was nevertheless not ranked high. A reason for this can be that it is expected that a place can be made safe, while things like a high population density cannot be achieved that easily. The highly ranked indicators might therefore be things that are very important for the selection of a location for a hub, but which can also not be obtained easily afterwards.

The developed conceptual model is just the starting point of a theory of (neighborhood) hubs and therefore needs to be developed further. It is important to investigate in future research which values are represented by other experts, or by the local residents. Moreover, the differences between this case study and other case studies could be interesting.

### Reflection on the literature

The results discussed above can be compared to the literature reviewed in the process of this research. It can be said that the general notion that many indicators should be taken into account when determining a suitable location for a neighborhood hub derived from the literature was also derived in the expert interviews. It became clear both from the literature and from the experts, that each potential place for a hub is different, needs a tailor-made supply of amenities and services and that a good mixture of the indicators needs to be achieved in order to find a suitable location. Also, it became clear that an integrated approach must be taken in the selection of locations for hubs, in order to achieve the most suitable outcome. Moreover, as visible from table 9, some of the indicators were assessed differently by the experts than by the literature. Although the results of the ranking in this research are not statistically significant, it can be said that maybe some of the indicators are overrated and other are underrated in the literature, at least for the case study discussed in this research. Therefore, the addition made by this research might be to question the high relevance of some of the indicators from literature (e.g. spatial density and demographic factors were ranked lower than in the literature, compare to table 9). On the other hand, the research verified the general importance of many of the potential indicators derived from literature.

In comparison with the existing literature (Appendix 1), it can be concluded that this research added a new potential methodology for systematically deciding on the placement of (neighborhood) hubs. This methodology could be further developed to be applied on a wider scale and more quantitative. The research also added several important indicators, such as “draagvlak” or the proximity to logistics, which were not represented in the literature before and can play an important part in the selection of locations in the future (compare to Appendix 3). It can be said that the research both added to the knowledge base on the range of potential indicators as well as has given an indication of the potential importance of the single indicators and the relation between the three dimensions mobility, energy and society towards each other. Related to this is the addition to the knowledge base on the combination of the energy hub topic with the mobility and society hub. As discussed in the scientific relevance chapter, this combination has not been researched a lot and the current research was able to explore the potentials and problems of integrating the three functions. With respect to the conceptual model and the analytical framework, it can be said that in the expert interviews, also the energy function turned out to be the one with the least connections to the other two dimensions. In this sense, the research verified the existing literature and added that a combination could still be fruitful. Moreover, in the course of the research the concept of the lowest level of hubs was further explored, and it was possible to add to the knowledge base on these specific types of hubs. For example, it turned out that the experts can imagine different sizes of the neighborhood hubs, fulfilling different functions, but all being very accessible in order for them to be used.

### Limitations of the research

After discussing the answers to the research questions and the conceptual model, the limitations of the research are discussed. There are several aspects that show the limitations of the research: first, it can be said that the approach taken by the researcher is not the approach common in practice; in practice, locations for hubs are rather chosen on the basis of the availability of space or the redevelopment of land than on the basis of a clearly outlined selection of priorities. Therefore, it might be questioned whether a different and maybe more practice-oriented approach should have been chosen. On the other hand, it can be argued that the

Another argument that was also discussed by some of the experts is that the hub could run the risk of being seen as a goal in itself, and not a solution only applied for specific problems (Expert 12, 2020, p. 9; Expert 8, 2020, pp. 3–4). This might also be the case because in policy and science, there are so many aspects connected to the topic and one might easily loose sight of the actual goal or problem to solve. Moreover, one point discussed in the expert interviews was that the method applied might have gone the wrong way; instead of starting at an existing problem and searching for a solution for it, it searched for a method to systematize the solution (Expert 12, 2020, p. 10; Expert 6, 2020, p. 6). It might therefore be more useful and important to start from the side of users and understand which problems they face and how these could be solved. As was discussed before, the local residents of a potential location for a hub definitely need to be taken into account when customizing the concept.

A further limitation of the research is that the method is relatively complex and extensive; moreover, it is neither fully qualitative nor fully quantitative, which means that it neither results in a statistically significant, sharp answer, nor does it give a full in-depth picture of the local situation. However, as it is an explorative research, important lessons for future research on the topic can be drawn from it (see below).

Moreover, it can be said that the measuring methods applied in the GIS analysis are not as accurate as one might wish; for example, for the accessibility there are way more accurate alternatives, which could be applied in future research. These methods could then also be systematized in order to analyze a whole city or region on their potential for the placement of hubs. As the application in GIS was only the testing of the method in this research, these alternatives were to time consuming to apply.

Another limitation of the research is that the opinions of the local residents was not taken into account, but only the opinions of experts. An alternative or addition could have been to conduct a survey or additional expert interviews with the inhabitants on their opinions on the indicators. This limitation has to be taken into account when interpreting the results and transferring them to other contexts.

The last limitation that is discussed is that the results of the research are not easily transferable to other contexts because of the methods applied and of the specificity of the case neighborhoods. The indicators selected here are thought to be important, but it is not sure, whether they are actually the most important because of the little representativeness of the study (Corbetta, 2003, p. 24). It is therefore not possible to use the results of the ranking just like that for other cities, or even other neighborhoods in the city of Zwolle, because the results here were established on the basis of the case. As a next step, it could be suggested to do a wider, more representative survey, that shows how experts and residents see the indicators. However, as discussed before, the extensive list of potential indicators can be used to decide on the priorities in other contexts, and this in-depth exploration is thought to have been an important step towards the understanding of the concept of the neighborhood hubs.

### Recommendations for future research

An alternative for future research could for example be to conduct a statistically representative survey on which of the collected indicators are perceived as the most relevant by many spatial planners, by the residents of a specific city, or even of the whole of the Netherlands. Moreover, as discussed above, alternative methods of measuring the selected indicators could be tested. Additionally, it could be tried to systematize the analysis of the selected indicators in a GIS system, so that the analysis could easily be transferred to another context. Another alternative for future research is the detailed exploration especially of the social and the energy function of neighborhood hubs and their necessities and potentials. Moreover, the analytical framework could be used to further explore which changes of which of the indicators have the most impact on the suitability of a location. Furthermore, factors that influence the willingness to make use of a neighborhood hub and also things that keep people from making use of it could be analyzed in order to improve the usability of the hubs.

### Recommendations for practice

It became clear from the literature review and the expert interviews, that finding a suitable location for a neighborhood hub must always be a tailor-made solution especially for the location, people and businesses in the surrounding. The involvement of the inhabitants of the neighborhoods is a very important part of the process, that cannot be neglected. The analysis applied in this research was intended to answer several questions and add to the knowledge base on the topic of neighborhood hubs. One of the results is an extensive list of indicators that can be taken into account when searching for or evaluating a location. This list can be used by experts, researchers or policy makers also outside of the case study. The results of the ranking might not be representative for other cases than the two case neighborhoods, but they can give a first indication for other cases and municipalities. As for the GIS analysis, which was intended to function as a test of the method and to try to indicate the potential of different locations in the neighborhoods, it is concluded that the analysis fulfilled this aim.

Moreover, it became very clear in the course of the research that almost all of the collected indicators have some relevance in some way for the selection of a location for a neighborhood hub. Therefore, it can be recommended that a wide range of them is included in the analysis of or search for potential locations, in order to arrive at suitable locations that work out in the end.

### Conclusion

The goal of this research was to find out how suitable locations for neighborhood hubs could be reached by selecting indicators, ranking them and testing the method in a GIS system. As discussed in chapter 4.4., it can be concluded that this research goal was successfully reached. A lot of useful information on the three functions of a neighborhood hub could be collected in the course of the research, as well as a wide range of indicators to take into account when selecting a location.

The methods applied here can still be improved and there are a lot of questions still remaining on the topic of (neighborhood) hubs. However, it can be concluded that this research provided a valuable exploration of the topic in science and policy and was able to give a first indication of how a location search could be conducted.

For the application of this method in practice it is important to note that a combination of a relatively neutral ranking, local knowledge, the interests of the local residents and the planning of the municipality is expected to have the highest potential for arriving at a good solution for everybody.

Neighborhood hubs and hubs in general are a topic intensively researched in science and policy at the moment, and a lot of questions still remain to be answered. It is recommended to always keep the goal one wants to reach with the application of the concept in mind, and not to forget about taking into account the local residents.

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