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Transit-Oriented Development in the Finnish Context: Establishing Design Guidelines for Spatial Development

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Abstract

Throughout history, the growth of cities has been considered a great source of prosperity. However, in recent years negative environmental impacts have led to a growing concern about the consequences of the sometimes seemingly unlimited urban growth. One of the key topics when speaking about these negative environmental impacts is mobility. With the increasing importance of mobility in the modern urbanized world, improving the urban built environment to stimulate the use of sustainable modes of transport is one of the major challenges for today’s land use and transport planners.

The research in this thesis builds upon the reciprocal interaction between the (design of the) built environment and travel behavior. Use is made of the concept of transit-oriented development (TOD), a well-established planning approach originating from the US, aiming at achieving a shift in modal share towards sustainable forms of transport, while simultaneously creating a more livable environment with high standards for urban space.

Much of the available research on TOD is, however, mainly based on the policy scale and the regional planning scale, while attention to the detailed design level has been minimal. Furthermore, much of the research has focused on the North-American context. Consequently, practical design guidelines for TOD in the European and Finnish context are still lacking.

This thesis aims at bridging the gap between academic research on the topic of built environment and travel behavior, and the professional practice of land use planning. This is done, first of all, by examining the relation between land use, design, and sustainable modes of mobility in academic research, and second, by producing spatial design guidelines for TOD in the Finnish context.

The main method used to bridge the gap between research and design is the creation of guidelines, a research method for environmental design disciplines defined by Prominski. The creation of the guidelines has been done in two ways. *First*, a study of three best-practice examples of TOD (Rieselfeld, Vauban, and Hammarby Sjöstad) has been done, from which a number of guidelines have been extracted. *Second*, the applicability of these guidelines for the Finnish context has been examined through several test designs for the Malmin kenttä district, a new urban development area in Helsinki. Simultaneously have new guidelines been developed throughout the process.

The creation of the toolbox of TOD guidelines for spatial development in the Finnish context forms an important first step in translating the available academic knowledge into usable practical tools for Finnish planners. Although a comprehensive understanding of the functioning of the related theoretical models is still required to achieve large goals such as a modal shift, the toolbox provides a set of practical guidelines that planners can directly apply to their work. Furthermore, the guidelines may, in combination with the test designs, spark a larger discussion on the role of TOD in Finnish planning and the importance of a good integration of land use and transport planning.

Keywords

transit-oriented development; TOD; mobility; design guidelines; spatial development; urban planning; light rail; best-practice example

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Table of Contents

1. Introduction ... 4
   1.1. The 2050 Helsinki City Plan ... 4
   1.2. Public transit at the center ... 5
   1.3. Research objectives and questions ... 6
2. Theoretical framework ... 8
   2.1. The built environment and transport ... 8
   2.2. Transit-oriented development ... 12
   2.3. Light rail development ... 20
3. Methodology ... 25
   3.1. Research objectives ... 25
   3.2. Research and design ... 26
   3.3. Research methods ... 27
4. Best-practice examples ... 30
   4.1. Rieselfeld, Freiburg ... 30
   4.2. Vauban, Freiburg ... 39
   4.3. Hammarby Sjöstad, Stockholm ... 48
5. Test designs ... 59
   5.1. Brief overview of the historic development of Helsinki ... 59
   5.2. Current planning strategies ... 62
   5.3. Test designs ... 71
6. Discussion ... 84
   6.1. Built environment and travel behavior ... 84
   6.2. Design guidelines for TOD ... 88
   6.3. Limitations of the study and suggestions for further research ... 90
7. Conclusion ... 92
References ... 94
Appendices ... 104

1. Introduction

Urban growth of cities all over the world has brought prosperity, increased mobility, centralization of commerce, new modes of communication, and many other positive aspects. However, negative impacts like the fragmentation of green spaces, growing car dependency, and the negative environmental effects have led to a growing concern about the consequences of the seemingly unlimited urban growth. Several institutions, including the United Nations, have recognized the role of cities as a leader in combating social, economic, environmental, and spatial problems (UN-Habitat, 2020). Producing up to 70 percent of the harmful greenhouse gases, while only covering a mere 2 percent of the land, the role of cities in combating, for instance, climate change is not surprising (UN-Habitat, 2011).

Also in Finland the degree of urbanization has been increasing steadily over the last decades. Currently, over 72 percent of the Finnish population lives in urban areas and this number is expected to grow in the future (Helminen et al., 2020). The Helsinki Metropolitan Area, which includes the neighboring cities Espoo, Vantaa, and Kauniainen, as well as 10 other municipalities, forms the most urbanized and populated area of the country and is home to roughly a quarter of the Finnish population, while the municipality of Helsinki itself houses approximately 11 percent of the population (City of Helsinki, 2020a).

As the economic and political center of Finland, the City of Helsinki has recognized its important role in combating several of the aforementioned social, economic, environmental, and spatial problems. For instance, the City of Helsinki has committed to make Helsinki carbon-neutral by 2035, reducing the greenhouse gas emissions by 80 percent in comparison to the level of 1990 (City of Helsinki, 2018). The 'Action Plan' for carbon neutrality contains objectives for various sectors, such as transport and the construction and use of buildings. Furthermore, the City of Helsinki has declared a climate emergency as the first Finnish city, acknowledging its role and the role of other cities in the climate crisis (City of Helsinki, 2020b).

1.1. The 2050 Helsinki City Plan

Besides the Action Plan for carbon neutrality, the 2050 Helsinki City Plan will play a major role in tackling the current and future challenges facing the city. The ambitious plan, adopted in 2016, presents the overall vision for spatial development and guides land use for further detailed planning. The plan is based on the vision of Helsinki transforming from a city with a strong monocentric character to that of a polycentric network city (Helsinki City Planning Department, 2016). The city aims at transforming the current structure of the city by the 'urbanization' of several of the existing sub-centers, the implementation of new light railways, and the 'boulevardization' of several highway arteries.

Important in both the Helsinki City Plan and the Action Plan is the focus on more sustainable modes of transport, like walking, cycling and public transport. Although car ownership in the city has increased (395 passenger cars per 1 000 residents in 2010 and 411 passenger cars per 1 000 residents in 2017), the CO_2 emissions have been reduced as a result of a decrease in overall car usage (City of Helsinki, 2018). Through densification and diversification of land use around existing and new rail infrastructure, combined with higher costs for car usage (e.g. higher parking and congestion fees), the City of Helsinki hopes to further reduce the CO_2 produced by car traffic.

One of the newly proposed light railways of the plan is the *Viikin-Malmin light rail* (VIIMA), which will serve as a test case later on in this thesis (see Chapter 5). The VIIMA light rail will connect the center of Helsinki, through Arabia, Viikki, and the former Malmi airport, to the center of Malmi. The implementation of the light rail will open up opportunities for more efficient land use and can contribute to the goals for a carbon-neutral Helsinki and other goals concerning economic, social, and environmental sustainability. However, in order to achieve these goals, it will be crucial to recognize the inherent relation between land use, design, and rail transit.

1.2. Public transit at the center

Much of the previous research on people’s travel behavior has provided evidence that land use has a strong influence on the choice of travel mode (Hrelja et al., 2020; Newman et al., 2016). Several scholars such as Wegener, Fürst, and Bertolini have attempted to explain this relationship through cyclical schemes, in which land use and transport systems interact in a reciprocal rather than a linear way (see Section 2.1.). It could thus be concluded that both land use planners and transport planners, two of the professions shaping our living environment, can have a great influence on people’s travel behavior and ultimately on the share of CO_2 produced by traffic. This line of thought is supported by research of various cases showing that a good integration of land use planning and transport planning can lead to increased shares of public transport, walking, and cycling and reduced car usage (Hrelja et al., 2020).

One of the well-established land use planning concepts which builds forth on the aforementioned relation and translates the theory into a usable way of thinking for practitioners is *transit-oriented development* (TOD). By locating public transit connections at the center of dense and mixed neighborhoods, TOD attempts to make full use of the potential of these places in creating both a livable neighborhood as well as influencing travel behavior of people to more sustainable modes of traffic (see Section 2.2.). It is exactly this thought that also drives the 2050 Helsinki City Plan.

1.3. Research objectives and questions

Several scholars have however noted that much of the available research on TOD is mainly based on two levels, namely the policy scale and the regional planning scale, and that *"attention to detailed, site level urban design issues inherent in TOD has been minimal"* (Jacobson & Forsyth, 2008, p. 54). It is on this level, that many of the practitioners in the planning field are active and the aims of TOD are translated into our real-life surroundings. Furthermore, much of the research has focused on the North-American context, which is, due to several factors such as differences in planning systems and cultural elements, difficult to translate into usable tools for the European context (Hrelja et al., 2020; Pojani & Stead, 2015). In general, it can thus be concluded that practical design guidelines for TOD in the European context are lacking.

The main objective of this thesis is to bridge the gap between academic research and professional practice. This is done, first of all, by examining the relation between land use, design, and sustainable modes of mobility, and second, by producing practical spatial design guidelines for TOD in the Finnish context.

To achieve the objective of the thesis, a number of research questions have been formulated. These research questions are as follows:

1. What is the relation between the built environment and travel behavior?
2. What is TOD and what are its main principles?
3. What are the impacts of light rail projects?

4. What kind of TOD design guidelines can be derived from best-practice examples?
5. Are the derived TOD design guidelines applicable to the Finnish context and what new guidelines can be found through test designs?

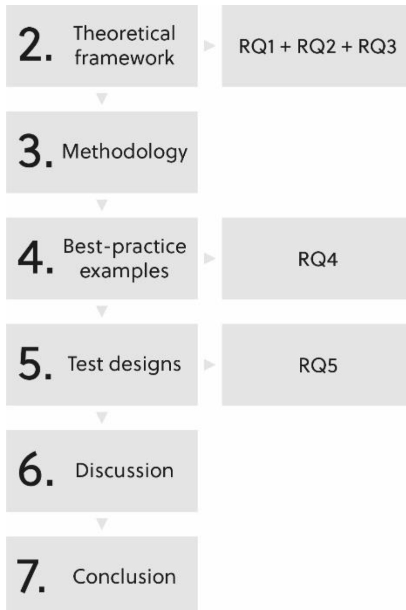

Figure 1 – Thesis outline and related research questions

2. Theoretical framework

The subject central to this thesis is the relation between land use, design, and sustainable modes of mobility. The theoretical framework in this chapter presents the baseline on available knowledge of this research topic in academic literature. The focus of the literature research has been on the aforementioned topic, the planning concept of transit-oriented development, and the impacts of light rail development.

2.1. The built environment and transport

One of the most important and most well-researched topics in the profession of urban planning and transport planning is the relation between the built environment and transport (demand) (Ewing & Cervero, 2010). In much of the previous research, a strong link has been found between the two topics (Næss et al., 2018). With the increasing importance of mobility in the modern urbanized world, improving the urban built environment to stimulate the use of sustainable modes of transport is one of the major challenges for today's urban planners (Bertolini, 2012; Hrelja et al., 2020).

2.1.1. The transport land use cycle

Several have argued that the relation between the two topics is no linear process, but rather reciprocal or a two-way interaction (Bertolini, 2012; Straatemeier & Bertolini, 2020; Wegener & Fürst, 1999). In other words, the built environment and transport system influence and affect one another. One of the models explaining this complex process is the 'transport land use feedback cycle' (Figure 2, left and middle). The simplified cycle (Figure 2, middle) demonstrates in a highly abstract manner the relation between the transport system and land-use in four steps; (1) the various types of land use influence where activities such as living, working, and recreating take place, (2) the activities that take place influence the use and development of different types of transport systems, (3) the available modes of transport affect the accessibility of the location, and finally, (4) the accessibility of the locations influence on their turn where different types of land use develop. Bertolini (2012) agrees with the argumentation behind the cycle, but suggests that a layer of complexity needs to be added in order to take into account external factors influencing the cycle (Figure 2, right). These external factors are represented by the dashed arrows in the scheme. Bertolini argues for instance that land use is not merely depending on accessibility conditions, but also on factors such as the availability of land, regional demand, and local environmental conditions. In turn, the activities that take place in a certain location do not only depend on the land use, but also by socio-demographic conditions. Furthermore, Bertolini argues that the response times of changes in the four elements vary greatly. Where land use and transport development takes time and can be regarded as relatively slow processes, activities and accessibility can change relatively quickly.

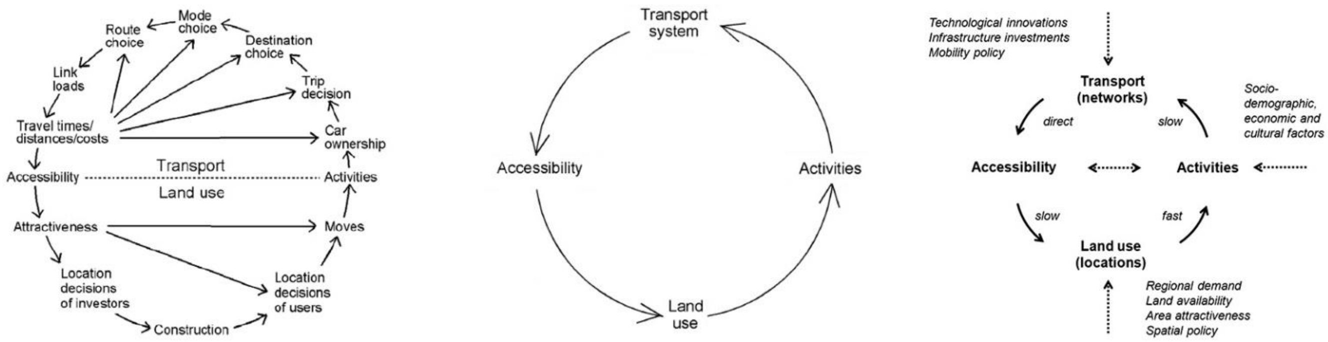

Figure 2 – Left: The land use transport feedback circle by Wegener (1996)
Middle: The land use transport feedback circle by Wegener & Fürst (1999)
Right: The transport land use cycle by Bertolini (2012)

2.1.2. The node-place model

The logic behind the transport land use cycle also supports the use of the node-place model, developed by Bertolini (1999). The node-place model aims at examining the relation between node and place values, mainly in areas served by public transit (Hynynen, 2005; Salat & Ollivier, 2017). In the development of the model, Bertolini (1999) recognizes the potential of public transit nodes in generating large, intense, and diverse flows of people for activity in the vicinity of the station or stop. However, Bertolini also argues that, as a result of weak place values, this flow of people does not necessarily always turn into a large amount of local activity. If understood right though, public transit nodes have the potential to become a place where social and economic activities flourish in a relatively sustainable way through the use of sustainable modes of traffic.

The node-place model presents a simplified diagram through which Bertolini's theory is argued (Figure 3). The y-axis depicts the node value of an area. The node value refers to the accessibility of the node, consequently, the potential of the node to generate flows of people. The node-index measures the accessibility through the accessibility by various modes of transport such as public transit, car, and bicycle. The x-axis depicts the place value of an area. The place value concerns the intensity and diversity of activities, thus, the potential for staying and doing something. The place-index is measured by the population and employment density, and the degree of functional mix within a radius of 700 meters from the entrance of the transit node (Bertolini, 1999).

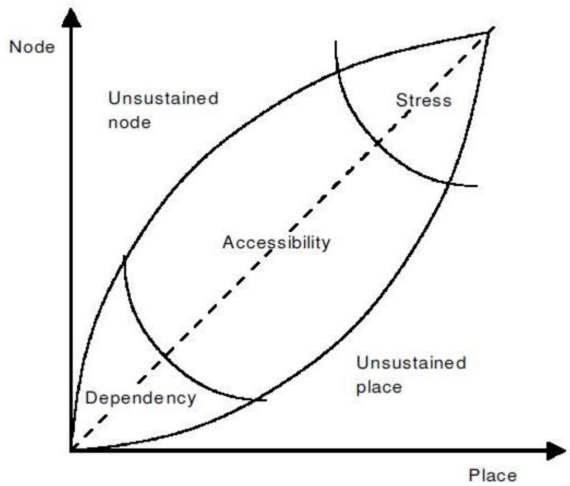

Figure 3 - The node-place model (Bertolini, 1999)

As can be seen in Figure 3, five different situations can be identified in the node-place model. *First*, the model can be in balance. In this case both the node and place values are strong, the ideal scenario. In this situation, the market value of the area is maximized (Salat & Ollivier, 2017). An example of such an area is Hammarby Sjöstad in Stockholm (see Section 4.3.). *Second*, the situation can be in stress. In this case, both the node values and the place values have come close to the maximum capacity. Salat & Ollivier (2017) label the area around the Shinjuki station in Tokyo as an example of a situation in stress, as real estate and the number of users are still increasing and new public transit lines are being added. Bertolini (1999) notes that although these areas have great features, these areas are also so heavily developed that it may lead to a number of conflicts. *Third*, an area can be dependent. These areas neither have high node values nor high place values. In these areas, there is hardly any competition for free space and a low demand for place values. In these cases, the area must make use of other aspects to sustain. *Fourth*, in unsustained nodes, the node values are far more developed than the place values. Examples of such places are large infrastructure nodes such as King's Cross in London (Salat & Ollivier, 2017). Lastly, *fifth*, concern unsustained places. Here, the intensity of place values exceed the node values. In these kind of situations, more transportation facilities are necessary in order to restore the balance of the model. An example of such a place is Hudson Yards in New York (Salat & Ollivier, 2017).

2.1.3. The five Ds

Much of the research on the relation between the built environment and travel demand have been centered around the 'five Ds'; density, diversity, design, distance to transit and destination accessibility (Ewing & Cervero, 2010; Hrelja et al., 2020). The five Ds are indicators used to research and explain the influence of the built environment on the travel demand. The original three Ds, density, diversity, and design, were first formulated by Cervero & Kockelman (1997). Later, two additional Ds were added to account for the influence of the distance to the transit and destination accessibility.

Density is relatively easy to measure and can concern various topics, of which population, jobs, and floor area are the most typical. A higher density has traditionally been associated with a positive effect on the travel demand for sustainable modes of traffic (walking, cycling, and public transit). This relation has several reasons, such as the increasing amount of short trips due to availability of services and the availability of better public transit connections as a result of the increasing amount of passengers. Weckström (2016) notes that whereas population and employment density are often direct indicators of activity in the area, the floor area ratio is not. Several building types such as storages and more recently data centers require large areas of floor space but often employ little amount of people.

Diversity refers to the diversity in land use functions and services. Diversity can be measured in different ways, for instance the availability of services within a certain distance and the job-to-housing ratio (Ewing & Cervero, 2010). A close related indicator to diversity is mixedness, which is often used a similar manner. Kockelman (1996) however notes that mixedness does not concern the diversity in functions and services in a certain area, but rather concerns the way in which these functions and services are situated relative to each other. For instance, an area can contain a high variety of functions and services, and thus be diverse, however if these functions and services are separated into their own zones, the area is not mixed. Just like density, a higher diversity and mixedness is often associated with a higher use of sustainable modes of traffic.

Generally stated, the *design* indicator concerns the walkability or walking experience. Whereas density and diversity are relatively simple indicators to measure trough calculation, design is more difficult as it includes a wide array of quantifiable and non-quantifiable aspects such as the average block size, number of intersections, permeability of blocks, street trees, building setbacks, and the visual quality of the walking experience (Cervero & Kockelman, 1997; Ewing & Cervero, 2010; Weckström, 2016). Cervero & Kockelman (1997) note that the design of places is unquestionably related to travel behavior as good designs can on the one hand improve the accessibility to services by foot or bike and on the other hand also provide amenities, such as parks and squares, for an increased travel experience. Although the relation between the visual quality of the built environment for walking and a higher share of walking are logical, evidence is mixed on the effects of for instance block size and number of intersections (Weckström, 2016).

Distance to transit relates to the distance to the nearest rail or bus stop, and can be measured as an average of the shortest street routes from houses and workplaces in an area, route density, distance between stops, or number of stations per area (Ewing & Cervero, 2010). Logically, a shorter distance to transit stops is often associated with a higher use of public transit.

Finally, *destination accessibility* can be either regional or local and is measured as the ability or ease of access to other destinations (Ewing & Cervero, 2010). Destination accessibility can be measured through mobility or accessibility (Weckström, 2016). Mobility refers to the ability of a person to travel with a certain mode of transport. This can for instance be measured by the availability of transport services. Accessibility refers to the amount of different places one can travel to from a certain place. This can for example be measured through the sum of potential destinations within a certain time.

2.2. Transit-oriented development

A well-established land use planning approach that addresses the relation between the built environment and travel mode choice is TOD. TOD is often also mentioned in relation to the previously discussed transport land use feedback cycle, node-place model, and five Ds. Although there is no single definition of TOD, definitions often refer to the *"development of housing, employment, activity sites and public services around existing or new railway stations served by frequent, high quality and efficient intra-urban rail services"* (Knowles, 2012, p. 251). Furthermore, TOD is often characterized by a mix of functions, compactness, density, and well-developed pedestrian and bicycle connections (Cervero & Sullivan, 2011; Hrelja et al., 2020; Institute for Transportation and Development Policy, 2017; Weckström, 2016).

Among the first to develop and brand the concept of TOD was Peter Calthorpe during the late 1980s (Carlton, 2009). Although other scholars and practitioners had already attempted to promote similar approaches to land use design in relation to sustainable modes of transport, Calthorpe, in cooperation with others, succeeded at branding TOD as it became a *"fixture of modern planning"* (Carlton, 2009, p. 1). Calthorpe regarded TOD as *"a neo-traditional guide to sustainable community design"* (Carlton, 2009, p.1) and an approach to urban development on a greater regional level. During the early stages of the development of the concept, the research was mostly focused on the North-American context. In Calthorpe's opinion, the concept was to help *"redefine the American Dream"* (as cited in Carlton, 2009, p. 1).

Although the concept of TOD presented a modern view at the development of (sub)urban areas, especially in North-America, the development of more dense urban areas around transit connections is not necessarily a modern phenomenon. Dense urban areas with a mix of functions along and around public transit can already be found in the urban extensions and plans of cities during the late 19th and early 20th century (Jacobson & Forsyth, 2008; Knowles, 2012). Hence, Calthorpe deems himself *"a reviver rather than an originator of ideas"* (as cited in Carlton, 2009, p.1). The urban expansions around transit connections enabled cities to expand beyond their original core, often based on pedestrian connections, and develop into more regionalized polycentric areas with new cores situated around railway stations (Söderström et al., 2015).

A well-known and broadly discussed planning concept, often referenced in relation to the origins of TOD, is the *Garden City,* discussed by Ebenezer Howard in his book '*Garden Cities of To-morrow'* (1902). Around the turn of the twentieth century, Howard proposes the Garden City in response to the then heavily polluted industrial British cities, filled with smog and slums. Howard was convinced that the Garden City would be able to provide an alternative to the industrial city, giving its residents the best from both town and country, such as the beauty of nature, bright homes, gardens, and low rents. The drawing of the 'Group of Slumless Smokeless Cities' (Figure 4) represents Howard's conceptual scheme for the Garden City in a larger urbanized area. In his scheme, smaller satellite cities, connected by intermunicipal railways and separated by greenbelts, circle around the central city. Within the cities, streets were to be walkable and green, while larger factories and other polluting elements were directed towards the edge of the city. Strict borders of the cities were to prevent further urban growth which could eventually lead to sprawl. One can see how certain aspects of Howard’s Garden City relate to TOD, such as the focus on access by public transport and the creation of walkable streets. However, other aspects such as the low densities are deemed not desirable in regards to TOD. Furthermore, the total population of the agglomeration presented in the conceptual scheme is a mere 260 000, whereas the satellite cities house around 32 000 inhabitants, which is hardly comparable to some of the major cities of today’s world.

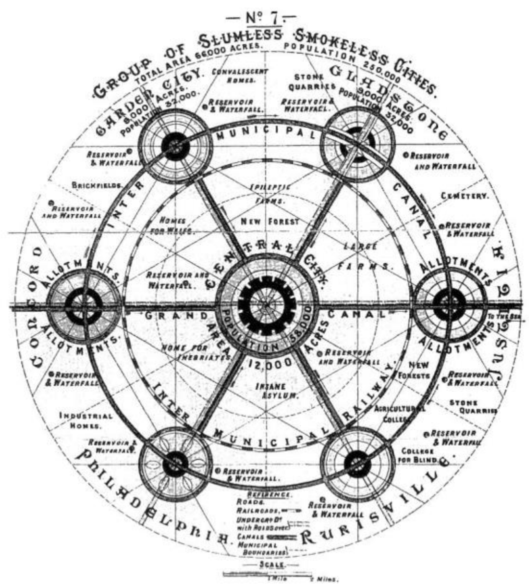

Figure 4 - Conceptual scheme of the 'Group of Slumless Smokeless Cities' (Howard, 1902)

Another well-known historical example, which has a stronger relation to the modern TOD concept, is the Five Finger Plan for Copenhagen (Figure 5). The original plan from 1947 contains five fingers, representing the corridors of urban development along existing or planned railway lines (Knowles, 2012). The areas in between the fingers functioned as green wedges, in which there was space for agriculture and recreation. In the plan, the area in the vicinity of every station would contain high-density housing and local shopping services, forming a local node for a larger service area (Knowles, 2012). In the years after the introduction of the plan, a strong link was found between the development of the public transit lines and the growth of population and employment. Soon after however, the TOD related effects of the plan decreased due to the slow development of the train lines, the large increase in car ownership (doubling from 1960 to 1970), and the construction of new motorways (Knowles, 2012). However, the regional plans of 1973 and 1989, produced by the Greater Copenhagen’s Capital Regional Authority, stayed true to the original principles introduced in the first Five Finger Plan. For instance, the 1989 Regional Plan permitted industrial and service facilities only to be constructed within one kilometer of stations on the radial railway corridors (Knowles, 2012). In the Traffic Plan for Copenhagen from 2003, the Helsingør corridor, in the first plan avoided due to its characteristic scenic coastline, was added alongside the other corridors (Knowles, 2012). The latest (significantly smaller) finger added to the plan is Ørestad, in which TOD principles have played an important role.

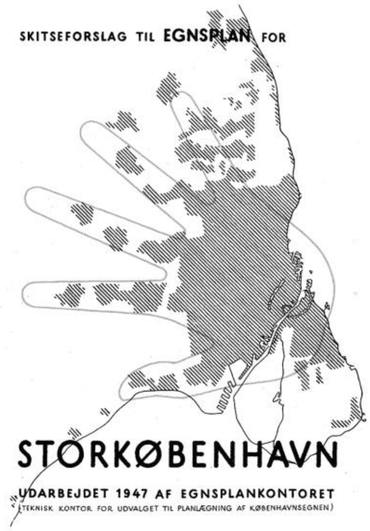

Figure 5 - The Five Finger Plan for Copenhagen (Norman, 2018)

2.2.1. Principles and guidelines

As previously stated, a single definition of TOD cannot be given. Whereas several have argued for TOD on a small scale, e.g. the near surroundings of a transit station, others have argued for the use of TOD on a larger scale, for instance as a regional planning approach. TOD can also take place in both city centers and suburban areas (Jacobson & Forsyth, 2008). Furthermore, much of the research and work on TOD originates from North America, where, in contrast to Europe, TOD-like development often forms an exception to the car-focused planning norm (Hrelja et al., 2020). Similar concepts to TOD can often be found in the European context under different names, such as the Swedish term *'stationsnära utveckling'* (station-adjacent development) or the Dutch term *'knooppuntontwikkeling'* (node development) (Hrelja et al., 2020; Krikken, 2020). Although a wide variety of descriptions can be found, the main principle behind the concept remains; the inherent relation between land use design and transport. Although literature provides a variety of distances related to TOD development, in general, a radius of 300 to 400 meters or 600 to 800 meters around transit stops, respectively 5 and 10 minutes walking distance, is used (Stojanovski, 2020; Weckström, 2016).

Hrelja et al. (2020) highlight three main characteristics of TOD. *First*, TOD intends to reduce the total demand for transport and increase the share of public transit, cycling, and walking. *Second*, TOD aims at creating a more livable environment with high standards for the urban space. *Third*, TOD can serve as a catalyst for (economic) development. Dittmar & Ohland (2004) note that the term TOD should only be used for projects that achieve five main aims, namely location efficiency, a rich mix of choices, value capture, place making, and a resolution of the tension between node and place. *Location efficiency* contains three main components; density, transit accessibility, and pedestrian friendliness. A higher density is important as it generates sufficient ridership for a high-quality transit system. An improved transit accessibility increases the ridership and convenience of using transit. Last, pedestrian friendliness relates to the street network and the quality of the walking environment. A *rich mix of choices* relates to the variety of services and spaces offered in the area. By offering a high variety of services and spaces, the amount of short trips increase, which decreases the need for car use. The definition of *value capture* differs per actor. For instance, residents of TOD will consider the savings of reduced car usage, whereas municipalities will consider higher tax income as a result of a higher density. *Place making* is important in order to shape a good living environment and provide an attractive walking environment. Many TODs have failed due to a lack of attention for shaping an attractive environment (Sharma et al., 2017). Finally, *a resolution of the tension between node and place* refers to the node-place model discussed earlier (see Section 2.1.2.). Sharma et al. (2017) note that understanding the role of a station is essential and that *every* station should be used for various functions, such as commercial, retail, and public spaces. A successful TOD provides not only a good transit node, but also a place for staying. A good mix of functions and spaces could provide activity throughout the day and evening.

The TOD Standard, a report *"to help governments devise their plans, policies, regulations, legislation, and investment priorities to promote access for all as a basic common good, a source of freedom and dignity, and an important pillar to create Just Cities"* (Institute for Transportation and Development Policy, 2017, p. 4), lays out eight core principles of inclusive TOD. *First*, walkability should form the foundation for sustainable access and mobility in urban areas. The pedestrian environment should be safe, active, vibrant, comfortable, and include ground-floor activities. *Second*, improved cyclability increases the catchment areas for transit stations and activate the streetscape. The cycling network should be safe and complete, and bicycle parking must be easily accessible. *Third*, urban areas should consist of a dense network of pedestrian and bicycle connections to minimize distances and offer a variety in routes. It is important that the pedestrian and bicycle network provides shorter routes than the motorized network. *Fourth*, high-quality transit should be accessible by foot. This means that maximum walking distances are defined as 1000 meters for rail transit. *Fifth*, TOD areas should contain a mix of functions and services to activate the streets throughout the day. A mix of diverse demographics and incomes is also required to create more socially sustainable cities. *Sixth*, high densities are necessary to provide high-quality transit and to combat unsustainable land use by urban sprawl. High densities also support the need for local services in the area. *Seventh*, the areas should be compact, reducing distances and time to access services and transit. *Eighth*, the land occupied by motorized vehicles should be minimized, supporting a shift from car use to more sustainable modes of transport.

Although these principles provide some guidance for the design of TOD, several have called for the need of more specific design guidelines, as research concerning this topic is often underdeveloped, especially in comparison to research on TOD at a policy and regional planning scale (Hrelja et al., 2020; Jacobson & Forsyth, 2008; Pojani & Stead, 2015). Up until this date, only a handful of systematic evaluations of the urban design quality of TOD projects have been made (Pojani & Stead, 2015). Jacobson and Forsyth highlight the importance of good urban design for TOD, as this is the *"stage of a project is where the goals and ideas of TOD are fitted to real-world constraints of space, time, and money"* (2008, p. 54). One of the studies that has attempted to formulate guidelines for TOD is done by Jacobson and Forsyth (2008). Jacobson and Forsyth divide the main urban design issues found through a literature review in twelve dimensions and group these into three topics (Table 1).

Processes	**Places**	**Facilities**
Time	Scale	Pedestrian/non-motorized orientation
Engagement with public	Public spaces for human use	Transit in the urban pattern
Programming	Safety	Car movement and parking
Maintenance	Variety and complexity	
	Connections	

Table 1 - Urban design topics related to TOD, adapted from Jacobson and Forsyth (2008)

Although many of the found principles and guidelines can be viewed as generalizable, several have noted that much of the research originates from North-America (Hrelja et al., 2020; Pojani & Stead, 2015; Thomas et al., 2018). It is thus important to note that, although the guidelines might provide a good starting point, the North-American TOD guidelines cannot be implemented on a one-to-one basis due to several factors, such as the differences in *"nature of the urban environment, the system of governance and the availability of different modes of transport (and the propensity to use them)"* (Pojani & Stead, 2015, p. 131).

For instance, Pojani & Stead (2015) found through workshops with several Dutch TOD specialists that, although their generated design guidelines in general match with the guidelines from North-America, several more specific design guidelines often relate to the country specific planning, design, and living culture. For example, where North-American TOD guidelines often highlight the need for surface car parking, this is viewed as undesirable in the Netherlands (Pojani & Stead, 2015).

2.2.2. Green TOD

More recently, a new TOD trend can be found in several cities, which consists of a combination of the principles of TOD and green urbanism. 'Green TOD', as Cervero and Sullivan (2011) define it, combines the benefits of both TOD and green urbanism, like compact development, high-quality transit access, mixed use, green roofs, self-sufficient buildings, and zero waste. Although some new developed neighborhoods combine concepts of both TOD and green urbanism, there are only a few that have consciously made use of the benefits of a synergy between the two. Examples of such neighborhoods are discussed in Chapter 3. A combination of the two concepts can yield benefits in four ways (Cervero & Sullivan, 2011). *First*, higher densities do not only provide sufficient ridership to support high-quality transit, they also reduce heating and cooling expenses, improve resource-use efficiency, and enable other green urbanism elements depending on high volumes. *Second*, a mix of functions and services in urban areas encourage walking and cycling and reduce the use of motorized vehicles. Furthermore, the combination of residential and commercial functions allows for complementary heat and energy needs. *Third*, high-quality transit reduces the need for car usage and will lead to a reduction in emissions and an improvement of the air quality. A reduced car usage also decrease the need for parking and enables the increase of more pervious surfaces like courtyards and community gardens.

Fourth, whereas transit stations are most often situated on the outskirts of eco-neighborhoods, in green TOD they can become the center of the community.

Although Cervero & Sullivan (2010) observe that TOD is often associated with a certain type of households, e.g. childless couples and Generation X'ers, they argue that several TODs that have successfully incorporated aspects of green urbanism also prove the child-friendliness of the concept. By providing (nearly) car free streets and an abundance of communal spaces, green areas, and playgrounds, TOD projects such as Rieselfeld (see Section 4.1.) and Hammarby Sjöstad (see Section 4.3.) have proved to provide a child-friendly environment.

2.2.3. Commercialization around stops

As transit stops form the centers for new communities in neighborhoods based on TOD and generate the most pedestrian activity, the area in the vicinity of the stops are naturally also the areas containing most of the commercial activities and other services as commercialization is closely linked to pedestrian movement (Stojanovski, 2020). The commercialization of the ground floors, design of street spaces and transit stops, and other urban design elements are of great importance in activating street life and helping to create comfortable and safe places for waiting and hanging out. In order to create such places, it is important to understand the relation between different rail transit typologies and the commercialization patterns around them.

As mentioned before, a maximum radius of 600 to 800 meters is generally accepted in literature concerning TOD. However, the amount of passengers, and thus potential customers, is most often at its maximum within 100 to 200 meters of walking distance from a transit stop (Stojanovski, 2020). This approximately corresponds with the visual range of the social field of vision described by Gehl (2010), in which one is still roughly able to identify movement and body language.

An analysis of nine neighborhoods containing rail transit in three Swedish cities presents evidence that every transit stop forms an urban node that attracts potential customers and that commercialization around these nodes is often limited to a 100-meter viewshed (Stojanovski, 2020). Furthermore, depending on the typology of transit infrastructure and stops, as well as its integration in the street design, the patterns of public space and commercialization differ greatly from the areas defined by the standard radius. Rather than a perfect circle surrounding the stops, more amoebic and elongated areas of commercialization are much more common (Figure 6).

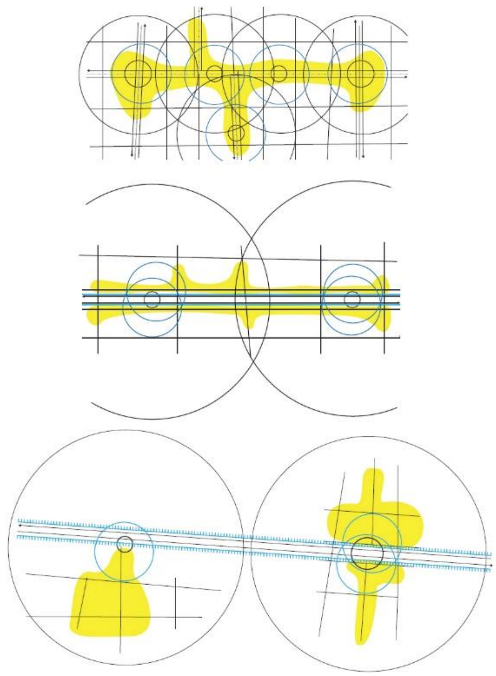

Figure 6 – Commercialization (in yellow) around transit stops with a 100-meter viewshed (blue circle). From top to bottom: Transit system fully integrated in street, transit system partially separated from street, transit system fully separated from street (Stojanovski, 2020)

Although the study is only based on nine different cases in the Swedish context, it successfully proves the point that urban planners must focus on viewsheds, type of transit stop, the integration of the transit system in the street design, and the aligning of the facades, rather than on the generally accepted walking radii. These kind of lessons can be used in the planning and design of new neighborhoods, as well as existing ones when considering the positioning of the stops and the integration of the rail transit in the street patterns.

2.3. Light rail development

As discussed previously, TOD is often associated with the development of forms of rail-based transit. Over the past decades, light railways have gained an increased interest over traditional railways and metro systems as a result of their lower implementation and construction costs while still providing fast connections (Ingvardson & Nielsen, 2017). Cohen-Blankshtain and Feitelson (2010) define two rationales for the implementation of a light rail system. The first rationale used is to generate a greater demand by increasing the accessibility to underdeveloped areas. The land use in these areas will be subject to increased land rents and higher building densities, which can eventually also lead to changes in mobility hierarchies (Higgins et al., 2014). The second rationale used is that a new light rail will serve the existing demand, especially in congested traffic corridors. In this rationale, the purpose of the light rail is to reduce the pressure on the existing traffic infrastructure and thus reduce congestion, travel times, and pollution. Next to these two rationales, light rail development is also used as a planning tool to *"achieve wider urban development goals and foster sociable and healthy cities that boast a higher quality of life"* (Ferbrache & Knowles, 2017, p. 109) and as a catalyst for regeneration and quality improvement of the public space.

While the literature presents an overwhelming amount of potential benefits linked to the implementation of a light rail system, which is discussed in the following sections, many projects have failed to achieve the desired (socio-economic) outcomes (Olesen & Lassen, 2016). As a result, criticism on light rail development mainly focuses on the economic irrationality behind the favorability of the development of a light rail over, for instance, bus rapid transit (BRT). A review of 86 public transport systems by Ingvardson and Nielsen (2017) shows that similar positive effects on travel time, modal shifts, and property values can be found regardless of the public transport system choice. Also Hensher argues that *"buses, especially bus-based transitway systems are arguably better value for money, and if designed properly, can have the essential characteristic of permanence and visibility claimed to be important to attract property development along the route which is compatible with medium to high-density corridor mobility"* (2016, p. 291).

However, in contrast to BRT, light rail often not only functions as a means of transport, but as stated before, also as a planning tool and catalyst for regeneration, an improvement of the public space, and a contribution to the sustainable image of a city. BRT is indeed more flexible, easier, and cheaper to implement than a light rail, however as a planning tool, these characteristics are also its weakness. Whereas the implementation of a light rail means a large investment into the development of a traffic corridor for many decades, routes of BRT might change and can thus not provide the same certainty as a planning tool. Light rail projects where transport planning and urban planning have been developed simultaneously and in conjunction with one another have often led to the most successful projects (Ferbrache & Knowles, 2017). Additionally, Engebretsen et al. (2017) note that several studies have shown that, although buses do have the capability to reach similar positive effects, the use of public transport in corridors served by light rail is higher compared to similar corridors served by bus.

The effects of a new light rail system can be divided into two categories; direct effects and indirect effects (Olesen, 2014). Direct effects are caused directly by the implementation of a light railway, for instance a change in accessibility. Indirect effects are caused by the direct effects and can include, for example, changes in housing prices and effects on location decisions for living and working. Olesen (2014) argues that such indirect effects should also play a role in the decision making process.

2.3.1. Impacts on land use

The most visible and tangible impacts of light rail development are the impacts on land use. The impacts of a new light rail on land use are tightly connected to the previously discussed transport land use cycle and TOD planning approach. In TOD, light rail development is often combined with dense land use development. In these cases, a more dense development is seen as a way to combat urban sprawl, but is also necessary for the justification of the construction of a new light rail in terms of ridership as well as a solid base for the services provided in the neighborhoods. Few studies have however been able to isolate land use changes as an effect of the implementation of a light rail (Handy, 2005; Hurst & West, 2014). This is partly caused by the complexity of land use development processes of the city. Handy (2005) however notes that, although there is no evidence that light rail development can stimulate the total growth in urban land use of an area, the implementation of a light rail can influence and redistribute the locations in which more dense development takes place. Furthermore, several studies have been successfully able to isolate the effects of the implementation of a light rail on increasing real estate prizes (Hurst & West, 2014).

Although one must thus be cautious to not overestimate the power of a new transit route in land use development, research has shown that, if local conditions are receptive and the right factors are in place, these systems can have a measurable impact on land use (Higgins et al., 2014). Higgens et al. (2014) list six important factors that contribute to a larger change in land use in the areas surrounding new transit stops. *First*, the new rail transit needs to bring a significant improvement in accessibility. This also means the addition of transit-based employment and transit-based housing, as well as good connections to and from the transit stops. *Second*, there must be a (regional) growth in population and amount of jobs that justify the creation of mixed high density neighborhoods. There must also be a demand on the housing market for this type of housing. *Third*, the streetscapes and surroundings of the transit stops must be of high quality in order to attract project developers, companies, and residents. *Fourth*, also the social conditions around transit stops play an important role in the attractiveness of the areas and are able to attract several actors. *Fifth*, large parcels of land will offer more attractive possibilities for dense land development and are more suitable for project developers. *Sixth*, additional policies aimed at TOD, like restrictions of parking and car access, are necessary to promote the development and stimulate the use of public transit.

Most of the aforementioned discussed research on the impacts on land use originate from the United States. It is here important to note the difference in planning systems between the North-American and European, or more specific the Nordic context. Whereas land use planning in the United States is mostly done through zoning plans, in which for instance the maximum building restrictions are given, the role of the public institutions is the Nordics is far greater. This also means that in the Nordic context, the government is able to more successfully influence land use development, increasing the chance of success of development along light rail corridors.

2.3.2. Impacts on the image of a city

Rail-based transport systems in urban areas, like light rail, are increasingly linked to local place-making, discourses on sustainable mobility, sustainable cities, and social equity through the materialization of ideas on such topics and perceptions hold by related social actors (Niedzielski & Malecki, 2012; Ferbrache & Knowles, 2017). This means that transport infrastructure can no longer be only seen as a way to connect people and place, but also as a *"symbol of development, progress, and identity"* (Dimitriou & Trueb, 2005, p. 66). Ferbrache & Knowles (2017) list six impacts of light rail development on the image of a city. *First*, light rail projects provide a 'modern sense of place', which relates to both its technological sophistication as well as its appearance. Compared to busses, light rails contain a more 'mythical allure', and seem to attract more interest from local stakeholders such as residents, the media, politicians, and urban planners. In other words, *"trains are sexy and buses are boring"* (Hensher, 2016, p. 289). *Second*, due to the modern and mythical allure, light rail projects have been able to boost the image and reputation of a city. Cities like Freiburg, Grenoble, and Bergen, where the development of light rail and urban planning have gone hand in hand, are nowadays viewed as success stories and role models for other cities. The 'Grenoble Effect' for instance refers to the successful way in which the light rail project was integrated in urban development, where boulevards and other spaces for private vehicles were transformed to high-quality spaces for public transport and pedestrians. An example of such an improvement is presented in Figure 7. *Third*, light rail projects are able to contribute to a city's sense of identity, as elements of the local identity can be used in the design and appearance of the light rail. For instance, the trams in Angers, a city known for its agriculture, are decorated with colorful stripes representing the flower fields, whereas the design for the trams of Marseille are inspired by the bow of a ship, referring to the coastal image of the city. *Fourth*, light rail projects are linked to the concepts of social equity and equality, as they can provide access for disadvantaged groups in the city or improve the living conditions in deprived neighborhoods. The impacts linked to social equity also relate to that of a more equitable society and a better perceived quality of life within the city. *Fifth*, light rail projects are often associated with an improvements of environmental quality, such as less pollution and congestion, but also improved public spaces. Light rails have also been found to produce less noise and vibration than buses. *Sixth*, although literature suggests that light rail projects, in general, impact the image of a city in a positive way, disruptions during construction and budgeting problems can also give a negative image. Transparency of the development process can help reducing these negative impacts.

Figure 7 - Improvement of the public space in combination with the implementation of a light rail in Angers, France
Left: Situation in 2008 (Google, 2008)
Right: Situation in 2018 (Google, 2018)

3. Methodology

The thesis does not necessarily present itself as a traditional research thesis nor a traditional design thesis, but rather builds upon the relation between academic and professional practices. Deming & Swaffield note that it is this relation, commonly found in environmental design disciplines such as urban planning and landscape architecture, that creates a *"fertile intellectual environment for research"* (2011, p. 48).

3.1. Research objectives

Although the research objectives for this thesis were already briefly discussed in the introduction (see Section 1.3.), it is worth briefly discussing the motives behind research in environmental design disciplines in a more general way. Understanding these motives is also of importance when selecting the right research methods.

Deming & Swaffield (2011), define three motives that drive research in environmental design disciplines; intellectual, opportunistic, and ethical. Intellectual motives come forth out of a lack of understanding of a phenomenon. Opportunistic motives arise from changes and contain a response or transformation of a condition or need. Ethical motives emerge from a wish to solve certain issues and often relate closely to one's personal values. However, although the motives for research may differ, a design or research always starts a similar way, with *"an awareness, articulation, and acceptance of a problem"* (Deming & Swaffield, 2011, p. 48).

As introduced in Chapter 1, the problem central to this thesis is the gap between academic research and professional practice associated with the relation between land use, design, and sustainable modes of mobility. My personal motives for the research in this thesis arise from a combination of the aforementioned three motives. The relation between land use, design, and sustainable modes of mobility is a widely discussed topic in academic literature, however, as previously discussed, translations into usable tools or the link between academic and professional practices is often lacking. In this, I recognize a research gap, or as Deming & Swaffield (2011) define it, an intellectual motive. As the thesis also deals with the changing urban environment, and includes a design aspect, or a *"projection of a possible future landscape"* (Deming & Swaffield, 2011, p. 49), it can also be said that the research is motivated through opportunistic motives. Finally, it can be argued that the research in this thesis is also ethically motivated, as it deals with a broad socio-environmental problem for which new solutions are sought.

3.2. Research and design

In order to bridge the gap between academic and professional practices, it is important to first address the key difference between research and design in environmental design disciplines, such as urban planning and landscape architecture. Deming & Swaffield argue that one of the major differences *"lies in the way an investigation is motivated and framed"* (2011, p. 52). Whereas the incentive of a design is often to seek a solution or plan for a specific place or situation, the goal of research is to contribute to a theory and to produce generalizable knowledge. Inherently though, research methods are often part of the design process, for instance through a site analysis, literature review, or survey (Deming & Swaffield, 2011; Milburn & Brown, 2003).

Several scholars have however noted that a design process may be justified as a research or part of a research if framed correctly (Deming & Swaffield, 2011; Jansson et al., 2019; Lenzholzer et al., 2016; Nijhuis & De Vries, 2019). A design process, may it be research through design, a design experiment, or a different design method, can be justified as an independent research method if *"it produces new generalizable knowledge about the world through its purposes, protocols, and outcomes"* (Deming & Swaffield, p. 206). In order to become a justifiable research method, the design process must, like any other research, meet several criteria to assure the integrity and legitimacy of the outcomes. In order to become a legitimate research method, Nijhuis & de Vries (2019) argue that the design process must meet the following five criteria: purposefulness, reliability, consistency, transparency, and usability. *Purposefulness* refers to the objectives and questions of the research, in other words, the goals being sought after. *Reliability* concerns the validity of the research and if the outcomes are verifiable, for instance by external experts. *Consistency* relates to the working methods and principles being used, and choices being made in a coherent way. *Transparency* refers to the comprehensibility of the process and answers the question if the process can be repeated in a similar way by others. Finally, *applicability* concerns the relevance of the outcomes and if these can be applied in practice.

A multitude of methods that meet these criteria might be used in order to bridge the aforementioned gap between research and design. One of these methods is discussed by Prominski (2016), who proposes the creation of guidelines as a means to translate both findings of research and design. The guidelines function as an abstraction of a certain principle and can serve a purpose outside of a specific case. In other words, guidelines, as proposed by Prominski, have the capability to contain generalizable knowledge which can be applied in other situations and act as a bridge between *"the mass of research evidence and its application in a complex situation"* (Prominski, 2016, p. 196). These guidelines *"are neither totally specific nor completely universal and represent structured knowledge bundles at an intermediate level"* (Prominski 2016, p. 196).

Prominski (2016) introduces two methods for the creation of guidelines. Both methods require the establishment of a theoretical framework as a first step. The theoretical framework provides the theoretical background on a research topic and is necessary for the evaluation of the guidelines throughout the process. The first method concerns the creation of guidelines through 'best-practice examples'. The choices for the best-practice examples are argued through the findings in the theoretical framework and concern studies of real life cases. The second method to obtain guidelines is through test designs. Although the test designs concern specific cases, such as the design of a new park or residential area in a given location, the goal is to obtain generalized knowledge and eventually the creation of generalizable guidelines. As previously discussed, it is important that the complete process adheres to the aforementioned five criteria to be able to be justified as a legitimate research.

3.3. Research methods

Throughout the research process, I have made use of a variety of research methods, both more traditional research methods as well as research methods related to design. The theoretical framework, presented in the previous chapter, provides the background on the research topic of the relation between land use, design, and sustainable modes of transport. The theoretical framework has been established through a literature review and presents the baseline on the available knowledge on the research topic.

For the development of the design guidelines, I have followed the two methods previously discussed (Figure 8). The first method concerns the creation of generalizable guidelines through an analysis of best-practice examples, for which the theoretical framework provided the starting point. The chosen best-practice examples were cases that were presented as good examples of TOD throughout literature and are found in a context comparable to the context of Finland. The selected examples are Vauban and Rieselfeld in Freiburg, and Hammarby Sjöstad in Stockholm. The descriptions and analysis of the best-practice examples are based on literature, maps, images, and other digital material. Due to the travel restrictions as a result of the COVID-19 measures, I have unfortunately not been able to visit the sites and have thus only made use of the available digital material.

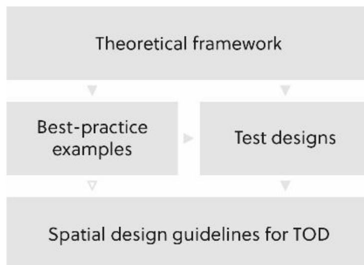

Figure 8 – Process going from theory to practice

In order to develop a structured and easily usable matrix of design guidelines, I have made use of a similar categorization as used by Jacobson and Forsyth (2008) and Pojani and Stead (2015). In a similar attempt at creating design guidelines for TOD, the authors have categorized several relevant dimensions into three different topics, namely, place-making, facilities/logistics, and process. During the research process, I have mostly focused on the first two topics, as these are most tangible for urban planning practitioners. Research on the topic of process has not been ignored during the evaluation of the best-practice examples, but does not form a part of the final design guideline matrix. Furthermore, certain guidelines can be attached to several dimensions. In these cases, the guideline is placed in the most relevant dimension to avoid repetition. The topics and related dimensions discussed are:

- Topic 1 – Place-making
    - Dimension 1: Scale and density
    - Dimension 2: Public spaces for human use
    - Dimension 3: Safety
    - Dimension 4: Variety and complexity
    - Dimension 5: Connections
- Topic 2 – Facilities/Logistics
    - Dimension 6: Pedestrian/Cyclist orientation
    - Dimension 7: Transit in the urban pattern
    - Dimension 8: Car movement and parking

After the creation of the design guideline matrix, I have made use of the second method discussed by Prominski (2006), which concerns the development and testing of guidelines through test designs. The chosen case for the test designs is the development of the VIIMA light rail in the Kiitotienkorttelit and Sunnuntaikorttelit neighborhoods in the new Malmin kenttä district in Helsinki. The case has been selected based on the planning characteristics and potential for TOD, and forms an adequate case for the development and testing of design guidelines. The design guideline matrix provides the starting point for the test designs. The goal of the method is to test the applicability of the generated guidelines from the best-practice examples for the Finnish context and for the urban planning profession in general. Before the test design process started, a brief analysis of the site and relevant existing plans was made to get familiar with the area and planning context.

The results on the applicability of the guidelines as well as the other developed guidelines are discussed in the discussion chapter of the thesis (see Chapter 6). Also the limitations of the study have been discussed in this chapter.

4. Best-practice examples

This chapter presents a discussion and analysis of three best-practice examples with the goal of extracting generalizable spatial design guidelines for TOD. The selected best-practice examples are Vauban and Rieselfeld in Freiburg, and Hammarby Sjöstad in Stockholm (Figure 9). The focus of the analysis is on the urban form of the neighborhoods and the impacts generated by the development of the rail transit. The main findings for TOD are summarized in a table at the end of each section.

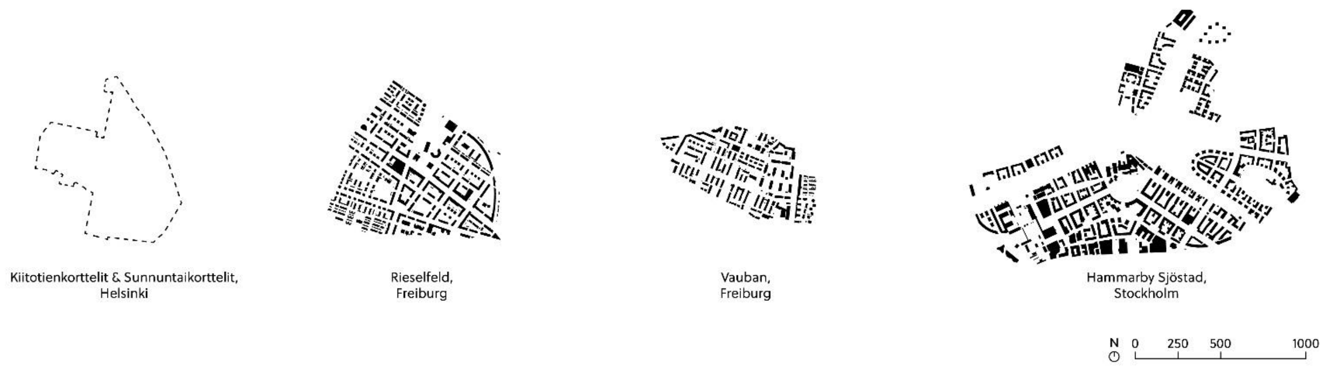

Figure 9 – Scale comparison of the test design area in Helsinki and figure-ground diagrams of the best-practice examples

4.1. Rieselfeld, Freiburg

The first best-practice example discussed is Rieselfeld in Freiburg. The neighborhood, located in the west of the city, houses around 9 600 inhabitants and 880 jobs, and is connected to the city center by tram (Figure 10) (City of Freiburg, n.d.). Construction of the neighborhood started in 1994 and finished in 2011 (Modarress-Sadeghi & Konstari, 2015).

The city of Freiburg is well known for its sustainable transport and land use planning and is widely regarded as Germany's *"environmental capital"* (Buehler & Pucher, 2011, p. 45). Freiburg's long lasting tradition in sustainable traffic and land use planning started during the 1970s. Whereas the center of Freiburg was rebuild in its historic compact form after World War Two, in which the city had suffered greatly from several air raids, much of the other development in the post-war era took place at the outskirts of the city (Buehler & Pucher, 2011). As development was mostly focused on accessibility by car and bus, old tram lines were removed and the overall amount of public transit services was reduced. Freiburg's development during this period followed a similar development found in many other German cities. However, a change in the direction of development took place in the late 1960s and early 1970s, after the public opinion on car-oriented growth shifted due to the growing concern for the environmental and social problems related to car use, the oil crisis of 1973, and plans for the construction of a new nuclear power plant in the vicinity of the city, which stimulated the growing concern for environmental issues even more (Buehler & Pucher, 2011). In the following decades, several integrated transport plans were made that focused on movement by tram, bicycle, and walking rather than by car. The land use policies also shifted towards development around public transport corridors, especially in areas in the vicinity of the expanding tram network (Buehler & Pucher, 2011). During the planning process, the cooperation with citizen groups and local businesses played a large role, resulting in a strong participation tradition.

Figure 10 - Location of Rieselfeld in Freiburg (Google, n.d.-a)

One of the areas that displays Freiburg's strong tradition in participation and in connecting transport and land use planning is Rieselfeld (Figure 11). Planning for the neighborhood started at the end of the 1980s, after a strong economic growth had led to a growing demand for housing in the city. The city proposed over 20 possible locations for a new neighborhood and eventually decided to develop part of the Rieselfeld. The Rieselfeld area, which can be translated in English as 'sewage farm', originally functioned as a wastewater treatment area, from which the purified water flowed towards the river Dreisam (Rieselfeld Projekt Group, 2007). After the completion of a new water treatment plant at the end of the 1980s, the area was taken out of use as a wastewater treatment area due to increasing pollution.

The City of Freiburg envisioned Rieselfeld to become an exemplary project for future sustainable development projects. In order to reach this goal, guidelines defining the new ‘eco-suburb’ were made by city planners in cooperation with local environmental sustainability experts (Broaddus, 2010). The set guidelines aimed, for instance, at concentrating the office and retail spaces along the transit corridor, high residential densities, and a range of different financing and housing forms (Broaddus, 2010). The guidelines formed the basis for the competition in the years 1991-1992, which aimed at finding an architectural proposal for the new neighborhood. The competition was won by a joint effort of various architects from the Freiburg and Lörrach area (Brombach, 2012). After further development of the winning entry and the acceptance of the plan in 1993, the area was divided into four building phases and the sale of the plots started.

Figure 11 – Left: Figure-ground diagram of Rieselfeld
Right: Satellite image of Rieselfeld (Google, n.d.-b)

The main axis of the neighborhood is formed by the Rieselfeldallee, along which the tram runs (Figure 12). In order to reduce the use of the car and make the neighborhood attractive for new residents, the tramline was taken in use in an early stage. The extension of the tramline opened in 1997, when around a 1000 inhabitants lived in the area (Cervero & Sullivan, 2010). The three stops are strategically located so that the entire neighborhood is located within 600 meters of a tram stop and a large part of the area within 300 meters (Figure 12). The neighborhood thus adheres to the radii of TOD discussed earlier. The tramway consists for a large part out of green tracks with grass, giving the axis a more green character. The green tracks also add to the share of permeable surface in the area, thus also contribute to the storm water management system in the area. Along the tramway, lanes of trees on either side of the track accentuate the axis (Figure 13).

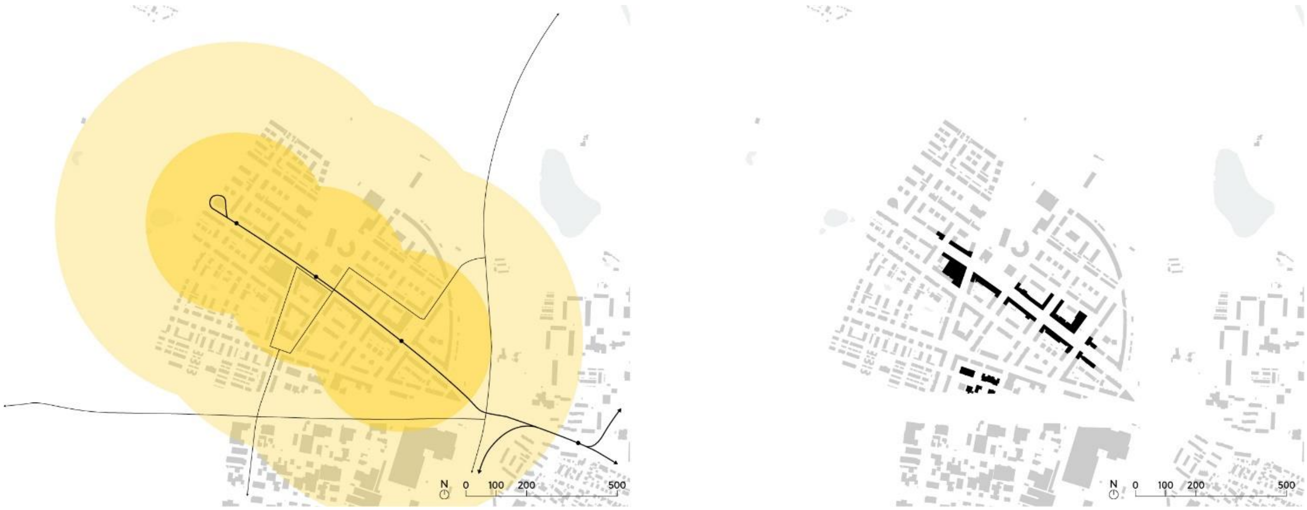

Figure 12 - Left: Public transport connections, two rings around the stops with a radius of 300 and 600 meters
Right: Commercial activity in ground floor

As was agreed upon in the set guidelines, most of the commercial activity takes place along the Rieselfeldallee, giving the ground floor an open character while contributing to street activity (Figure 12 & Figure 13). With the exception of some company buildings in the south of the area, all of the commercial spaces are easily accessible by public transport. The wide sidewalks in front of the commercial spaces also provide space for terraces and bicycle parking.

Figure 13 - Left: Green tram tracks and lanes of trees to accentuate the axis (Chung, 2011a)
Right: Ground floor functions along the Rieselfeldallee (Chung, 2011b)

Creating a good public and private infrastructure was another important objective in the development of the area. Goal was to provide all services in the neighborhood to increase the amount of short trips and thus reduce the need for trips by car. Whereas the commercial spaces are located along the Rieselfeldallee, the public facilities such as the schools, neighborhood center, and church are mostly connected to the public spaces and public green spaces (Figure 14). Most of the public facilities are situated in the green wedge perpendicular to the Rieselfeldallee. The green wedge connects to the open spaces Käsbach and Dietenbach north of the area and redirects inhabitants towards these areas rather than the nature reserve west of Rieselfeld (Rieselfeld Projekt Group, 2007).

Figure 14 - Left: Public squares and public green spaces (with a park-like feeling)
Right: Public services such as schools, libraries, and sports facilities

The green wedge consists of two parts, namely the square Maria-von-Rudloff-Platz in the center of the neighborhood and the green spaces northeast of the square (Figure 15). The public square is strategically connected with the tram stop and houses the church and neighborhood center. Both of these buildings form, due to their architectural quality and function, important landmarks in the area. Also the Geschwister-Scholl-Platz, located at the eastern tram stop, is connected to the public transport.

By locating the services and public squares in close relation to the tram stops, the design follows some of the main principles of TOD and provides good places according to the node-place model. By connecting the services and public space to the tram stops, the design makes good use of the flows of people while also providing places to hang out.

Figure 15 - Left: Connection between the Maria-von-Rudloff-Platz and the tram stop (Westermayer, 2014)
Right: The green wedge and Maria-von-Rudloff-Platz (Rieselfeld Projekt Group, 2010)

Another goal set in the development of the area was to reduce the use of the car and increase the share of public transport, cycling, and walking. This has been one of Freiburg's main goals for many decades, special attention was thus paid to the prioritization of these modes of transport in the design and street layout of Rieselfeld. Access to the neighborhood by car is organized through three inlets, connecting the neighborhood to the two main roads outside of the area (Figure 16). Although cars can make use of the one way streets along the tramway on the Rieselfeldallee, traffic is calmed and priority is given to pedestrians and cyclists. This measure also permits the absence of crosswalks. Additionally, the change of surface material at crossings, from asphalt to cobblestones, emphasize the role of the car as a guest in the area.

Figure 16 – Left: Car infrastructure
Right: Walking and cycling infrastructure

The general speed limit in the area is 30 km per hour and there are several traffic-calmed streets, creating pleasant and safe streets for walking, cycling, and playing (Figure 17) (Cervero & Sullivan, 2010; Rieselfeld Projekt Group, 2007). Although the building blocks are in some cases relatively large, all of them are accessible by foot and bicycle, creating a very connected network for pedestrians and cyclists. As only 31% of the resident trips are done by car, whereas 16% of trips are done by walking, 28% by cycling, and 25% by public transit, it can be said that the design of the urban form has contributed to a reduction of car usage (Cervero & Sullivan, 2010).


Figure 17 - Left: Residential street with a maximum speed of 30 km per hour (Chung, 2011c)
Right: Pedestrian and cycling path through a courtyard (Chung, 2011d)

Private parking in the area is mostly organized in underground garages and some smaller private above-ground garages whereas public parking is placed along the streets (Figure 17 & Figure 18) (Schröder-Klings, 2011). Public parking in the neighborhood is free, with the exception of the parking places along the Rieselfeldallee (Broaddus, 2010). A ‘park and ride’ facility can be found in the south of the neighborhood and provides access to the Geschwister-Scholl-Platz tram stop. The underground parking garages are paid for by the residents through the housing costs and thus negatively affect residents who choose to live without a car. Critique can also be given to realized amount of parking spaces in the neighborhood, which exceeds the total amount of personal vehicles by about 900 (Broaddus, 2010). In total, there are about 1,2 parking spaces available per household (Foletta & Field, 2011). However, as a result of measures to demotivate car use by stimulating other modes of transport, the amount of cars per inhabitant in Rieselfeld was in 2003 still significantly lower than the average of Freiburg, respectively 300 and 427 per 1000 inhabitants (Müller, 2015).

Figure 18 - Left: Car parking on ground level
Right: Building heights

The highest building densities are located along the Rieselfeldallee (Figure 18). Further away from the tram stops, the density and height of the buildings decrease and the share of low-rise buildings and row houses increase. As one of the aims was to create an architecturally diverse neighborhood, the building blocks are divided into small plots. This meant that a block is not sold as a whole to just one investor, but is divided between five to ten investors (Brombach, 2012; Rieselfeld Projekt Group, 2007). Another aim was to provide a neighborhood which is affordable and consists for 50% of social housing. However, due to various economic and political reasons, only the first two building phases reach this amount, as the third and fourth building phases consist mostly out of free-market housing (Brombach, 2012).

The built area along Rieselfeldallee mostly consists of multistory housing of five or six floors with commercial activity in the ground floor (Figure 19). The building heights give a feeling of continuity along the street, whereas the diversity in colors and building styles provide variation. Away from the Rieselfeldallee, the building types and heights vary (Figure 19). The large courtyards have lush vegetation and are for common use. The style of the buildings is simple and the most common texture of the facades is plaster. Timber and metalwork are used for the balconies (PRP, URBED and Design for Homes, 2008). Although Rieselfeld contains low-rise buildings and has a green character, the neighborhood is with 121 inhabitants per hectare still the 4th most dense neighborhood of Freiburg (City of Freiburg, n.d.).

Figure 19 - Left: Building heights between five and six floors along Rieselfeldallee (Lion, 2016)
Right: Row housing and apartment buildings further away from Rieselfeldallee (Freiburg Study Tour, 2012)

It could be said that, although some of the original goals have not been reached, Rieselfeld provides a good example of TOD and achieves all five aims formulated by Dittmar & Ohland (2004), namely location efficiency, a rich mix of choices, value capture, place making, and a resolution of the tension between node and place. By shaping a dense neighborhood sufficient ridership is generated as well as a sufficient amount of customers for the available commercial services. The planners have at the same time succeeded to provide lively urban spaces by locating them in connection to the tram stops and public services. Furthermore, the green and traffic calmed streets contribute to the pedestrian and bicycle friendly character of the neighborhood.

Dimension	**Main findings**
Topic 1: Place-making	
Dimension 1: Scale and density	• Provide a sufficient amount of tram stops so that the maximum walking distance is 600 meters.
	• Organize the neighborhood around a central axis.
	• Develop a boulevard like structure along the tramway with higher densities than in the rest of the neighborhood.
	• Accentuate the main axis with higher buildings, decrease the height as you move further away.
	• Provide a variation in density further outside of the direct surroundings of the tramway.
	• Use, as a general rule, maximum building heights of around five or six floors.
Dimension 2: Public spaces for human use	• Provide large courtyards for common use.
	• Connect public spaces to transit stops to make use of the passenger flows.
	• Connect several public spaces to create a corridor of public spaces.
	• Create green space to develop a local storm water management system.
	• Use the public spaces to guide people to leisure areas.
	• Prohibit access for motorized vehicles.
Dimension 3: Safety	• Design safe streets for playing by implementing traffic-calming measures.
	• Create ground floor functions and other interesting functions at and around public spaces to provide 'eyes on the street'.

Dimension 4: Variety and complexity	• Divide large building blocks into smaller plots to reduce the risk of monotonous blocks. • Use a variety in building materials and colors, while creating unity in the overall building style.
Dimension 5: Connections	• Design moderate-size, permeable, and interconnected building blocks. • Provide shortcuts for non-motorized traffic. • Reduce the access streets for cars.
Topic 2: Facilities/Logistics	
Dimension 6: Pedestrian/cyclist orientation	• Provide a continues network of bikeways and sidewalks. • Locate shared bicycle stations close to public amenities, transit stops, and public spaces. • Let cyclists make use of the roads rather than sidewalks where possible. • Provide space for bicycle parking close to public amenities and commercial spaces. • Design semi-public spaces within courtyards. • Provide safe streets for playing.
Dimension 7: Transit in the urban pattern	• Develop the transit corridor as the spine of the neighborhood. • Locate spaces for commercial activity in close proximity to the transit stops. • Connect transit stops to public spaces. • Provide easy access to the transit stops. • Ensure modal integration of buses and light rail. • Give a green character to the railway (e.g. by adding vegetation to the tracks and planting trees along the railway).
Dimension 8: Car movement and parking	• Minimize the amount of access roads to the neighborhood. • Reduce the amount of car traffic along the transit axis. • Allow on-street parking along main roads. • Create underground parking garages. • Prohibit cars from entering courtyards. • Reduce the maximum speed to 30 km per hour.

Table 2 – Summary of the main findings for TOD in Rieselfeld

4.2. Vauban, Freiburg

Next to Rieselfeld, the city of Freiburg contains another famous example of TOD and sustainable urbanism, Vauban. Vauban is located in the south of Freiburg, about three kilometers from the city center (Figure 20). The neighborhood houses around 5 200 inhabitants and about 660 jobs (City of Freiburg, n.d.). With around 133 residents per hectare, Vauban is the densest neighborhood of Freiburg (City of Freiburg, n.d.).

Figure 20 - Location of Vauban in Freiburg (Google, n.d.-a)

Vauban is located on a site formerly used as a barrack area by the French armed forces, who withdrew from the area at the end of the Cold War. After the withdrawal, the site became vacant and 34 of the 38 hectares was bought by the City of Freiburg from the German state for a sum of about 20 million euros in 1992 (Coates, 2014). The remaining four hectares were bought by the student organization *'Studentenwerk'* and '*SISU'*, the *'Selbstorganisierte Unabhängige SiedlungsInitiative'* (Self-organized independent settlement initiative). The acquisition of the land meant an opportunity to create a second sustainable urban district next to Rieselfeld, of which the planning had also recently started. Development in the area started with the conversion of six of the old barracks into student housing by Studentenwerk. Next to this, SISU made clear that it wished to create an alternative housing community in the area (Coates, 2014). As this was not in line with the goals of the City of Freiburg, a compromise was reached, and SUSI was allowed to develop four other barracks. Simultaneously, a group of environmentally minded citizens believed that the guidelines used in the development of Rieselfeld were not sufficient for Vauban, and started working on a vision of a more sustainable and car-free neighborhood. In order to organize more efficiently and realize the ambitious goals, the group founded 'Forum Vauban' in 1994 (Stadtteil Vauban, n.d.). In the same year, a competition was held to find the architectural concept for the new district, which was won by a joint effort of Büro Kohlhoff & Kohlhoff together with several other Stuttgart based firms (Coates, 2014).

In cooperation with Forum Vauban, the city planners continued planning of the area, hereby a focus was put on participatory planning methods. Throughout the process, Forum Vauban advocated for stricter environmental and guidelines, such as the addition of more passive housing and the establishment of a community center in one of the former barracks (Coates, 2014). Although the City of Freiburg remained sceptic about the development of a car-free area, a compromise was reached where a parcel at the eastern edge of the neighborhood would remain vacant in case a parking garage was needed in the future (Broaddus, 2010). After the approval of the master plan, which included the car-free streets, the project generated a lot of interested and a long waiting list was formed (Foletta & Field 2011). With everything set in place, Forum Vauban received the task of coordinating the *'Baugruppen'* (building cooperatives/groups) who wished to build their own housing blocks. Later, Forum Vauban became the residents' association (Broaddus, 2010). The area was then divided and built in three phases. By handing out the plots gradually, the revenues for the city were used to finance infrastructure and amenities for the next building phase (Kasioumi, 2011).

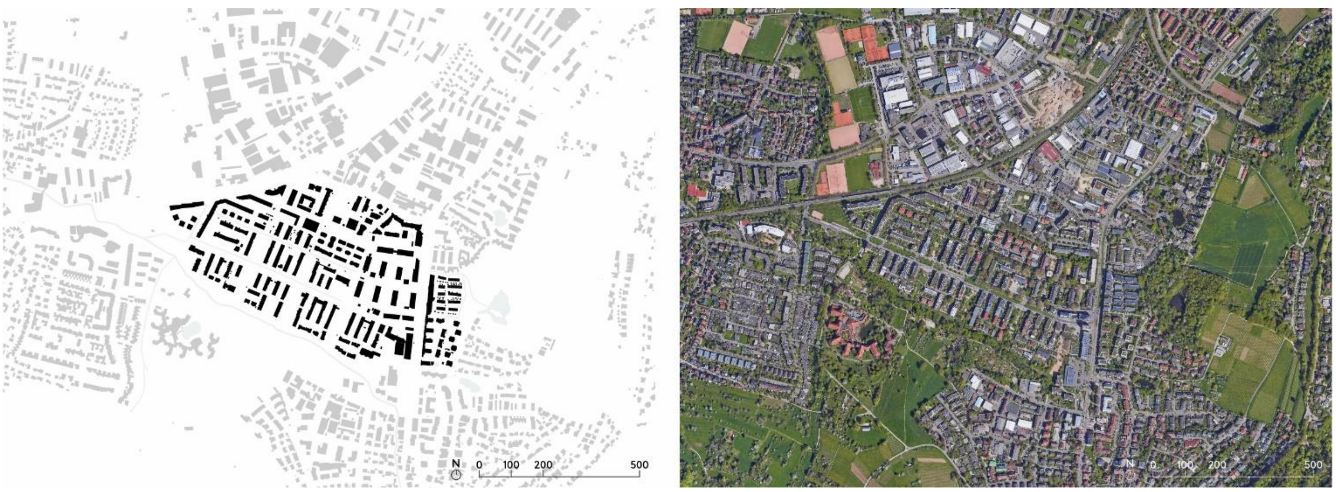

Figure 21 - Left: Figure-ground diagram of Vauban
Right: Satellite image of Vauban (Google, n.d.-c)

Similar to Rieselfeld, Vauban is organized along an 800 meter long main axis, the Vaubanallee, containing the tramway and three stops (Figure 22). Due to the compactness of the neighborhood, almost every residence is located within a 300 meter radius of a stop. Unlike Rieselfeld, the tram in Vauban was taken in use in a late stage of the development, in 2006, after a large share of the residents had already moved to the area. The reason for the late implementation of the tram was the fact that another tramline, to which the Vauban tram would connect, had to be constructed first (City of

Freiburg, 2016). The tramline also connects to the bus lines at the borders of the neighborhood. To dampen the noise and contribute to the managing of the storm water, the tramway consists out of grass, giving the main axis a green character (Figure 23).

Figure 22 - Left: Public transport connections, two rings around the stops with a radius of 300 and 600 meters
Right: Commercial activity in ground floor

Although there is commercial activity located along the tramway, the layout of the buildings create a less strong axis than is the case in Rieselfeld (Figure 22). The larger commercial services like supermarkets are located along the Merzhauser Straße (Figure 23) and Paula-Modersohn-Platz in the east of Vauban. Next to this, some commercial buildings are located in the north of the area. Due to the short distances to the services, all trips are short and can be done by bike or foot.

Figure 23 - Left: Green tram tracks giving the axis a green character (Brandt, 2009)
Right: The 'Sonnenschiff' building along the Merzhauser Straße contains offices and stores (weinbaukunst, 2014)

The mobility concept of Vauban is one of the core elements and functions as the basis for the other qualities of the neighborhood (Kasioumi, 2011; Sommer & Wiechert, 2015). The main idea behind the mobility concept is not to ban the car from the neighborhood, but rather shape an area where a car would not be needed in daily life (Beim & Haag, 2010). Demotivating the use of the car has been done through a so-called ‘push and pull strategy’, where on the one hand the use of the car is made more difficult by e.g. reducing the amount of parking and on the other hand alternatives are made more attractive e.g. by providing good public transport.

Access by car to the neighborhood is organized through three inlets, connecting the neighborhood to the two main roads bordering the area (Figure 24). The speed limit for the main roads in the area is 30 km per hour and all other streets have a speed limit of 5 km per hour (Cervero & Sullivan, 2010). When entering the neighborhood from the east, the road shifts from the northern side of the tramway to the southern side of the tramway. This has been done in order to protect the historic plane tree lane. Whereas the cars continue on the southern side of the tramway, the pedestrian and bicycle path continues along the lane (Figure 24 & Figure 25).

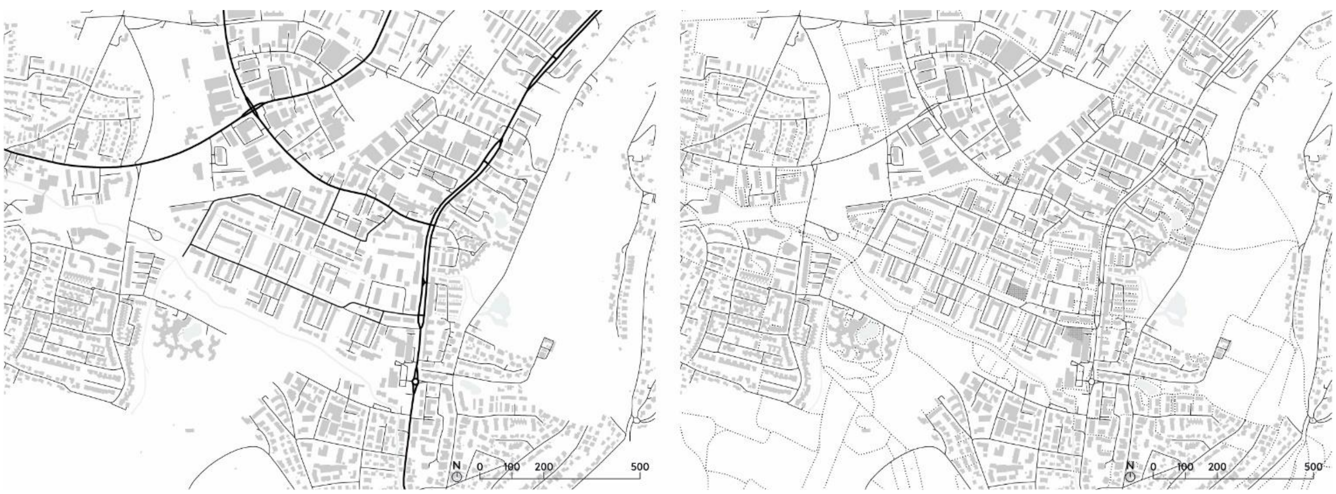

Figure 24 - Left: Car infrastructure
Right: Walking and cycling infrastructure

Connected to the Vaubanallee are several U-shaped traffic-calmed streets, in which parking is not allowed. Implementing this measure also means that these streets form safe spaces for children to play (Figure 25). The large front gardens with lush vegetation give the streets and intimate and green character. To slow down traffic, the surface material changes from asphalt to cobblestones at the intersections.

Figure 25 – Left: Traffic-calmed streets with lush vegetation (Emmett Russell architects, 2018)
Right: Pedestrian and bicycle path along the Vaubanallee (sdg21, 2019)

In contrast to Rieselfeld, Vauban does not contain one main green corridor but rather three smaller ones, connecting the neighborhood to the open areas and the Dorfbach stream in the south (Figure 26). The green areas also function as ventilation corridors and provide cool air during hot summer days (Coates, 2014; Foletta & Field, 2011). The corridors are bordered by the backyards of the neighboring houses. Next to these corridors, the neighborhood also contains two main public squares, namely the Alfred-Döblin-Platz and the Paula-Modersohn-Platz.

Figure 26 - Public squares and public green spaces (with a park-like feeling)
Right: Public services such as schools, libraries, and sports facilities

Connected to the two public squares are several public services, such as the primary school and Haus 37, and various commercial spaces (Figure 26). By connecting the public spaces to the public services, good use is made of the flows of people. For instance, the Aflred-Döblin-Platz in the center of the neighborhood, is used for markets but also houses Haus 37, which serves as the community center of Vauban (Figure 27).

Figure 27 - Left: Green corridor connecting the neighborhood to the open areas in the south (kai.bates, 2012)
Right: The Alfred-Döblin-Platz and Haus 37 (Poudou99, 2009)

As mentioned before, the mobility concept for Vauban forms an important part of the unique character of the neighborhood. One of the guidelines developed by Forum Vauban during the planning process was unbundled parking, in other words, car-related costs will only be provided to residents willing to pay for the construction costs of the parking garages (Broaddus, 2010). Furthermore, the parking garages were to be located at the edge of the neighborhood (Figure 28 & Figure 29). Although the first two phases were successfully built as car-free areas, investors were reluctant and built the remaining areas with the traditional 1:1 parking standard (Broaddus, 2010). To ensure that residents living in the parking-free blocks without a bought parking space in one of the garages would still own a car and park it outside of the neighborhood a legal contract has to be signed with the Car-free Living Association agreeing to not own a car (Foletta & Field, 2011). The measures to reduce the amount of cars have succeeded leading to a low number of about a 170 cars per 1000 inhabitants (Broaddus, 2010). Also the modal split proves the success of the measures as only 16% of the trips is done by car (Scheurer & Newman, 2009). The limited amount of parking spaces has also led to greener streets, as less space is required for parking, giving the neighborhood a more green character.

Figure 28 - Left: Car parking on ground level
Right: Building heights

Despite the fact that Vauban is statistically the densest neighborhood of Freiburg, a large part of the residents finds the scale and density appropriate (Sommer & Wiechert, 2015). Different to Rieselfeld, the main axis does not contain the tallest buildings as these are situated on the edges of the neighbourhood. The overall is roughly four to six floors with several higher landmarks placed in visually exposed locations such as the small residential tower at the Paula-Modersohn-Platz (Figure 28 & Figure 29). Architecturally the neighborhood provides a wide variety of interesting buildings due to the freedom for design permitted to the Baugruppen (Coates, 2014).

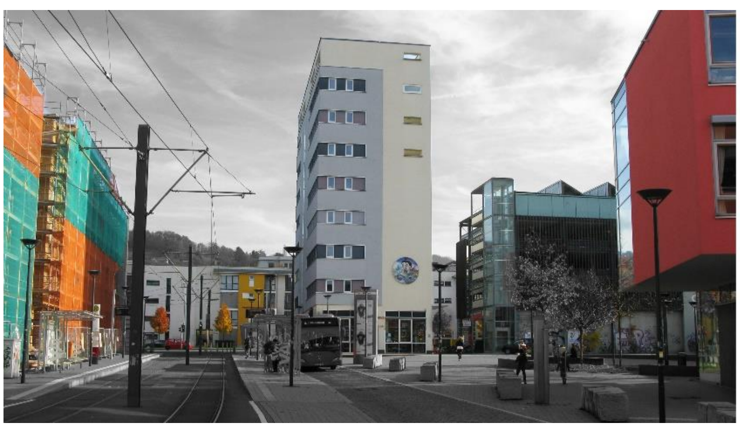


Figure 29 - Left: The buildings around the Paula-Modersohn-Platz (Schwarzkopf, 2012)
Right: The Solargarage next to the Merzhauser Straße (triolog-freiburg, n.d.)

Although the socio-economic structure of Vauban is rather specific and special, the planning process, regulations, goals, and design are inspiring and relate closely to the aims of TOD. The density, mixedness of services, and regulations for the usage of cars contribute to the livability of the neighborhood and good use has been made of the flows of people in the placement of public and commercial services. The reduced number of street parking has led to greener streets and strategically situated green spaces give the neighborhood a friendly character despite the high density.

Dimension	Main findings
Topic 1: Place-making	
Dimension 1: Scale and density	• Provide a sufficient amount of tram stops so that the maximum walking distance is 600 meters. • Organize the neighborhood around a central axis. • Provide a variation in density. • Locate landmark buildings in visually exposed places. • Locate larger buildings such as parking garages along big roads to reduce traffic noise. • Use, as a general rule, maximum building heights of around five or six floors.
Dimension 2: Public spaces for human use	• Connect public spaces to transit stops to make use of the passenger flows. • Locate the public spaces in such a way that they contribute to e.g. flow of air. • Use the public spaces to guide people to leisure areas. • Create multipurpose public spaces.
Dimension 3: Safety	• Design safe streets for playing by implementing traffic-calming measures. • Create ground floor functions and other interesting functions at and around public spaces to provide 'eyes on the street'.
Dimension 4: Variety and complexity	• Divide large building blocks into smaller plots to reduce the risk of monotonous blocks. • Use a variety in building materials and colors, while creating unity in the overall building style. • Provide architectural freedom to building groups and project developers.
Dimension 5: Connections	• Provide shortcuts for non-motorized traffic. • Reduce the access streets for cars.
Topic 2: Facilities/Logistics	
Dimension 6: Pedestrian/cyclist orientation	• Provide a continues network of bikeways and sidewalks. • Locate shared bicycle stations close to public amenities, transit stops, and public spaces. • Let cyclists make use of the roads rather than sidewalks where possible. • Provide space for bicycle parking close to public amenities and commercial spaces. • Provide safe streets for playing.
Dimension 7: Transit in the urban pattern	• Develop the transit corridor as the spine of the neighborhood. • Locate spaces for commercial activity in close proximity to the transit stops. • Connect transit stops to public spaces. • Provide easy access to the transit stops. • Ensure modal integration of buses and light rail. • Give a green character to the railway (e.g. by adding vegetation to the tracks and planting trees along the railway).
Dimension 8: Car movement and parking	• Minimize the amount of access roads to the neighborhood. • Reduce the amount of car traffic along the transit axis.

- Reduce the amount of surface parking to a minimum.
- Create parking garages at the edge of the neighborhood.
- Provide unbundled parking, making it cheaper to live in the neighborhood not owning a car.
- Reduce the maximum speed to 30 km per hour in main roads and walking speed elsewhere.

Table 3 - Summary of the main findings for TOD in Vauban

4.3. Hammarby Sjöstad, Stockholm

The third best-practice example is Hammarby Sjöstad in Stockholm. The neighborhood is located around the Hammarby lake (Figure 31), about three kilometers south of the city center (Figure 30), and currently houses around 20 000 inhabitants and 11 000 jobs (Sjöstadsbladet, n.d.). Hammarby Sjöstad, and especially its underlying concept of the Hammarby Model, has received much praise for its comprehensive and sustainable approach to urban planning (Fraker, 2013). Next to this, Hammarby Sjöstad has also been recognized as a great example of TOD, as public transport plays a major role in reaching the goals of sustainability set for the neighborhood. The analysis in this section mostly focuses on the areas along the Tvärbanan, south of the Hammarby lake.

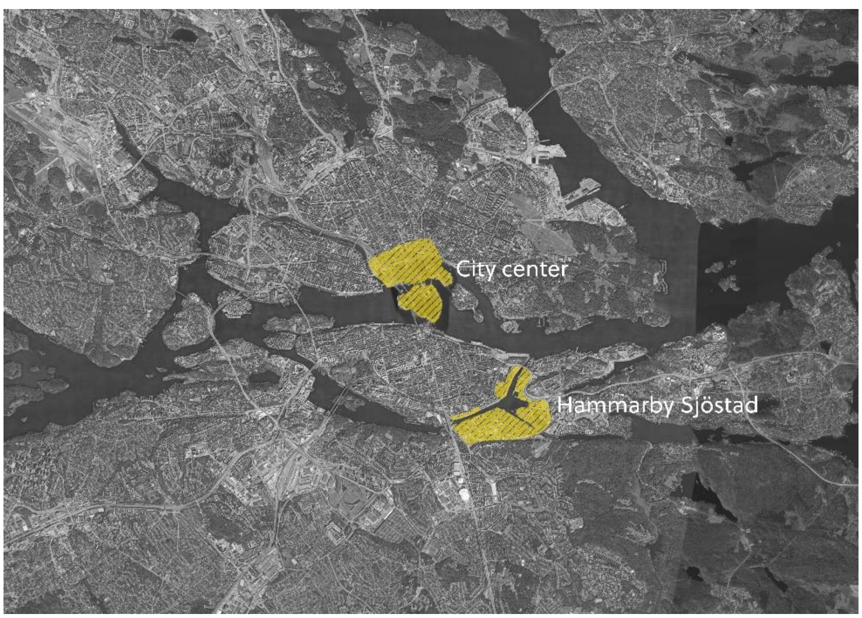

Figure 30 - Location of Hammarby Sjöstad in Stockholm (Google, n.d.-d)

Already since the 1940s, rail networks have played an important role in the development of Stockholm (Söderström et al., 2015). Inspiration for Stockholm's radial development along transport corridors came from the Copenhagen Five Finger Plan (Figure 5). Although the introduction of the car heavily influenced development of the city during the 1960s and 1970s, more recent plans have focused on the role of public transport and cycling.

Planning for the area started in the 1990s and coincided with a fast economic growth in Sweden, leading to a great demand for new housing (Fraker, 2013). Due to the close proximity to the center, the then industrial Hammarby area had for a long time already been regarded a good place for the development of housing and was eventually designated as a mixed-use development area in 1993 (Bott et al., 2019; Gaffney et al., 2007). With this decision, Hammarby Sjöstad became the largest housing development project in Stockholm since the 1960s, a time in which large-scale housing projects were developed through the nationwide Million Program which ran between 1965 and 1974 (Fraker, 2013; Jernberg et al., 2015). Several lessons learned from the large-scale projects in the Million Program, such as the consequences of sprawled and low-quality housing, guided the decision-making process in the development of Hammarby Sjöstad (Jernberg et al., 2015). The approaches behind the development of the area were also guided by the Stockholm City Plan 99, in which it was decided that the city should be build inward and achieve *"sustainable urban development in accordance with the international community as reflected in the 1996 Istanbul Habitat Agenda"* (as cited in Fraker, 2013, p. 44). Furthermore, the plans were used for the Olympic bid for 2004 as a landmark project for sustainable urban development (Kasioumi, 2011). The ambitious plans for the area included the 'twice as good' strategy, which meant that the environmental performance of the neighborhood had to be twice as good as the standard performance of areas built in the early 1990s (GlashusEtt, 2007). Although the Olympic bid was lost, planning with the original environmental objectives continued.

In order to reach the ambitious environmental targets, three methods were established; environmentally friendly planning, a change in lifestyle, and technology solutions development (Mahzouni, 2015). Responsible for the planning of the area was the Hammarby Sjöstad Project Team, which functioned as a separate unit within the City of Stockholm administration. The planning process included, for instance, soil decontamination, the preparation of a master plan, and planning for the (technical) infrastructure (Fraker, 2013). In cooperation with the Stockholm Water Company, the energy company Fortum, and Stockholm's Traffic and Waste Management Administration, the team developed the Hammarby Model, a *"holistic approach to infrastructure service provision"* (as cited in Fraker, 2013,

p. 46). The Hammarby Model is an integrated model for energy, waste, and water management and aimed at creating a closed cycle of sources.

Construction of the neighborhood started at the end of the 1990s and was built in several phases. The detailed plans for the various phases were made through a ‘parallel sketches’ method, in which three to four architecture and planning firms were asked to design detailed plans for the sub-area, after which the city planners evaluated the plans and used the best elements to create the final detail plan (Jernberg et al., 2015). To guide the planning process, comprehensive design codes were formed, which included principles, guidelines, and requirements for, for example, the district character, architectural style, and apartment standards (Fraker, 2013). Plots were distributed based on the ideas for innovative design and aimed at investors interested in implementing *“experimental and environmentally friendly technologies or concepts”* (Bott et al., 2019, p. 244).

The project has faced various challenges, including a shift in political power, as the red-green coalition was replaced by a center-right coalition in 1998. Although the new center-right coalition supported the environmental goals for Hammarby Sjöstad, the program became non-binding and more responsibility was given to the private developers to implement environmental aspects (Mahzouni, 2015). Furthermore, the new coalition adjusted the parking norm from 0,25 per apartment to 0,7 per apartment after protests of residents (Mahzouni, 2015). These parking norms were initially set low by the red-green coalition in an attempt to reduce car usage and encourage the use of the new light rail.

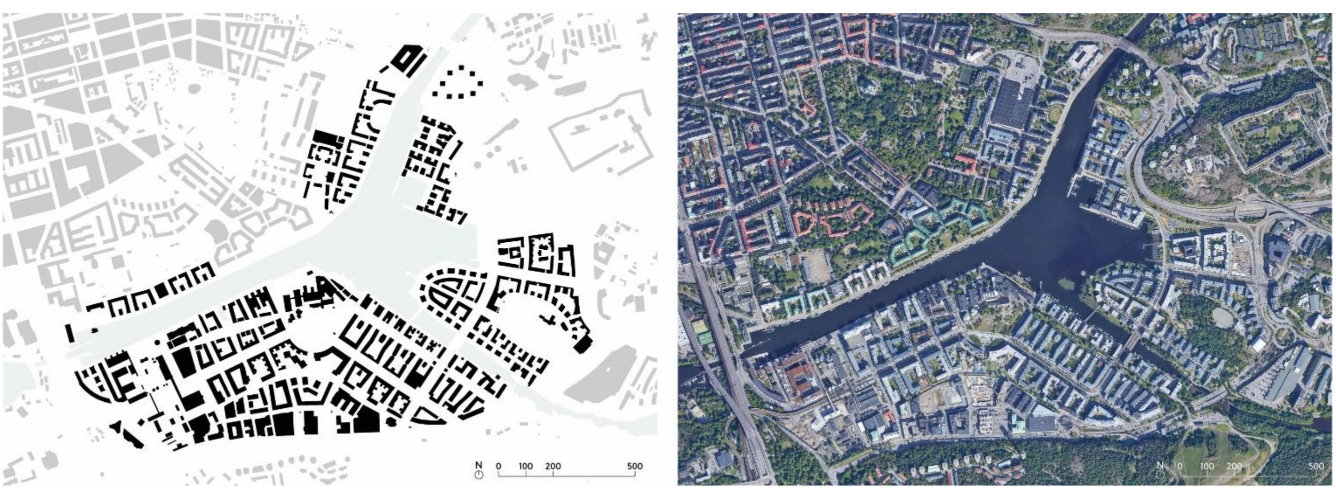

Figure 31 - Left: Figure-ground diagram of Hammarby Sjöstad
Right: Satellite image of Hammarby Sjöstad (Google, n.d.-e)

Three detailed goals for transportation by the year 2010 were set in the environmental program:

- 80 percent of the trips by residents and workers should be by foot, bicycle, or public transit
- 15 percent of the households should be signed up to carpooling programs
- 5 percent of the workplaces should be signed up to carpooling programs (Fraker, 2013; Salat & Ollivier, 2017)

The infrastructural backbone of the neighborhood is formed by a 37,5 meter wide boulevard which contains the main road and light railway (Figure 32 & Figure 35). To reduce the use of the car and establish ‘sustainable habits’, the Tvärbanan, the orbital light rail connecting Solna in the north to Sickla in the south, was implemented in an early stage (Jernberg et al., 2015). In 2000, the first section of the Tvärbanan was opened, which ran between Liljeholmen and Gullmarsplan, located southwest of Hammarby Sjöstad. The section between Gullmarsplan and Sickla Udde, the most eastern stop in the area, was taken in use in 2002, only several years after construction started. The last section, connecting Hammarby Sjöstad to the Sickla station, opened in 2017 (City of Stockholm, n.d.). The bus lines also make use of the light rail track, which consists of asphalt. Due to the locations of the four stops, almost the entire neighborhood south of the Hammarby lake is within 300 meters of a stop. Furthermore, a free ferry service connects the southern areas of the neighborhood with Södermalm in the north throughout the year. Currently, Tunnelbanan, an expansion of the Stockholm metro network, is being constructed of which two new stops will be located in Hammarby Sjöstad.

Figure 32 - Left: Public transport connections, two rings around the stops with a radius of 300 and 600 meters, new Tunnelbanan as grey dashed line
Right: Commercial activity in ground floor

The light rail does not only function as a mode of transport but also shapes the character of the area. For instance, due to its recognizable structure, the Sickla Kaj stop does not only provide shelter from the weather, but also functions as a landmark upon entering the area after crossing the Sickla canal (Figure 33). In the center of the neighborhood, the Luma stop is located in the Lumaparken, placing public transport in the center of attention. Furthermore, with the exception of these two parts, lanes of trees run along the track, accentuating the axis (Figure 33).

Figure 33 - Left: The covered Sickla Kaj bus and light rail stop (Lerman, 2016)
Right: Trees along the track accentuate the axis (La Citta Vita, 2010a)

Although Hammarby Sjöstad mostly contains new buildings, some of the older industrial and commercial buildings are still remaining in the southern and western areas of the neighborhood. New commercial activity in ground floors, as well as some second floors, is located for a large part along the route of Tvärbanan and along the water (Figure 32). Almost every single ground floor along the Tvärbanan contains space for commercial activity, with the exception of two school buildings and the area around the Sickla Udde stop. The total length of the commercial façade is about 1800 meters on either side of the boulevard (Fraker, 2013). Overall, the ground floors along the Tvärbanan have an open character, providing 'eyes on the street', and generate pedestrian activity (Figure 34). Fraker, however notes that, due to the separated character of the boulevard, it can be questioned if it will allow for *"the synergy among shops necessary for it to be a successful commercial street"* (2013, p. 63). More commercial activity is located in the Lumafabriken building and in the ground floors and separate pavilions along the water (Figure 34).

Figure 34 - Left: Commercial activity along the water (Google, 2020a)
Right: Commercial activity along the Tvärbanan (Google, 2020b)

As said, the boulevard that runs along the Tvärbanan also forms the main transport axis for car traffic (Figure 35 & Figure 36). Another main road can be found south of the area. The boulevard provides fast access by car to the highways in the west and east. Other than these roads, all other roads are traffic calmed and mostly consist of cul-de-sacs (Figure 36). In contrast to the car infrastructure, the walk- and bikeways form a dense network and provide quick access to the public spaces, the waterfront, the courtyards, and the public transit stops (Figure 35). Furthermore, the apartment blocks contain sufficient bicycle storage, making it easier to use a bicycle (Gaffney et al., 2007). A survey from 2007 on the use of transport modes in the area shows that the measures to reduce the use of the private car have worked, as 79% of the journeys is done by walking, cycling, or public transit (Jernberg et al., 2019).

Figure 35 - Left: Car infrastructure
Right: Walking and cycling infrastructure

Figure 36 - Left: The main car axis along the Tvärbanan (La Citta Vita, 2010b)
Right: Cul-de-sac and traffic-calmed street (La Citta Vita, 2010c)

One of the goals in the development of the neighborhood was the creation of a mixed-use district with courtyards, parks, and public spaces with a minimum of 25-30 square meters within 300 meters of every apartment (Fraker, 2013). With the implementation of several linear parks, semi-public courtyards, and a public waterfront, the neighborhood reaches this goal and provides plenty of green and public space for the residents (Figure 37). Fraker notes that due to the accessibility of public spaces, these are just *"as dominant as the streets and buildings"* (2013, p. 63) and that *"the public space of Hammarby Sjöstad is as much about a lake and park as it is about the city"* (2013, p. 63).

Initially, the planners believed that the neighborhood would be mainly attractive for elderly residents, who would move back to the city from the suburbs (Fraker, 2013). However, due to the qualities the neighborhood provided, such as the high quality of public spaces, traffic-calmed streets, and good public transit connections, the neighborhood proved to be mainly popular with young families with children. The planners responded to this by providing more schools and other community facilities to accommodate these households. Most of the public services, such as school and libraries, are connected to the public spaces, the public transit system, or both (Figure 37).

As mentioned before, one of the methods to reach the environmental goals was to change the lifestyles of the residents to more environmentally sustainable ones. In order to encourage such changes and educate residents about their role, GlasshusEtt was built. The building itself demonstrates new environmental technologies and functions as an information center for residents and visitors (Bott et al., 2019).

Figure 37 - Left: Public squares and public green spaces (with a park-like feeling)
Right: Public services such as schools, libraries, and sports facilities

The green spaces and publicly accessible waterfront also serve as areas to retreat from the busy city life. Parts of the original natural landscape along the water have been preserved or restored and create intimate spaces whereas the spaces along and on the water provide open views of the lake (Figure 38). The green spaces also function as areas for storm water retention (Bott et al., 2019). To ensure the quality of the water before it ends in the Hammarby lake, the storm water is captured locally and flows through a sequence of bioswales, canals, and basins, through which the water is purified (Figure 38). Being a visibly pleasing element in the public space, the storm water system also contributes to the quality and character of the neighborhood.

Figure 38 - Left: Publicly accessible waterfront (Ignatieva, 2014)
Right: Linear park 'Sjöstadsparterren' with storm water canal (aslinth, 2006a)

As stated before, with the change in political power, the parking norm increased from 0,25 to 0,7, which is higher than the average of 0,5 in the center of Stockholm. Parking for residents is mostly organized in parking garages under the buildings and although the overall use of the car is relatively low, 62 percent of the households still own a car (Fraker, 2013). The higher parking norms have also resulted to more parking along the streets, meaning nearly every accessible road for cars includes parking (Figure 39).

Figure 39 - Left: Car parking on ground level
Right: Building heights

Several guidelines and goals for the urban form dictate the architecture of the neighborhood, these include for instance:

- Use of the inner-city street dimensions (6–18-meter residential streets), block size (60–70 meters by 120–200 meters), and building heights (2–8 floors)
- Views to the water from the buildings
- Restricted building depths, set-backs, and multilevel apartments
- Large balconies and terraces, big windows, flat roofs, and pale plaster facades facing the water (Fraker, 2013)

With the exception of some higher towers, the tallest buildings are located along the main axis with 6 to 8 floors, from where the building heights decrease towards the water (Figure 39). To provide views from the apartments to the water, the blocks open up in the direction of the Hammarby lake and form U-shaped buildings. In contrast to the typical inner-city blocks, the courtyards are mostly semi-public and contribute to the pedestrian accessibility (Figure 40). The comprehensive guidelines, in combination with the fact that each building block has been designed and built by multiple architect-developer teams, has led to a diverse neighborhood while also expressing unity in architectural style (Figure 40).

Figure 40 - Left: Semi-public courtyards contributing to a better pedestrian network (aslinth, 2006b)
Right: Sjöstadsparterren park bordered by residential blocks and GlashusEtt in the center (Kylberg, 2006)

Although throughout the process several changes have been made, such as the increase in minimum amount of parking, Hammarby Sjöstad proves to be a great example of TOD. Compared to the previous two examples, Rieselfeld and Vauban, Hammarby Sjöstad is set in a more urban environment and has a more city-like character. Good use is however made of the public spaces, the views on the lake, and the semi-public courtyards, providing the neighborhood with a green character. The creation of the Hammarby Model, leading the overall vision, has strengthened the final results in creating a livable and sustainable neighborhood.

Dimension	**Main findings**
Topic 1: Place-making	
Dimension 1: Scale and density	• Provide a sufficient amount of tram stops so that the maximum walking distance is 600 meters.
	• Organize the neighborhood around a central axis.
	• Provide a variation in density.
	• Accentuate the main axis with higher buildings, decrease the height as you move further away.
	• Use, as a general rule, maximum building heights of around five or eight floors.
	• Open up the buildings towards open spaces such as a waterbody.
Dimension 2: Public spaces for human use	• Connect public spaces to transit stops to make use of the passenger flows.
	• Use the public spaces to guide people to leisure areas.
	• Create multipurpose public spaces.

	• Use the public space to make the storm water system visible as an attractive element.
	• Provide calm and peaceful places in contrast to the busy urban spaces.
Dimension 3: Safety	• Design safe streets for playing by implementing traffic-calming measures.
	• Create ground floor functions and other interesting functions at and around public spaces to provide ‘eyes on the street’.
Dimension 4: Variety and complexity	• Divide large building blocks into smaller plots to reduce the risk of monotonous blocks.
	• Use a variety in building materials and colors, while creating unity in the overall building style.
Dimension 5: Connections	• Provide shortcuts for non-motorized traffic.
	• Reduce the access streets for cars.
Topic 2: Facilities/Logistics	
Dimension 6: Pedestrian/cyclist orientation	• Provide a continues network of bikeways and sidewalks.
	• Let cyclists make use of the roads rather than sidewalks where possible.
	• Provide space for bicycle parking close to public amenities and commercial spaces.
	• Provide safe streets for playing.
Dimension 7: Transit in the urban pattern	• Develop the transit corridor as the spine of the neighborhood.
	• Create landmark status for the tram stops by adding built elements.
	• Locate spaces for commercial activity in close proximity to the transit stops.
	• Connect transit stops to public spaces.
	• Provide easy access to the transit stops.
	• Ensure modal integration of buses and light rail.
	• Give a green character to the railway (e.g. by adding vegetation to the tracks and planting trees along the railway).
Dimension 8: Car movement and parking	• Place the main road along the railway.
	• Create cul-de-sacs to reduce the amount of traffic in smaller streets.
	• Create parking garages underneath the buildings.

Table 4 - Summary of the main findings for TOD in Hammarby Sjöstad

5. Test designs

This chapter presents the test designs based on the real life case of the development of the VIIMA light rail in the Malmin kenttä district in Helsinki. The test design method forms the second step in the process of extracting generalizable spatial guidelines for TOD. The development of the VIIMA light rail cannot be seen as a single planning intervention, but should rather be seen in the full context of the historic development of Helsinki and the land use plans and regulations made within the various levels of the Finnish planning system. The overview helps with understanding the planning context, may guide the design process, and anchors the outcome in the right sociocultural setting. First the case introduced through the historic development of Helsinki and various planning strategies. After this, the three test designs are presented.

5.1. Brief overview of the historic development of Helsinki

The current characteristic urban configuration of Helsinki has a long development history, in which the various eras of development are still easy to recognize. The foundation of the town of Helsinki dates back to 1550, when King Gustavus Vasa of Sweden orders the burghers of Rauma, Ulvila, Porvoo, and Tammisaari to move to Helsinki (City of Helsinki, 2019). Helsinki remained a compact town in the following centuries under Swedish rule. The town however hold an important strategic position during the wars, which was accentuated by the construction of Suomenlinna in 1748. In 1809 the Swedish era came to an end after Finland was conquered by Russia. Finland became an autonomous Grand Duchy and in 1812 Helsinki was made the capital of Finland (Zetterberg, 2017).

It was during this period that Helsinki grew quickly and became the most important city of Finland as an administrative center, university city, and the biggest industrial city of the country (City of Helsinki, 2019). The densification and replacement of the original wooden structures in combination with expansions along the tramways towards the north led to a population growth of about 70 000 inhabitants from 1850 to the year 1900 (Weckström, 2016). Next to this, the opening of the two (commuter) railways, Päärata in 1862 and Rantarata in 1903, stimulated the development of the smaller cores surrounding the center of Helsinki, such as Malmi, Tikkurila, and Pitäjänmäki, which profited from the increased accessibility by rail and also developed smaller industrial areas (Weckström, 2016).

Where the period before World War Two mostly focused on the expansion of the city along the tramways and around the railway stops, the after war period is characterized by suburbanization. Four main reasons lay at the foundation of the suburbanization of Helsinki. *First*, as a result of the municipal reform in 1946, where the smaller municipalities of Huopalahti, Haaga, Oulunkylä, Kulosaari, and large parts of the Helsinki rural municipality were merged into Helsinki, the city gained space for expansion outside of the original city borders (Weckström, 2016). *Second*, due to the loss of Karelia to Russia, a large group of Finnish inhabitants was relocated to the Helsinki area. This in combination with the postwar baby boom led to a large demand for new housing. *Third*, the emergence of cars and buses in urban areas meant that expansion was possible in any direction regardless of the existing railway and tram routes (Söderström et al., 2015). *Fourth*, function separation and decentralization formed part of the main planning ideals of the postwar period (Weckström, 2016).

Although the single-family house was still seen as the ideal way of living in Finland, apartment buildings were necessary to deal with the growth of the amount of inhabitants. The design of the first neighborhoods constructed in the postwar period showed a strong relation with its natural surroundings. The form of the built structure contrasts with the strict grids found in the center and is characterized by the many green areas in between the buildings. The development of prefabricated construction further stimulated the construction of taller buildings and required a different urban form as sufficient space for cranes was required. The design of the neighborhoods of the 70s show a shift in planning ideals with the compact city as a result (Weckström, 2016). The focus of the compact city paradigm was on creating a livelier city with public life in the spaces outside of homes and a separation of motorized and non-motorized traffic to create more safe spaces for public meeting. The neighborhoods of the 80s and onwards show another shift in paradigm, as focus was not anymore on traffic separation, but rather traffic calming (Weckström, 2016). The separation of functions continued with the introduction of the malls.

The way the center of Helsinki is situated, surrounded by the sea and islands, further increased the problematic accessibility and led to even higher concentrations of traffic. To deal with the increase in car traffic and increasing amount of inhabitants, the first plan for a metro network was presented in 1963 (Weckström, 2016). This first plan contained 86 kilometers of (partially underground) metro infrastructure and a grand total of a 108 metro stations. After proposals and plans in the following years were continuously downscaled, the first section of the metro, connecting the eastern suburbs with the center, opened in 1982 (Weckström, 2016). The potential for dense residential development along the metro was however reduced due to the routing of the metro along the highway Itäväylä, the weak link between transport planning and urban planning, and the already existing housing around the new metro stations (Figure 41). Furthermore, bus terminals were implemented near the metro stations for the feeder bus system, further decreasing the potential for dense urban development. In the late 80s and beginning of the 90s the metro network was gradually expanded towards Mellunmäki, Ruoholahti, and Vuosaari. As urban areas were simultaneously built with the metro network, a stronger connection between urban planning and transport planning can be found in the plans for these areas (Weckström, 2016).


Figure 41 - Left: Traffic towards the center of Helsinki on the Kulosaari bridge in the 1960s (Helsinki Kuvia, n.d.)
Right: Construction of the Silitie metro station (Helsinki Kuvia, 1972)

A similar process can be found in the development of urban areas around the commuter train stations between Huopalahti and Martinlaakso where six new stations opened in 1975 (Weckström, 2016). The decision to create less feeder bus lines for the commuter train stations reduced the need for bus terminals in the station areas, generating space for more dense development in the vicinity of the station. This trend, which shares many similarities to the concept of TOD, continued with the opening of additional train stations and the Ring Line, connecting the center to the Helsinki-Vantaa Airport.

Over the last couple of decades, the focus of development has again shifted towards rail-based transit, as was the case in the prewar period. Recent planning efforts have been aimed at preventing the unfavorable effects of motorized traffic by a stronger focus on an improved rail based accessibility. The introduction the Raide Jokeri, a light rail which does not connect to the center but rather connects multiple hubs circling around the center, also shows a further dedication to the development of urban hubs outside of the traditional center and the creation of a network city.

5.2. Current planning strategies

The Finnish planning system contains four different levels on which legal land use plans and regulations are produced. The plans and regulations produced in these four levels are the national land use guidelines, regional land use plans, local master plans and the detailed plans. Besides these four levels that produce legally binding plans and regulations, a fifth voluntary level is of importance for land use planning in the bigger Helsinki area. This level consists of a regional cooperation of 14 municipalities, producing the Helsinki Region Land Use, Housing and Transport Plan 2019, better known as MAL 2019.

5.2.1. National land use targets

The Ministry of Environment forms the highest level of the Finnish planning system. On this level, the legislation, guidelines, and national land use targets for planning are produced. The National Objectives of Land Use must be taken into account and promoted in the lower planning levels according to the Land Use and Building Act. The national land use targets, valid since 2018, can be divided into five categories:

- Functional communities and sustainable mobility
- Efficient transportation system
- Healthy and safe living environment
- Vibrant natural and cultural environment and natural resources
- Renewable energy supply (City of Järvenpää, 2020)

5.2.2. Uusimaa regional plan 2050

The second highest level in the Finnish land use planning system is formed by the Regional Councils. In the case of the City of Helsinki, this is done by the Helsinki-Uusimaa Regional Council, a joint regional authority for the Helsinki-Uusimaa region consisting of 26 municipalities as members and financiers. The Regional Council produces the regional program and regional plan, and functions as a body for the regional and land use planning for the Helsinki-Uusimaa area and the promotion of local and regional interests (Uudenmaan Liitto, n.d. a). The most recent regional plan, the Helsinki-Uusimaa Land Use Plan 2050, has been approved in 2020 and consists of a long-term plan for urban and green structures and the transportation network on a generalized level. The regional plan guides municipal planning as well as other strategic planning of land use (Mansikka, 2020). The regional plan has the following goals:

- A sustainable direction for growth and balance between the various regions
- Responding to climate change and sustainable use of natural resources and nature
- Increasing wellbeing and attractiveness as well as sustainable competitiveness
- A focus on the essentials (Uudenmaan Liitto, n.d. b)

The region plan is based on the challenges facing the Helsinki-Uusimaa region. These challenges include:

- An increasing population (expected to grow by 550 000 residents and 290 000 jobs by 2050) and structural dispersion leading to increasing urban sprawl and need for travelling
- Challenges of competitiveness caused by a need for more (space for) workplaces and employees with affordable housing
- Dependency on private cars and the challenge of promoting more sustainable modes of travel
- Comprehensive global challenges like climate change and ageing of the population (Mansikka, 2020)

5.2.3. Helsinki Region Land Use, Housing and Transport Plan 2019

As mentioned earlier, land use planning in Helsinki contains a fifth voluntary level in addition to the four official levels of the Finnish land use planning system. The Helsinki Region Land Use, Housing and Transport Plan 2019, or MAL 2019, is a strategic plan of 14 municipalities in the bigger Helsinki region. The foundation of the MAL 2019 is formed by three earlier developed plans, namely the Helsinki Regional Land Use Plan MASU 2050, Housing Strategy ASTRA 2025, and the Helsinki Traffic Systems Plan HLJ 2015 (HSL, n.d.). The MAL 2019 guides land use planning within the region and defines the processes necessary to achieve the objectives of land use, housing, transport, and decreasing emissions (Salmikivi, 2019). The report presents concrete measures to reach the set goals by 2030, but also provides directions for development until the year 2050. Furthermore, it also provides a framework for the participating municipalities and the state of Uusimaa to cooperate on a long-term development of the region (Salmikivi, 2019). The challenges for the region described in the MAL 2019 are similar to the ones described by the Helsinki-Uusimaa Regional Council and include, among others, the rapid population growth and emissions caused by traffic (Salmikivi, 2019). The plans are based on the predictions of a population growth of 500 000 residents and 300 000 jobs compared to the year 2018 (HSL, 2019). The MAL 2019 does not cover topics such as business operation, services, green connections, nature values, culture environment preservation and environmental health issues (Salmikivi, 2019).

The MAL 2019, as well as the MASU 2050 and ASTRA 2025, determine the primary development zones in which a majority of the housing production will take place. The primary development zones are mostly located within the vicinity of existing or new train stations. The strong connection between public transport and housing production is one of the measures taken to reduce car dependency and stimulate the use of more sustainability modes of transport. In this sense, the produced plans share many characteristics with TOD.

5.2.4. 2050 Helsinki City Plan

The third legal level of the Finnish land use planning system is formed by the master plans and general plans produced on the municipal level. The current master plan for Helsinki, the 2050 Helsinki City Plan adopted in 2016, presents the general directions for land use and vision until the year 2050. The plan consists of a grid with a cell size of 100 by 100 meters and does not contain any precise boundaries, emphasizing the general and strategic character of the plan. The master plan guides the detailed planning, in which more specific boundaries are created based on detailed studies, taking into account the specific features of an area. The master plan, presented in Figure 42, is accompanied with thematic maps that present more detailed plans on which the master plan is based. The thematic maps include topics such as the recreational and green network, public transport, and cultural environments. The plans presented predict Helsinki to house approximately 860 000 inhabitants and 560 000 jobs in the year 2050 (Helsinki City Planning Department, 2016). This means a growth of roughly 200 000 inhabitants compared to the year 2019 (Statistics Finland, 2020). Hereby it is important to note that the master plan presents more land use reserves for residential areas than required for the population growth until 2050.

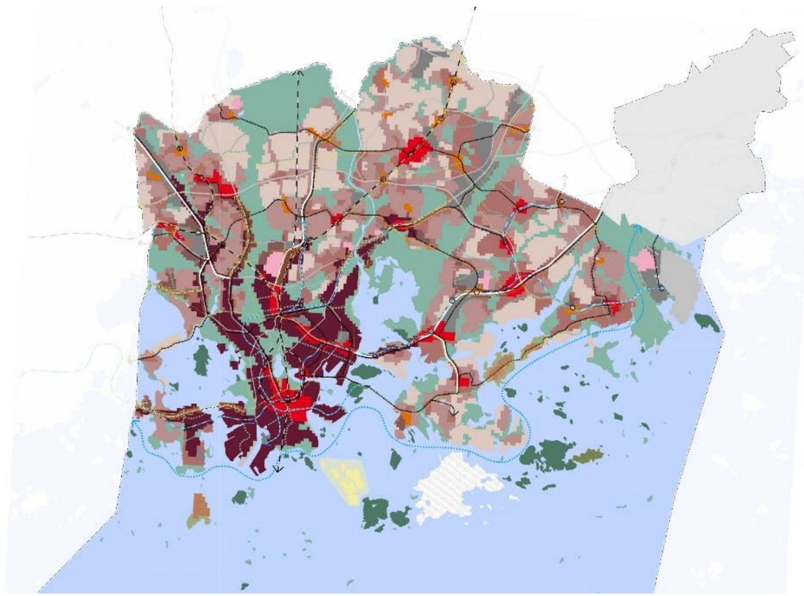

Figure 42 - The 2050 Helsinki City Plan (Helsinki City Planning Department, 2016)

The main concept of the master plan is based on transforming Helsinki from a city with a dominant single core into a rail-based network city with multiple urban hubs. To stimulate this transformation, the master plan includes plans to densify and urbanize the current suburban centers, implement new rail infrastructure, and convert several highway arteries into 'city boulevards'.

Until today, the accessibility by car, in comparison to public transport, has been superior in almost all parts of Helsinki, except for the center of the city (Helsinki City Planning Department, 2016). However, it is likely that the rapid and large growth of the population will generate a big pressure on the current infrastructure, eventually resulting in congestion issues and a decrease in accessibility. Where in the past transport planning and land use planning were, in practice, often done separately, the current master plan is based on a strong interlinkage of the two disciplines, recognizing the potential benefits (see Chapter 2). Walking, cycling, and public transportation are prioritized above the usage of the private car, guiding towards the use of more sustainable modes of transportation. This goal is in line with the earlier discussed National Objectives of Land Use and regional plans. The boulevardization of several highway arteries also plays a major role in stimulating the change in mode of transport and integrating the urban fabric in districts where the highways currently form barriers (Helsinki City Planning Department, 2015a). New light rail connections along the (former) highway arteries, such as the VIIMA and Tuusulanväylän light rail, will improve the radial connections while the transversal connections are improved with the implementation of the Raide Jokeri 1 and later Raide Jokeri 2. The new light rail connections will also contribute to the creation of a rail-based network city.

The master plan aims at a radial expansion of the city center in order to achieve higher densities and stimulate productivity. The master plan contains three categories of central areas. The first category is the 'C1 Business and service center'. These areas are characterized as functionally mixed areas with commercial and public services, housing, recreation, and urban culture. The areas are more efficient and productive than the surrounding areas. The spatial layout of the area is oriented towards the pedestrian accessibility. The areas designated as C1 centers are the downtown area, the Pasila – Vallila – Kalasatama axis, and the bigger suburban centers. The second category is the 'C2 Downtown'. Also these areas contain a functional mix of services, but are in general less dense than the C1 centers. Next to pedestrian accessibility, other sustainable modes of transport like cycling and public transport are stimulated. The boulevardization of several highway arteries plays an important role in the expansion of the C2 area, as about a third of the complete reservation for construction in the master plan is located in these former highway zones. The third category is the 'C3 Local center'. The C3 centers also contain a mix of functions, but have a less regional function than the C1 and C2 centers and mostly contain local services. Ground floor services are located in the key locations and there is a focus on the sustainable modes of transport.

Even though the center of Helsinki contains a mix of functions, including residential and recreational, the area forms the largest business area of Finland. Furthermore, the city of Helsinki produces a significant part of Finland's gross domestic product (Helsinki City Planning Department, 2016). This means that an important goal of the master plan is to ensure the high productivity by retaining and expanding the business areas, while simultaneously keeping housing prices and labor costs reasonable and jobs accessible by sustainable modes of transport. While a mix of functions in the urban areas is seen as the ideal, the workplace and (small) industrial areas will still be necessary. As no additional workplace and industrial areas have been added in the master plan, maintaining and improving the accessibility of the existing areas is of great importance.

The densification and expansion of the built area will put an increasing pressure on the existing green areas of the city. The current green structure of Helsinki is characterized by a combination of large green fingers and smaller neighborhood parks. The connectivity of the green areas plays a major role in the structure of the city. The master plan mainly aims at an improvement of the quality and accessibility of the existing recreational areas. Furthermore, the characteristic shoreline will play a greater role in recreation for the future residents. The master plan aims at maintaining the larger green areas, but allows for modifications on the edges where, for instance, the buffer zones of the current highway arteries are transformed into residential areas.

Although the boulevardization of several of the highway arteries still plays a major role in the master plan, the amount of city boulevards has been reduced as a result of court cases in which the Helsinki Administrative Court and the Supreme Administrative Court reversed parts of the proposed master plan (Granqvist et al., 2019). The reversed plans include the boulevardization of parts of the Lahdenväylä, which influences the direct surroundings of the VIIMA light rail. In these reversed areas, the earlier approved 2002 master plan will remain in force.

5.2.5. Viikin-Malmin light rail

As discussed in the previous section, new light railways will play a major role in connecting the various new and existing urban hubs in the future network city and enable the development of currently underused land. One of these new light railways is the VIIMA light rail, which runs from the center of Malmi, through the Malmin kenttä district, Viikki, and Arabia, towards the center of Helsinki. The plans also include the future extension through the Malmin kenttä district to Jakomäki and will connect to other tram lines at a number of stops (Figure 43). Although the plans for the boulevardization of the Lahdenväylä have been partly reversed, it is still estimated that in the year 2050 the areas within a 500 meter radius of the VIIMA light rail stops will contain between 30 000 and 45 000 more residents and approximately 12 000 more jobs than at present. This means a fair share of the projected population growth in Helsinki will take place in the impact area of the VIIMA light rail. Construction of the light rail is planned to start in 2027 and to be completed in the early 2030s.

Carbon neutrality is a key sustainability goal for the City of Helsinki. However, sustainability does not merely concern carbon neutrality, but rather also includes other social, economic, and environmental topics. This is why, in congruence with the Helsinki City Plan, the proposed VIIMA light rail does not just function as a transport link, but also forms part of a larger urban development program for northeastern Helsinki. Throughout the planning process, transport planning and urban planning are tightly intertwined, and various themes are linked to the development of the light railway. The intermingling of the two disciplines is a necessity as systemic changes in mobility habits and other sustainability topics are only possible when they become a natural part of people's lives and thus closely relate to both the disciplines.

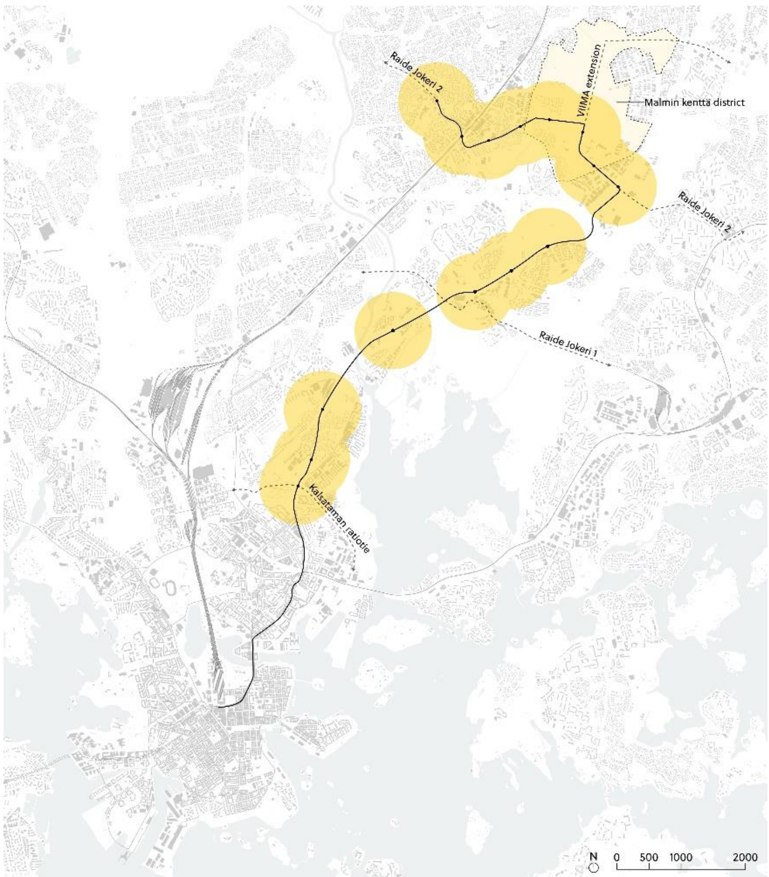

Figure 43 - The VIIMA light rail route, new stops with a 600 meter radius, and the location of the Malmin kenttä district in the northeast

5.2.6. Malmin kenttä district

The largest development area along the VIIMA light rail is the Malmin kenttä district. The district is located on the former Malmi Airport and will be transformed into a residential area. Once completed, the district will house around 25 000 inhabitants and approximately 2000 jobs. The district is part of the Malmi district, currently home to about 29 000 residents (City of Helsinki, 2020c). The Malmi district, and more specifically the center of Malmi, functions as an important hub for the northeast of Helsinki.

The transformation of the Malmi Airport into a residential area has been a heavily discussed topic for several decades. After the completion of the new Helsinki-Vantaa Airport, built for the Olympics of 1952, the Malmi Airport lost its function as an international airport and continued as a hub for domestic flights (Arkkitehtitoimisto Freese & Arkkitehtitoimisto Schulman, 2016). As a result of the decreased importance of the airport, the City of Helsinki stated as early as the 1970s, that in the long run the area would be needed for a non-airport use, hinting at potential urban development in the area (Helsinki City Planning Department, 2015b). More detailed studies on possible urban development were made during the 1980s. These plans, however, never progressed due to the controversy over the financing of a replacement for the airfield and the recession during the early 1990s (Helsinki City Planning Department, 2015b). The project received renewed attention during the early 2000s. Early studies from this time mostly consisted of low density housing areas, whereas in later stages the plans grew increasingly in density. The agreement from 2014, in which the state agreed on ceasing all operations at Malmi Airport by 2020, marks a significant point in the development of the plans as it opened the long awaited chance for construction in the area.

The airport area, and specifically the airport buildings and runways, were defined a nationally significant cultural environment by the National Board of Antiquities in 2009 (Torres Gómez, 2017). The recognition of the cultural importance of the airfield in combination with the active use of the area, has resulted into a public backlash against the project. The main catalyst for critique is formed by the association 'Friends of Malmi Airport', which opposes the termination of aviation services at the Malmi Airport. Also during the preparations for the Helsinki City Plan, the transformation of the airport into a residential area was a heavily discussed topic.

Although the project received critique, planning of the area continued, resulting in the so-called outline plan (Figure 44). The outline plan was presented in 2015 and accepted in 2016. The outline plan forms the basis for further development but carries no legal weight. The plan presents the contours for infrastructure, neighborhoods, and green spaces, giving a rough layout of the future area. The spatial structure of the plan is first and foremost based on a green network of recreational and natural areas, positioning the area in the larger context and linking the larger green areas in the surroundings, such as the Fallkulla estate, the forests of Kivikko, and the Longinojapuisto. Furthermore, the plan reflects on and enhances the current characteristics of the area, such as the runways, long views, and the historically and culturally valuable terminal area.

Figure 44 – Outline plan for the Malmin kenttä area (Helsinki City Planning Department, 2015b)

The neighborhood is planned to become a diverse, dense, and urban residential area, where the demographics will reflect the multicultural character of the surrounding areas of the Malmi district. The goal is to provide public spaces and courtyards of high quality which will also function as a part of the local storm water system. Furthermore, wood construction as well as the use of other building materials that have the least possible impact on the environment will be promoted. Local renewable energy production will also play a big role in the future of the neighborhood.

The transport system for the district is for a major part based on public transport solutions in combination with a dense pedestrian and bicycle network. The VIIMA light rail will form the infrastructural backbone for the area and provide fast connections to the center of Malmi, Jakomäki, and Viikki. In the long term, the addition of the Raide-Jokeri 2 light rail will also provide a fast link to the Kontula metro station. Although a new highway exit is planned to connect the district to the Lahdenväylä highway, the use and ownership of cars in the area will be discouraged. Instead of surface parking on the building premises, parking will take place in local parking garages. The parking garages are to include other functions, such as commercial activity in the ground floor and playgrounds and sports fields on the roof.

The test designs concern two new neighborhoods within the Malmin kenttä district, namely Kiitotienkorttelit and Sunnuntaikorttelit. The two neighborhoods are situated between the Longinoja river and new district park Lentoasemanpuisto (Figure 45). The two neighborhoods are the third and fourth detailed plan area after Nallenrinne and Lentoasemankorttelit, located in the south of the area. Whereas Sunnuntaikorttelit is defined as an 'A2 residential area' with a plot efficiency between 1 and 2 in the 2050 Helsinki City Plan, Kiitotienkorttelit is defined as a 'C3 Local center'. This means that Kiitotienkorttelit is supposed to become the local commercial center for the new district and thus house most services.

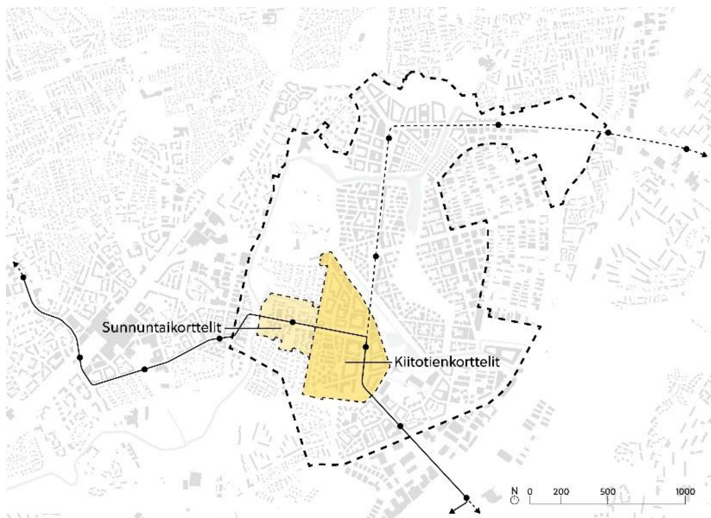

Figure 45 - Location of Kiitotienkorttelit and Sunnuntaikorttelit in the Malmin kenttä district with VIIMA light rail

5.3. Test designs

As stated before, the test design method forms the second step in the process of extracting generalizable spatial guidelines for TOD. The test designs have been made on two different scales, representing two of the most common working levels in planning practice; the master plan level (1:2000) and the detailed level (1:500). The test designs build forth on the main characteristics of the outline plan for the Malmin kenttä district, other detailed plans in the surroundings, and the specific characteristics of the site. The advantages of creating test designs are twofold: not only can the applicability of the findings from the best-practice examples be tested, but new design principles can be discovered as well. The master plan for the area is presented in the following section. Although various structures have been tested for the area, one main plan is forming the outcome. In the detailed level, three options based on a different layout of the main traffic corridor are shown in order to present the various outcomes of the effect of the street layout on the surrounding urban area. All findings of the test designs are discussed through a similar categorization as utilized in the analysis of the best-practice examples. As certain findings may fit to multiple dimensions, a finding is only discussed in the most relevant dimension in order to avoid repetition.

5.3.1. Master plan

The previously discussed outline plan for the Malmin kenttä district gives an overall impression of the scale and density of the new district, but does not necessarily represent a solution based on the principles of TOD. It is thus highly likely that the plan does not make full use of the potential of the implementation the VIIMA light rail. The test design process has resulted in the master plan presented in Figure 46. A larger version of the master plan with a legend can be found as Appendix A. The corresponding diagrams can be found as Appendix B. The presented master plan area will house approximately 10 500 inhabitants and have roughly 35 000 square meters of commercial spaces.

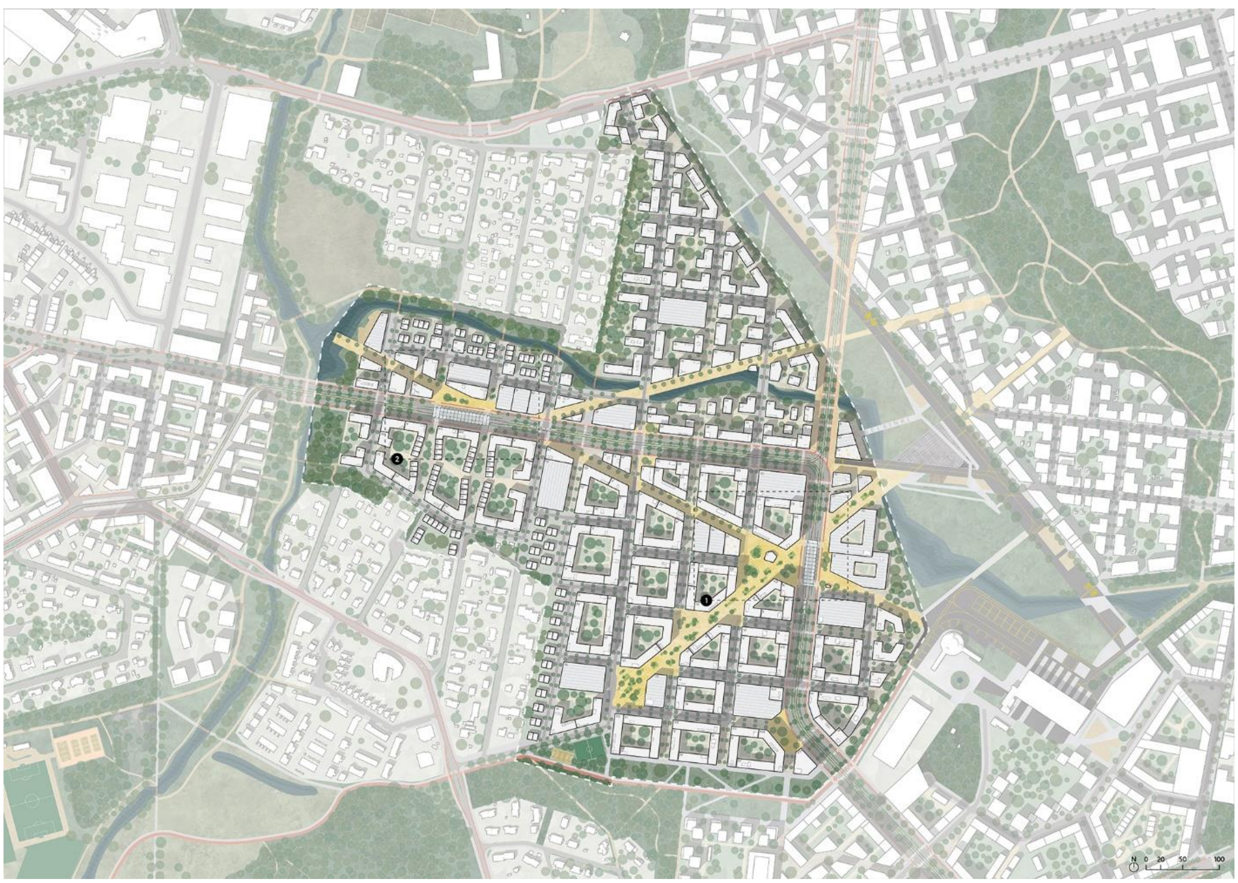

Figure 46 - The master plan for Kiitotienkorttelit and Sunnuntaikorttelit and the locations of the two detailed plans (a larger image can be found as Appendix A)

Place-making - Scale and density

A key dimension of TOD, or any urban planning project, is scale and density. Scale and density concern aspects like structural layout, building density, and building height. Just like the previously discussed best-practice examples, the master plan for Kiitotienkorttelit and Sunnuntaikorttelit is organized along a main corridor, containing both the main road and light rail. The new corridor is positioned on the location of the old runways, reflecting on the historical structures of the former airport. The area contains two light rail stops, one in Kiitotienkorttelit and one in Sunnuntaikorttelit. Adhering to the findings in literature and best-practice examples, the stops are located so that the complete neighborhood is situated within a maximum radius of 600 meters, meaning the complete neighborhood is within walking distance of at least one of the two light rail stops.

Although the whole area consists of a fairly dense structure, the highest building densities can be found along the boulevard. From there, the density gradually reduces as the distance towards the corridor increases. Overall, the average building height along the corridor is approximately six to seven floors, whereas further away the average building height reduces to about five floors. The main corridor also contains several landmark buildings of nine to twelve floors, marking the corridor as a main element from up close but also from a larger distance.

Public services and commercial functions are located in close connection to transit, either along the corridor or in the vicinity of the transit stops, both light rail and bus. Goal of this is to make use of the pedestrian activity the use of public transport generates and provide visibility for commercial services. The surroundings of the Kiitotienkorttelit stop, defined in the 2050 Helsinki City Plan as a local center, contain larger public services, such as an educational center, library, the 'Center for Economic, Social & Environmental Sustainability, and the 'Research and Information Center for Meadows', as well as several larger commercial spaces. The area in the vicinity of the Sunnuntaikorttelit stop also contain commercial spaces, these are however of a smaller size.

Place-making – Public spaces for human use

Although the district is located in a suburban area of Helsinki, the character of the district will be urban rather than suburban. This means that, in contrast to some of the surrounding areas, public spaces rather than private gardens will serve as meeting places for residents. The proposed master plan contains several urban squares and pedestrian corridors, highlighted in the master plan with a yellow color. Part of the corridors and squares are situated on the former runways, again reflecting on historic elements of the site. Besides these, several new corridors have been created in sightlines of the new transit stops, placing these stops in a central position. In addition to directing residents towards transit stops, the corridors also guide people towards commercial and public services as well as the larger recreational areas such as Longinojanlaakso in the southwest and the new Lentoasemanpuisto in the east.

The direct surroundings of both light rail stops contain a public square along which several services are located. This way, referring to the previously discussed node-place model, the stops do not only form a node in the transport network, but also a place for activity. The surrounding buildings provide borders to the public space and contribute to a feeling of human scale.

Besides the public spaces, nearly every apartment block contains a green courtyard. There is no need for parking decks underneath the courtyards as parking is organized in several centralized parking garages, this means the courtyards can contain lush vegetation and contribute to infiltration of storm water.

Place-making – Safety

In order to create a pleasant urban district, a feeling of safety plays an important role. Safety in traffic is stimulated by providing large crosswalks on the main corridor, affecting the character of the road and slowing down the overall speed. Due to the small scale traffic calmed character and limited speed of the other streets, crosswalks are no necessity outside of the main traffic corridor.

Services with an open ground floor character are located along main pedestrian corridors and public spaces, creating a feeling of safety through the concept of 'eyes on the street'. Furthermore, the services generate pedestrian activity and a use of the public space throughout the day. This way, the transit stops also become more comfortable places for waiting.

Place-making – Variety and complexity

As to create an interesting and pleasant living environment, an urban planning project should contain a certain level of variety and complexity. Rather than forming one continues neighborhood with a monotonous block and building typology, the project area contains three zones with their own significant character. Whereas the southern part of Kiitotienkorttelit mainly contains enclosed blocks, similar to those found in central urban areas, the northern part of Kiitotienkorttelit and Sunnuntaikorttelit contain blocks with a more open character and allow for more passing through. Additionally, various housing typologies can be found within the zones, contributing to the level of variation and complexity of the neighborhoods.

Although the area is based around a grid like structure and contains various long pedestrian axes, the long lines are broken up by the presence of public squares and changes in character, providing an interesting pedestrian experience. Additionally, the building plots are relatively small, stimulating a variety in architecture.

Place-making – Connections

Connections, especially the non-motorized connecting to the transit stops, are of high importance in TOD. By creating relatively small and permeable building blocks, as well as shaping pedestrian corridors, the plan optimizes the connections for pedestrians and cyclists, making it easy to reach services, green areas, and transit. Furthermore, the gridiron-like structure provides a clear and simple urban fabric where it is easy to find your way.

Facilities/logistics – Pedestrian/cyclist orientation

In order to further stimulate walking and cycling, the local pedestrian and cycling network of the neighborhood has to be connected to a larger network. This light traffic network can, for instance, consist of shortcuts through green areas where motorized vehicles are prohibited, and thus provide faster routes in comparison to the car. For example, in the master plan, the Lentoasemanpuisto is free of motorized traffic, making cycling the fastest way to move between the neighborhoods on either side of the park.

Creating a clear hierarchy in the light traffic network also benefits the pedestrian and cyclist experience. Separated bike lanes can for instance be found along the larger roads as well as south of the neighborhood where the Baana (the bicycle highway network of Helsinki) is located. The speed of cycling is fast on these routes whereas the speed of cycling in the local roads, where the road is shared with motorized traffic, and in the shared space areas, where the space is shared with pedestrians, is slower.

Facilities/logistics – Transit in the urban pattern

The way how transit is positioned within the urban pattern is often the category that separates TOD neighborhoods from non-TOD neighborhoods. By positioning the light rail in the main corridor, attached to the public spaces and services, the light rail and its stops form an important physical element of the urban landscape and daily life. Being present as an element of daily life contributes to a modal shift, stimulating residents to make use of public transport, rather than a personal motorized vehicle.

To ensure a fast and effective transit connection, a corridor based on straight lines is preferred over a corridor with lots of turns. This also minimizes the noise caused by light rail, often the loudest in corners. The straight lines also ensure a good overview of the other traffic for the driver in terms of safety.

To stimulate multimodality, several mobility hubs are located throughout the neighborhood. The mobility hubs vary in scale and are always connected to a form of public transport, either bus or light rail. They are places where sustainable forms of transportation and needs of daily life meet as they contain, for instance, parcel lockers, a bicycle repair shop, and electric sharing cars, cargo bikes, bikes, and scooters. By providing these services in convenient locations, they contribute to reducing the demand for personal motorized vehicles. The mobility hubs also include information points for subjects like smart mobility, providing information to future residents on sustainable choices for transportation.

In order to further stimulate multimodality, the bus stops should be located in close connection to the light rail stop. The master plan, for example, makes use of combined bus and light rail stops, giving residents to opportunity to easily switch from one mode of transport to the other.

Facilities/logistics – Car movement and parking

Despite the fact that TOD is mainly focused on the movement and experience of the pedestrian, cyclist, and public transport user, the movement of the car and parking still play a large role in the character of the neighborhood and success of the application of the other guidelines.

Although the master plan allows for the usage of the car in most areas, a clear hierarchy with differences in character, profile, and speed provides clarity in the role of the car for the driver. The transit corridor serves as a collector road for the smaller local streets. Here the bicycle traffic is separated from the car. On the local streets, the car shares the space with the bicycle traffic and a slower speed is enforced.

Visitor parking takes place both in the main corridor and along the local streets. These kind of parking spaces can be used for several hours, for instance when visiting a store or a resident. Permanent parking however is located in centralized parking garages. These parking garages are mostly located along the main corridor, ensuring quick access and reducing the motorized traffic through the local streets. Also the larger commercial services like supermarkets are combined with a parking garage. Another benefit of centralized parking garages, especially in contrast to parking solutions that are constructed inside of each individual building block, is the pedestrian traffic they create from people walking from and to their car, contributing to the activity on the street.

5.3.2. Detailed plans

Although planning on master plan level is important, it is often the detailed level in which much of the design, thus guidelines, are translated into real life surroundings. To further establish guidelines on a more detailed level, three different variants in two different locations have been studied. All three variants make use of the same master plan layout, but differ in the solution for traffic (Figure 47). A design based on variant C for the second detailed area has not been developed, as this would not be possible within the constraints of the developed master plan and previously discussed outline plan. The five developed detailed plans can be found as Appendix C, D, E, F, and G.

The variant A positions the new light rail in the middle of the main corridor. This variant corresponds with the previously presented master plan and has a similar character of, for instance, Hammarby

Sjöstad. On either side of the light rail there is a green strip with trees, a lane for cars, parking, one-way bikeway, a sidewalk, and an area reserved for the services in the ground floors of the adjacent buildings. Variant B positions the light rail on one side of the corridor and on the side of the light rail the one-way bikeway has been changed into a two-way bikeway. As a consequence, the space reserved for services in the ground floor has been expanded and parking on one side of the road has been removed. In variant C the motorized traffic has been removed all together and has made place for a large shared space zone with light rail in the middle. As a consequence, bus connections have been removed as well. The light railway has a green character and edges of the green are raised to limit crossing and ensure safety, and can be used as seating. In the explanations of findings, the different variants will be referred to as 1A, 1B, 1C, 2A, and 2B where the number refers to the detailed area and the letter to the applied variant.

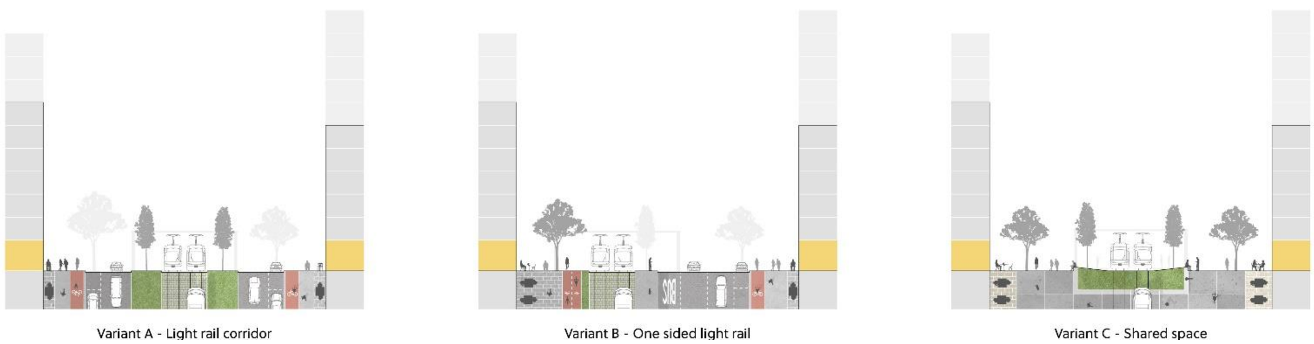

Figure 47 - Three different variants for the traffic solution in the main corridor used for the detailed test design areas

Place-making – Scale and density

Whereas scale and density on a master plan level refers to the structural layout of an urban area and the scale of the building blocks throughout the entire neighborhood, scale and density on a detailed level refers more to the scale from a pedestrian experience and to the density and placement of, for instance, commercial and public services.

One of the most important built elements of the city on eye level are the ground floors. In order to stimulate an attractive and pleasant pedestrian experience, all ground floors in the area have a minimum height requirement of 3,5 meters and must have an open character. As the project area concerns a local center in a suburban area though, not all ground floors will contain spaces for commercial or public services. It is thus important to locate services in the right place, where they have high visibility, can make use of the pedestrian activity, and contribute to a lively streetscape. The majority of the services should be located within the first 100 to 200 meters of a light rail stop, as this is the zone with the most pedestrian activity (Stojanovski, 2020). Additionally, services should be located in other areas with a lot of pedestrian activity, such as the axes that lead to the light rail stops and the corners of building blocks where crosswalks are situated.

As especially smaller businesses, such as restaurants, flower shops, and cafeterias, benefit from pedestrian activity, it is these kind of services that should be located in close relation to the light rail stops. Larger commercial spaces, such as grocery stores, may be located further away or should be located so that they can support the use of surrounding services. As a general rule, commercial spaces should increase in size as distance towards the transit node increases. Other types of ground floor activities that can benefit the pedestrian experience by opening up the facades are, for instance, communal spaces for residents, at home studios or offices, bicycle parking, and first floor apartments with an own entrance.

Several differences can be found in how the layout of the light rail corridor in the different variants affects the use of the ground floor. In 1A and 2A, the traffic separates the corridor and influences the use of either side equally due to the disturbance of the car traffic. Especially in these variants, the corners of building blocks will form points if interest due to the importance of the position of the crosswalks. In 1B and 2B, one can imagine that services will mainly be located along the light rail, where the noise and smell of the motorized traffic is reduced and the larger sidewalk in combination with the two-way bikeway stimulates activity. Especially those areas where the southern façade is located along this side, as is the case in 2B, the sun can influence the type of services and benefit, for instance, restaurants. Finally, the negative impact of motorized traffic is removed completely in 1C and it becomes clear that, with such a solution, it is important to stimulate ground floor use along the complete shared space axis as much as possible to prevent 'dead' walls.

Place-making – Public spaces for human use

In close relation to the ground floors are the public spaces. To activate the ground floors onto the streets, sufficient space for a hybrid zone 'between' the sidewalk and façade is required. For this hybrid zone, a distance of one to two meters is preferred, as this will lead to the most optimal solutions (van

Ulden et al., 2015). The different variants show different solutions, where the 1,5 meters is the most minimal distance for the hybrid zone, which is sufficient for, for example, a narrow terrace of a cafeteria. This hybrid zone can be designed in many ways, for instance with a difference in surface material, a small height difference, or by elements like small poles or trees.

Also microclimate plays an important role in the use of the public space by people. The trees provide shade and cool down the streets during warm summer days and reduce strong cold winds during winter. Terraces are mostly located in sunny areas on the southern and western facades. Vegetation also helps with breaking down large public spaces in smaller areas, as is the case in Kiitotienkorttelit.

A clear difference can be found between the public space surrounding the light rail stops in the different variants. As the light rail stop is located in the middle of the corridor in 1A and 2A, it can be seen from the public space, but does not become part of it. In other words, the fact that there is a light rail, other than providing access to the place, does not provide any benefits to the public space. By locating the light railway to one side of the road, as is the case in 1B and 2B, the stop opens itself towards the square and becomes an important element. Here, the change in surface material, from grass to stone, plays an important role in making it one with the public space. The most integrated variant is 1C, as the light rail rides through the public space and is fully part of it. Rather than creating elevated platforms, the railway itself lowers, blending the stops into the public space. The benefits for the public space are highest in this variant.

Place-making – Safety

A feeling of safety is important in the pedestrian experience of an urban area. The open ground floors and variety of services stimulate 'round-the-clock' activity and contribute to this feeling of safety through the concept of 'eyes on the street' and the increased pedestrian traffic. The public spaces should be designed so that they are well-lit, obstacle free, and have adequate sight lines.

In terms of traffic, the traffic calmed streets, large crosswalks, and separated bikeways all contribute to the feeling of safety. In the case of variant 1C, the elevated edges of the green tramway ensure safe crossings for pedestrians and cyclists.

Place-making – Variety and complexity

In order to avoid monotony, the public spaces and architecture should differ in character, material, and use. This also helps with giving a distinct character to the area. By positioning the larger commercial services, such as grocery stores, deeper into the building, smaller commercial spaces can be located along the streets, providing a greater diversity and more variation in the ground floor. The use of sustainable materials should also be stimulated.

Place-making – Connections

The light rail stop does not only form a node in the transit system, but also a node where people move to and start moving from. When exiting a light rail or bus, the surroundings have to be clear and it should it be easy for one to orientate. The green elements and buildings in the public space should be positioned so that they do not block walking routes, but rather help shaping them.

Facilities/logistics – Pedestrian/cyclist orientation

In order to stimulate cycling as an important mode of traffic for daily life, adequate bicycle facilities have to be organized to make it as easy as possible. All residential buildings need to comply with high standards for bicycle parking and the parking has to be easily accessible from both the street and staircase. Next to this, the hybrid zone in front of services can be used for bicycle parking, making it convenient to park your bicycle when visiting a store or office.

As said previously, the light rail stop also forms a node where people start moving from. In this sense, there are big differences between the different variants. Access to the stop in 1A and 2A is organized at the end of the stops, where crosswalks connect to the sidewalk. In 1B and 2B, the stop opens to the public square, making it possible for people to start moving in one direction over the entire length of the stop, making the crosswalks less important. This is especially the case in 1C, where, although there is a small height difference between the stop and the light rail, people can move into every direction. This is, of course, beneficial for the pedestrian. Additionally, the surrounding space in variant 1C is shared between the cyclist and pedestrian, which, most likely, slows down the cycling speed compared to the separated bicycle lanes.

Facilities/logistics – Transit in the urban pattern

To make the light rail an important element of the urban landscape, the stops are designed so that they become landmarks on their own. The canopies also provide shelter from the weather. The light railway has a green character, which helps dampening the noise and contributes to the storage of storm water.

There are clear differences in the character of the light rail in the three variants. Variant 1A and 2A provide a more traditional solution in which the speed of the tram can be optimized. Here it is mostly traveling through the area, but does not necessarily contribute anything to the pedestrian experience, this is also caused by the fact that the green area is located in the middle of the corridor. The light rail and bus share the bus stop, making it easy to switch between different modes of traffic. The node values in this variant are optimized. In 1B and 1C, the light rail is located along one side. A clear advantage is that, as mentioned before, the stop becomes part of the public space. Another advantage is that the green area becomes more visible for pedestrians and contributes to the experience. The driving speed can still be high, as it is separated from other traffic. A downside of this variant is the fact that the bus stop is not integrated anymore, making switching between the different modes of traffic more difficult. In 1C, the light rail is part of the public space and the driving speed is slower. This is a downside when talking about speed and efficiency, as the light rail has to reduce its speed and changing from light rail to bus is no longer possible. However, as the light rail drives slower, it adds to the 'urban' feeling of the area, as this is comparable to the situation in a traditional inner city.

Facilities/logistics – Car movement and parking

As mentioned previously, although TOD is mostly aimed at other modes of traffic than the car, it still plays a major role in the character of neighborhood. Providing a clear hierarchy in the streets helps defining the role of the car in a certain area. There are several major differences in how the different variants deal with the car traffic along the main corridor. Variant 1A and 2A provide the most space to cars, with parking on either side of the corridor and wide one-way lanes. The parking also serves a purpose, as it functions as a physical boundary between the pedestrians/cyclists and the cars. Variant 1B and 2B also provide space to cars in the main corridor, however one side of the parking has been removed, lowering the total amount of parking. Variant 1C removes the car all together, however, as a consequence, a new main street has to be located outside of the detailed area.

Visitor parking is also located along the smaller streets. Here, the parking spaces are made of grass tiling, rather than asphalt, contributing to the green character of the streets. Closer to the stores, visitor parking is only allowed for short periods (e.g. two hours) whereas further away it can be increased. This measure is taken to direct car drivers to the parking garages, which are connected to the larger commercial spaces. The maintenance and storage access should be located along the streets and larger parking spaces for trucks must be provided.

6. Discussion

In this chapter I will examine the significance of the findings in terms of the research objectives, research questions, and in light of the previous research. The main objective of this thesis was to bridge the gap between academic research on the topic of built environment and travel behavior, and the professional practice of land use planning. The research questions, formulated at the start of the process, are as follows:

1. What is the relation between the built environment and travel behavior?
2. What is TOD and what are its main principles?
3. What are the impacts of light rail projects?
4. What kind of TOD design guidelines can be derived from best-practice examples?
5. Are the derived TOD design guidelines applicable to the Finnish context and what new guidelines can be found through test designs?

First, I will discuss the relation between the built environment and travel behavior, which concerns the first three research questions. The theoretical findings are reflected upon through the best-practice examples and the test case of the VIIMA light rail. Second, I will discuss on the findings for TOD design guidelines and how these might be utilized in the professional field, this concerns the fourth and fifth research question. This is done by reflecting on the applicability and transferability of the guidelines found in the best-practice examples on the test case. Here I will also discuss the established guidelines for the Finnish context. Finally, I will discuss limitations of the study and propose suggestions for further research.

6.1. Built environment and travel behavior

The research in this thesis builds upon the relation between the built environment and travel behavior, for which much of the previous research has suggested a strong link can be found (Hrelja et al., 2020; Næss et al., 2018; Newman et al., 2016). Several theoretical models have attempted to explain the interaction between the two topics of built environment and travel behavior, such as the transport land use cycle (see Section 2.1.1.) and the node-place model (see Section 2.1.2.).

Wegener & Fürst (1999) and Bertolini (2012) argue that the relation between the two topics is a reciprocal interaction rather than a linear process. The transport land use cycle demonstrates this interaction in a simplified manner, where land use is affected by accessibility and the transport system is affected by the activities that take place. The functioning of this model also forms the basis of the node-place model (Bertolini, 1999), which aims at examining the relation between node and place values, mainly in areas served by public transit. Here, node values refer to the accessibility of the node, whereas place values refer to the intensity and diversity of activities. Bertolini (1999) argues through the model that, if understood right, public transit nodes have the potential to become a place where social and economic activities flourish in a relatively sustainable way through the use of sustainable modes of traffic.

There is no doubt that, with the increasing importance of mobility in the modern urbanized world, improving the urban built environment to stimulate the use of sustainable modes of transport is one of the major challenges for today's urban planners and plays a key role in reducing the amount of greenhouse gases (Bertolini, 2012; Hrelja et al., 2020). It could be argued that, in order to reach the full potential of their plans in stimulating a modal shift, it is, above all, of vital importance for practitioners to develop a comprehensive understanding of the theoretical functioning of the models and the relation between the two topics. Without this understanding, practitioners might attempt to contribute to the issue with the best intentions, but remain unsuccessful at doing so.

A well-established land use planning approach that is supported by the theoretical functioning of the models and can be used by practitioners, is TOD. Although there is no single definition of TOD, definitions often refer to the *"development of housing, employment, activity sites and public services around existing or new railway stations served by frequent, high quality and efficient intra-urban rail services"* (Knowles, 2012, p. 251). Hrelja et al. (2020) define three main aims of TOD. *First*, TOD intends to reduce the total demand for transport and increase the share of public transit, cycling, and walking. *Second*, TOD aims at creating a more livable environment with high standards for the urban space. *Third*, TOD can serve as a catalyst for (economic) development. Dittmar & Ohland (2004) note that the term TOD should only be used for projects that achieve five main aims, namely location efficiency, a rich mix of choices, value capture, place making, and a resolution of the tension between node and place.

Although the use of TOD as a planning approach is fairly common in the US, it is not yet in the European context. Pojani & Stead (2018), however, note that albeit might not be named as such, the principles of TOD have been an elemental part of planning in the European context for decades. This can, for example, also be seen in the historical development of Helsinki along the tram and train lines (see Section 5.1.). As it is, however, not named as such, the lack of a clear definition of the concept is potentially problematic in the European context, which may result in ambiguity and misunderstanding between the various involved actors, such as land use planners, transport planners, private developers, and the public transport authorities. Furthermore, although not specifically discussed within the constraints of this thesis, several have noted the difficulties in implementing TOD caused by institutional complexity, as it requires the involvement of many public and private actors (Hrelja, 2020; Krikken, 2020).

Next to this, due to the fact that, although not named as such, principles of TOD are often unconsciously part of the work of most European land use and transport planners, there is a risk that one implements certain things out of habit, rather than based on a comprehensive argumentation. In other words, if work is done out of routine and no special attention is given to, for example, the potential functioning of a transit stop as both a node and a place, one might fail to achieve the full potential without even realizing it.

In order to, at least partially, solve this issue, it is important that the two relevant planning disciplines, transport and land use, work together in a well-integrated manner. It is, for instance, often the case that in practice the two disciplines only meet several times throughout the planning process, without creating a fully integrated plan. For example, a transport planner might locate a light rail stop at an important traffic node with the argumentation of transport efficiency, while a land use planner locates the public space away from the traffic and thus the light rail stop. This process can be metaphorically explained with a broken zipper, rather than one that is fully interlinked (Figure 48).

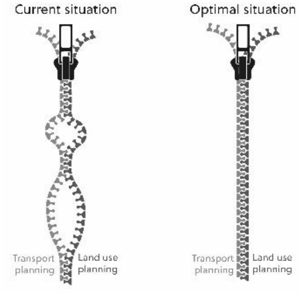

Figure 48 – The relation between transport and land use planning through the metaphor of a (broken) zipper

The discussed best-practice examples, however, provide good cases of a successful implementation of TOD and are supported by the functioning of both the transport land use cycle as well as the node-place model. Although all three cases have had some issues with the implementation of certain aspects throughout the process, for instance the changed norms for residential parking in Hammarby Sjöstad, the projects all display a good integration of transport and land use planning. All three cases have, for instance, been successful at stimulating the use of sustainable modes of traffic over the use of personal motorized vehicles.

The cases of Rieselfeld and Hammarby Sjöstad also show how the implementation of high-quality transit at an early stage may influence the modal share, as respectively tram and light rail were available for use when the first residents moved in. In the case of Vauban, the tram was implemented in a later stage, but the 'push and pull strategy' with strict restrictions for car ownership proved to be successful as well. Through these examples we can also see how the process of the land use transport feedback circle might be fast-tracked by implementing land use changes and transport simultaneously. This of course requires a good integration of the two disciplines.

The cases also present how other topics, such as the energy transition and climate adaptation, might become a part of the development of a TOD project, as was also discussed by Cervero and Sullivan (2011) through the concept of Green TOD. As the overarching goal of TOD is to reduce greenhouse gases and create more sustainable cities, these topics also deserve sufficient attention in the development of an area.

The test designs also built upon the relation between the built environment and travel behavior and take inspiration from the best-practice examples. The test case provides an ideal scenario for the development of a TOD project due to the planning situation, as current plans aim at transforming Helsinki from a monocentric city to a rail-based network city with multiple urban hubs, as well as the goal of implementing the VIIMA light rail in the project area itself. Besides this, the area contains hardly any existing structures, making the implementation of new TOD development easier.

Although it could thus be said that all the right ingredients for becoming a great example of TOD are in place, it can be questioned if the order in which things are implemented is desirable. That is, despite the fact that the first two detailed plans for the new district, Nallenrinne and Lentoasemankorttelit, have already been approved and construction will start relatively soon, planning of the VIIMA light rail is still ongoing and construction will not be finished before the early 2030s. Consequently, construction of the light rail will take place when people are already living in the area, which could negatively impact the image of the light rail and neighborhood (Ferbrache & Knowles, 2017). This means that, without a similar push and pull strategy as applied in Vauban, it is highly likely that the lack of high-quality transit for a number of years will negatively affect the modal share in the area. Next to this will the new highway exit at the Lahdenväylä highway be finished in 2025, which will also negatively affect the modal share as it greatly improves car accessibility.

This critique brings up an important point about both the test designs and the other created plans for the area; they present a final vision or situation, rather than a 'temporary' one, one in which the light rail has not been implemented yet. In other words, although the final solution may be developed through principles of TOD, the order of implementation, most likely, negatively affects the final outcome and temporary experience.

Ideally, these issues would be solved by implementing the light rail simultaneously with the rest of construction. However, if this is not possible, extra attention should be paid to the planning of the temporary situation, the negative impacts of the implementation phase, the availability of high-quality alternatives to private cars (e.g. BRT and bike and car sharing programs), and car restricting measures. This, again, requires a good integration of transport and land use planning.

6.2. Design guidelines for TOD

Several scholars have noted that much of the available research on TOD is based on the policy and regional planning scale (Jacobson & Forsyth, 2008; Pojani & Stead, 2015). A large part of the discussion from the previous section also concentrates on these two levels. Sharma et al., however, note that *"a significant limitation or failure for many current TODs is that less attention is given to making TODs attractive and pedestrian-friendly"* (2017, p. 14). This critique concerns a more detailed level, which deals with urban design issues, rather than the more abstract aforementioned topics. However, academic attention for this level has been rather limited and is mostly focused on the North-American context (Hrelja et al., 2020; Pojani & Stead, 2015). It could thus be said that, although principles of

TOD are often unconsciously part of the work of most European land use and transport planners, the lack of a clear definition of the concept and the limited attention for urban design issues on the detailed scale might eventually result in (partially) failed implementation of TOD.

The creation of design guidelines for TOD may help resolving some of these issues on a detailed scale and guide planners dealing with the implementation of TOD projects. Furthermore, as argued previously (see Chapter 3), the creation of guidelines could bridge the gap between academic research and the relevant urban planning professions. Two different methods have been used in the creation of the design guidelines, namely the extraction of guidelines through the analysis of best-practice examples and the planning of test designs. The categorization of the guidelines in two different topics and eight different dimensions was adapted from Jacobson & Forsyth (2008).

The extracted guidelines from the best-practice examples (see Chapter 4) provide interesting similarities, such as the way in which all neighborhoods are organized around the light rail as a central corridor and the way in which the public space and services relate to each other as well as to the public transit. Also have all cases implemented traffic-calming measures for local roads and created shortcuts for cyclists and pedestrians. We can however also find differences, for instance in building density, variation in building typologies, and the role of the main corridor in the car network. For instance, whereas in Hammarby Sjöstad the character of the main corridor is that of a very urban boulevard, the corridor in Rieselfeld and especially Vauban have a more suburban character with lower driving speeds.

The extracted guidelines from these best-practice examples provide interesting findings, one must however be cautious with transferring or applying them one-to-one to a different context (Hrelja et al., 2020; Olesen, 2014; Pojani & Stead, 2015; Thomas et al., 2018). This is, many of the design elements might function in a different context in a similar fashion, but this needs to be carefully examined, taking into account the context-specific *"urban forms, political and planning contexts, and cultural preferences in order for implementation to be successful"* (Thomas et al., 2018, p. 1211).

Taking this into consideration, the test designs in this research do not merely serve as a method to create additional guidelines, but also as a way of examining if the findings are suitable for the context of an urban area in Finland. This process of examining the findings of best-practice examples and planning of the test designs have ultimately resulted in a number of TOD guidelines for spatial development for the Finnish context, which can be found as Appendix H.

In general, it could be said that the extracted guidelines from the best-practice examples can also be applied to the Finnish context. This might be caused by the fact that the planning and design culture of the three countries, Finland, Sweden, and Germany, is relatively similar. The process of creating the test designs has however also resulted in additional guidelines, such as the placement of taller buildings around a transit stop (Guideline 1.5), the placement of smaller services in close proximity to the transit stop (Guideline 1.9), the implementation of mobility hubs (Guideline 7.3), and the implementation of centralized parking facilities with a ground floor function (Guideline 1.11 & Guideline 8.1). Furthermore, the different variants of the detailed designs show that one must be aware of the consequences of the chosen traffic solution, as this highly affects the character of the light rail corridor as well as the way in which people use the surrounding public space.

6.3. Limitations of the study and suggestions for further research

One of the most complex challenges to deal with throughout the process has been the relation between research and design *or* academia and practice. In the methods chapter (see Chapter 3), I have discussed the differences between research and design, the motives behind research in environmental design disciplines, how design could be justified as a research, and the creation of guidelines as a research method. As this thesis concerns a consultancy work for the City of Helsinki and I have been not only a scholar, but was also active as a worker for the City of Helsinki throughout the entire process, it was important to continuously reflect upon these topics in order to justify this thesis as a scholarly and independent work. This has at times been difficult, however, to my best knowledge, I have always managed to meet the criteria to assure the integrity and legitimacy of the outcomes.

One of the limitations of the study has been the fact that the creation of the guidelines is limited to the two topics of place-making and facilities/logistics, excluding the topic of processes. As mentioned in the chapter on methodology, research on the topic of process has not been ignored during the evaluation of the best-practice examples, but does not form a part of the final design guideline matrix. In hindsight, it could be said that, although not as tangible for urban planners as the other topics, the processes play a role of similar importance to the final outcome and could be researched in further studies as well.

Another limitation of the study is the selection of the best-practice examples. The limited amount of examples, three of which two are located in the same city, should be expanded for better results. Also the fact that the studies have been done remotely, without visiting the location, caused by COVID traveling restrictions, have limited the results. Furthermore, the best-practice examples only provide examples that have succeeded, it would, however, also be interesting to analyze less successful cases in order to understand the underlying reasons for potential failure.

Additionally, another clear limitation of the study has been the selected test case, which concerns a large development with hardly any constraints, as the current situation consists largely of an empty field. The case provides an almost ‘ultimate’ chance to develop guidelines for TOD, however projects like these are often hard to come by. It would thus be interesting to apply a similar research methodology to a case with different circumstances, such as a high dense urban infill project, a case in which a light rail is being developed in an existing urban structure, or a case from a more rural area with a train connection rather than a light rail.

Finally has my personal cultural background and profession affected certain decisions. Although I have been active in the field of urban planning in Finland for several years, my cultural background affects my view on questions like *‘what is urban development?’* and *‘what is the role of the car in the city?’*. Next to this have I previously graduated and worked as a landscape architect, rather than a land use or transport planner. For further research it would thus be good for experts with a Finnish background or different profession to test the developed guidelines in order to see if they are indeed applicable to the Finnish context and other disciplines. A workshop in similar fashion as done by Pojani & Stead (2015) might also contribute to the validity of the guidelines and expansion of the available knowledge.

7. Conclusion

Throughout history, the growth of cities has been considered a great source of prosperity. However, in recent years negative environmental impacts have led to a growing concern about the consequences of the sometimes seemingly unlimited urban growth. One of the key topics when speaking about these negative environmental impacts is mobility. Through their profession, land use and transport planners are able to contribute to solutions concerning mobility, for example by shaping an urban living environment that supports the use of sustainable forms of transport.

One of the well-established land use planning concepts that can be utilized by planners is TOD. Although originated from the US, TOD has gained a great interest in the European context in recent years. In general, TOD aims at achieving a shift in modal share towards sustainable forms of transport, while simultaneously creating a more livable environment with high standards for urban space. Furthermore, TOD may serve as a catalyst for (economic) development.

The shift in modal share and several principles of TOD also form important aspects of the ambitious goals in the City of Helsinki's Action plan for carbon neutrality and the 2050 Helsinki City Plan. By transforming Helsinki from a city with a dominant single core into that of a rail-based network city with multiple dense urban hubs, the city aims at reducing greenhouses gases related to mobility. However, in order to achieve these goals, the relevant actors, including land use planners, must comprehend the relation between the built environment and travel behavior.

In order to contribute to this understanding, this study aimed at bridging the gap between academic research on the topic of built environment and travel behavior, and the professional practice of land use planning. This was done, first of all, by examining the relation between land use, design, and sustainable modes of mobility in academic research, and second, by producing practical spatial design guidelines for TOD in the Finnish context.

The studies of the best-practice examples present cases of TOD in which a good integration of land use and transport planning has successfully led to a modal shift and the creation of livable neighborhoods in which social and economic activities flourish. Furthermore, they present how other topics that deal with creating more sustainable cities, such as the energy transition and climate adaptation, can become part of the development of a TOD project.

The test designs show how, taking into consideration the context sensitivity, a large part of the findings of the best-practice examples can be applied into the Finnish context. The design process of the test designs has also led to the creation of additional guidelines, which may in turn serve as inspiration to the planners of other countries. The test designs also provide an image of what a TOD-based project in the Finnish context might look like.

The creation of the toolbox of TOD guidelines for spatial development in the Finnish context forms an important first step in translating the available academic knowledge into usable practical tools for Finnish planners. Although a comprehensive understanding of the functioning of the related theoretical models is still required to achieve large goals such as a modal shift, the toolbox provides a set of practical guidelines that planners can directly apply to their work. Furthermore, the guidelines may, in combination with the test designs, spark a larger discussion on the role of TOD in Finnish planning and the importance of a good integration of land use and transport planning.

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Appendices

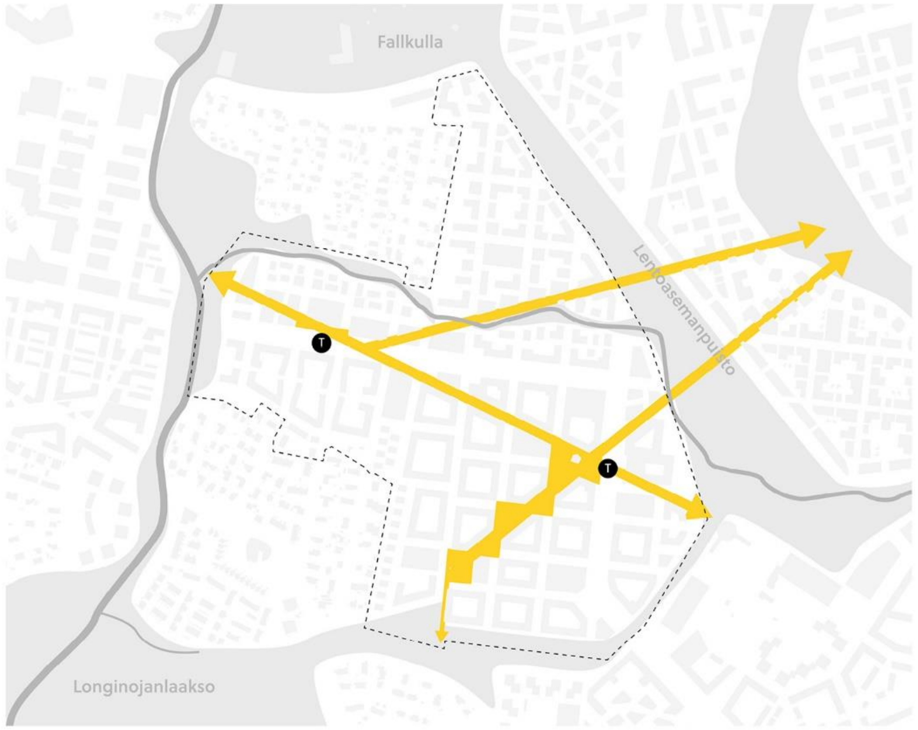
Appendix A: Master plan for Kiitotienkorttelit and Sunnuntaikorttelit

Appendix B: Diagrams for master plan

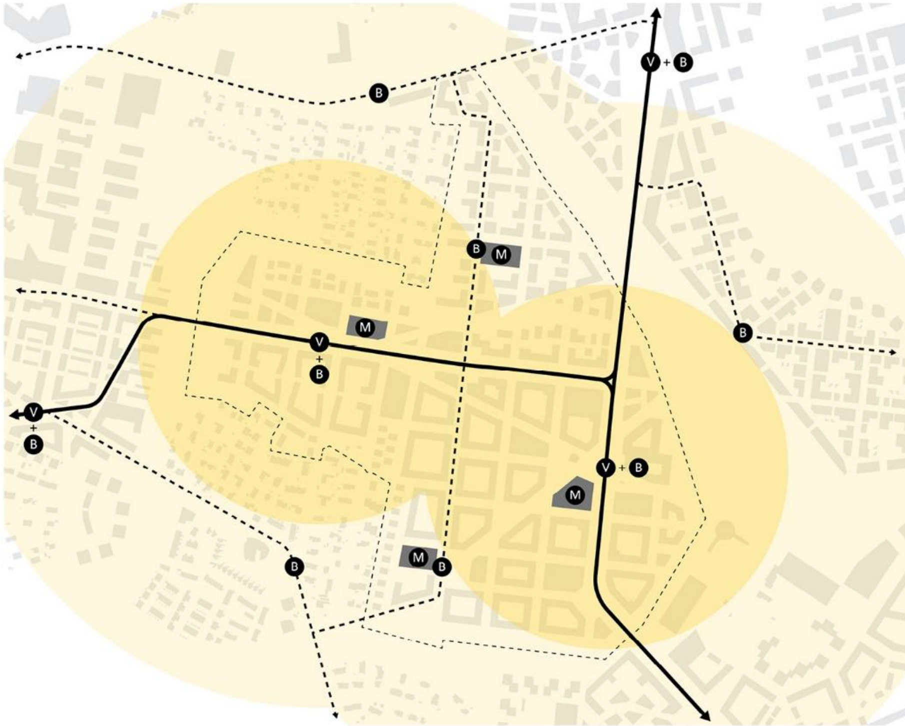
1. Existing situation
The test case area is located in the south western section of the former Malmi Airport and in between two existing small house areas. Currently, there are several built objects in the area, these include several houses and sheds, as well as some hangars. The most characteristic element of the area are the former runways.

2. Building heights
The average building height ranges from 5 to 7 floors. On the edges of the area, where the new buildings meet the existing ones, the height and scale of the buildings reduces. Next to this, there are several landmark buildings on bases along the former runways. The heights within the building blocks variety as well.

3. Functions
Commercial functions (black) are located along the main corridor and in the proximity of the bus stops. The public functions (yellow) are located in close proximity to the transit stops as well. A more flexible use of the ground floor for other services, such as home offices and studios, stimulated along the public space corridors (dotted).



4. Public space corridors
Three new public space corridors connect the surrounding neighborhoods and larger green spaces. Furthermore they provide attractive pedestrian and cycling access to the functions and large transit stops. In contrast to the surrounding green spaces, the corridors have a more urban character.



5. Public transit network
The public transit network consists of two light rail corridors (line) which follow the old runways and several supporting bus lines (dotted). In close relation to the transit stops are the mobility hubs, which support multimodality and form central points in the neighborhood. The complete neighborhood is located within 600 meters of high quality transit.

6. Car network
The main corridor serves as a collector road (thick line) and connects the center of Malmi to the new highway exit. Besides this, the roads that contain the other bus lines function as a local collector road (middle line) and the local roads (thin line) provide access to all building blocks. Parking garages are located in close proximity of the collector roads.

Appendix C: Detailed area 1 - Variant A

Appendix D: Detailed area 1 - Variant B

Appendix E: Detailed area 1 – Variant C

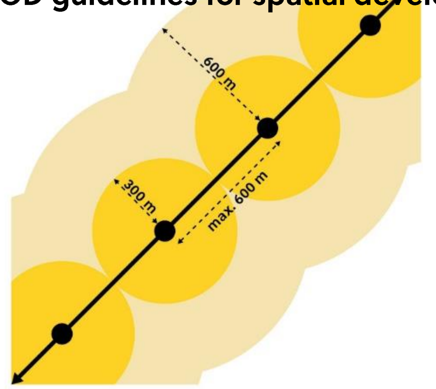
Appendix F: Detailed area 2 – Variant A

Appendix G: Detailed area 2 – Variant B

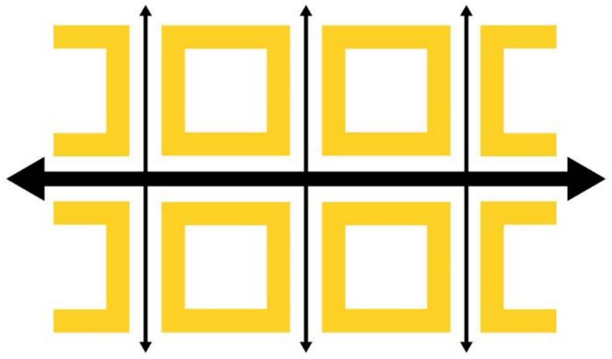
Appendix H: TOD guidelines for spatial development

Place-making

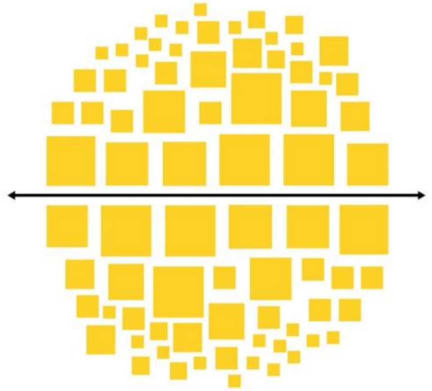
1. Scale and density



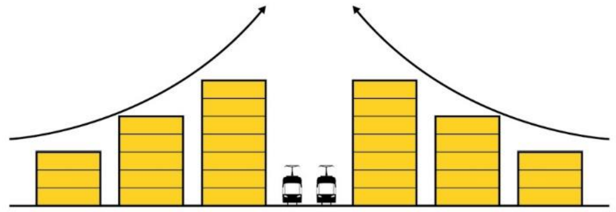
1.1. Maximum walking radius
Locate the transit stops so that the maximum walking distance between them is 600 meters. This corresponds with a walking time of roughly 8 minutes.



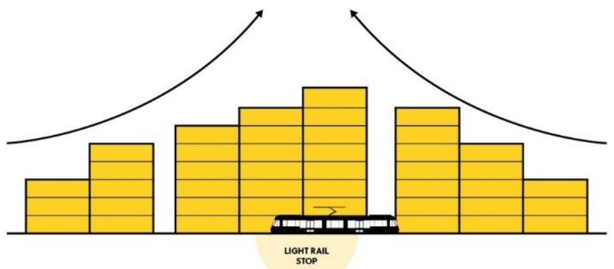
1.2. Main corridor
Create a main corridor based on the transit connection. Diverge smaller connections from the main corridor. This corridor may also contain the main car access for the area.



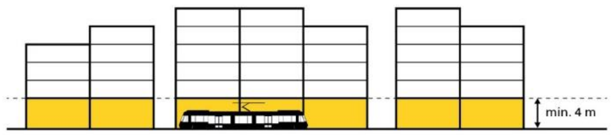
1.3. Scale of building blocks
Locate the largest building blocks close to the main corridor and increase variety in size and scale as distance increases. Provide a high variety of building typologies in the whole neighborhood.



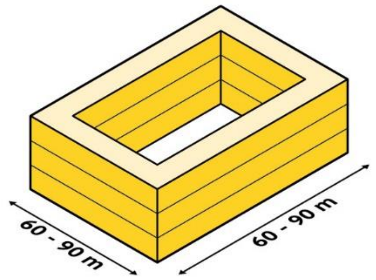
1.4. Building height along corridor
Position taller buildings, with an average building height of 6 to 8 floors, along the main corridor and decrease height as distance increases.



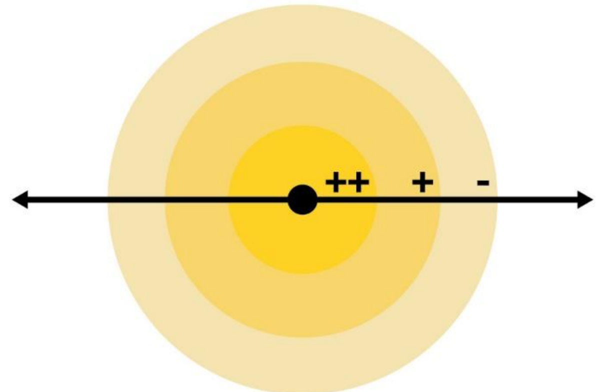
1.5. Building height around stop
Position taller buildings around transit stops and decrease height as distance increases. This contributes to pedestrian activity and ensures a landmark status for the area surrounding the stop.



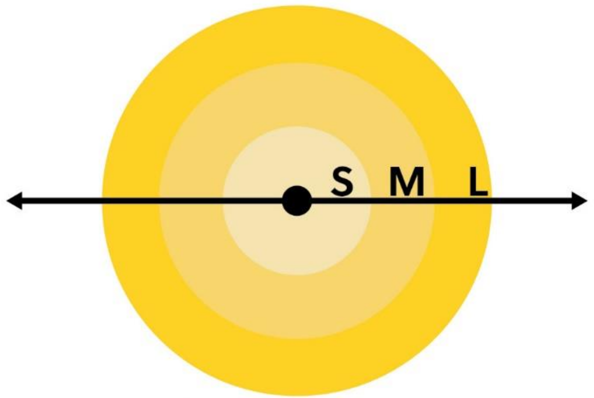
1.6. Minimum ground floor height
Provide a minimum ground floor height of 4 meters along the corridor as well as in other ground floors that contain services. This provides flexibility for use and contributes to the character of the area.



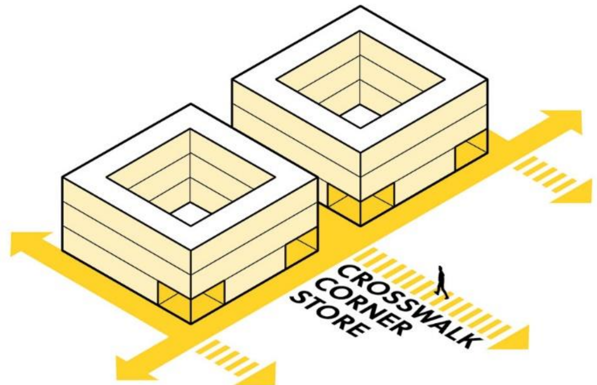
1.7. Building block dimensions
Shape building blocks so that the maximum width and length are between 60 and 90 meters. This prevents too large walking distances and ensures sufficient space for courtyards.



1.8. Service density
Decrease the amount of services as distance from the transit stop increases. Especially position services within the first 100 to 200 meters of the transit stop.



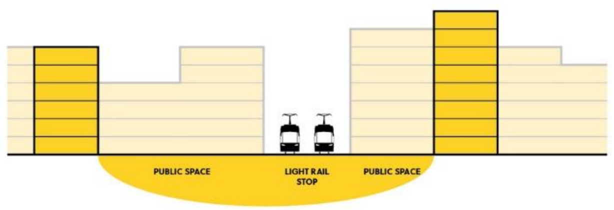
1.9. Service scale
Smaller services, such as restaurants and flower shops, have to be located in close proximity to the transit stop as these benefit most from pedestrian activity and contribute to the quality of ground floors. Larger stores can be located further away.



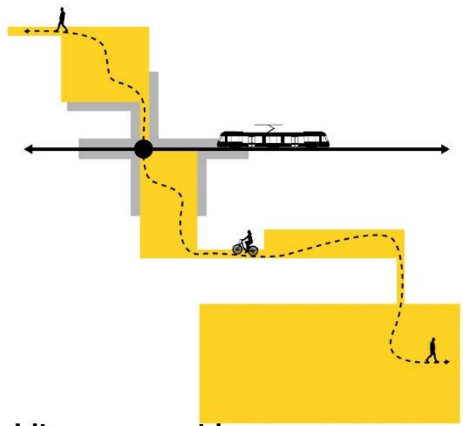
1.10. Crosswalk corner stores
The corners, especially those that align with crosswalks, form important points and should contain spaces for services as these are the most visible.

1.11. Parking garage ground floor
Larger parking facilities should contain an active ground floor and may serve as locations for larger commercial services, such as grocery stores. Part of the parking in the facility should be available for customers.

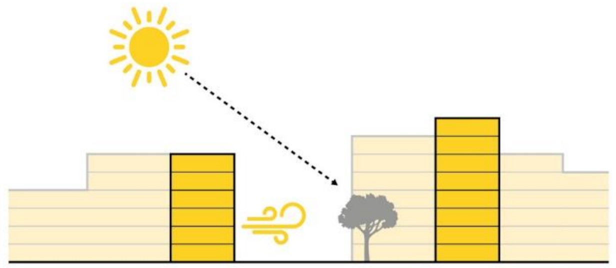
Place-making
2. Public spaces for human use



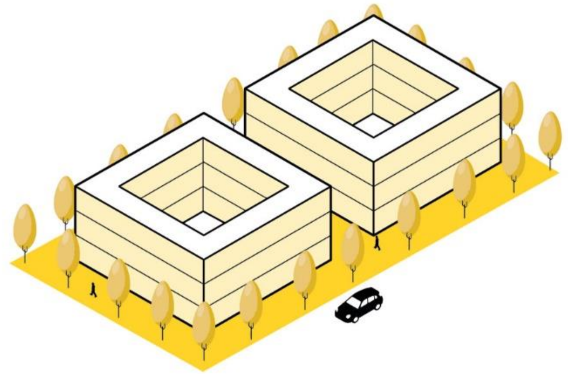
2.1. Public space around light rail stop
All larger transit stops should be connected to a public space, may it be a square or park. The public space serves as a gathering place, makes use of the pedestrian activity, and places public transit in a central role.



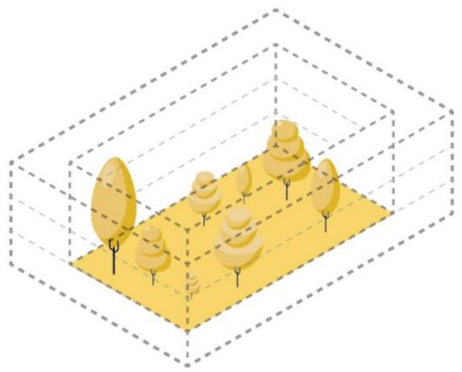
2.2. Public space corridor
Public spaces should be connected, creating a network for pedestrians and cyclists. The network can connect larger recreational areas, areas with commercial and public services, and the public transit stop.



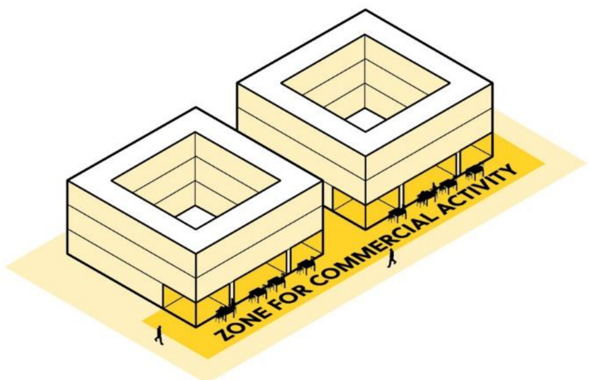
2.3. Comfortable microclimate
Locate and design public spaces so that there is a comfortable microclimate for the activity taking place. For example, reserve spaces for terraces at eastern or western facades and provide shade by placing trees.



2.4. Green streets
Create green streets by placing trees or other vegetation. The vegetation adds to the pedestrian experience but also serves a purpose in providing shade and preventing heat stress.



2.5. Green courtyards
Create green and lush courtyards for residents. Minimize the amount of parking decks under courtyards in order to make it possible to plant trees.

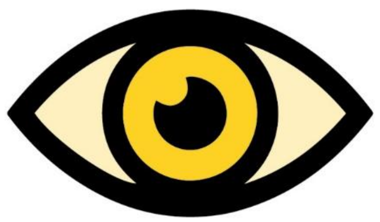


2.6. Hybrid zone
Create a hybrid zone in front of commercial spaces so that there is sufficient space for terraces, displaying products, or placing bicycle parking. Apply a minimum of 1,5 meter.

2.7. Prohibit motorized vehicles
Prohibit or limit the use and access of motorized vehicles in public spaces to make it more comfortable and safe for pedestrians and cyclists.

Place-making
3. Safety

3.1. Around the clock activity
Stimulate around the clock activity by providing a variety of services and comfortable public spaces, this is especially important around the transit stops. The pedestrian activity provides an improved feeling of safety.

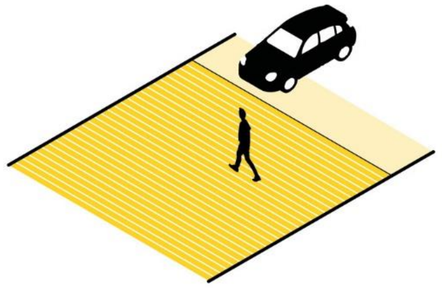


3.2. Eyes on the street
Create open facades with public and commercial services, and services for residents, such as common rooms, washing rooms, and bicycle parking. An open ground floor contributes the 'eyes on the street' concept.

3.3. Lighting
Provide sufficient lighting, especially in areas with a large amount of pedestrian activity.

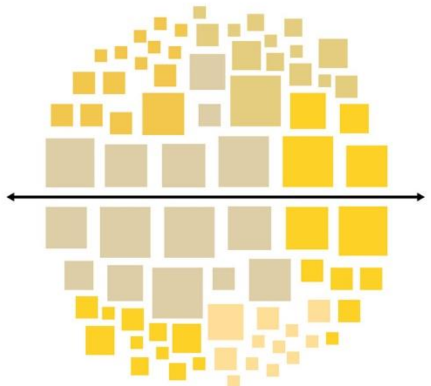
3.4. Limited driving speed
Limit the maximum driving speed for cars to 30 km/h. A lower driving speed helps reducing the amount of accidents and makes it possible to cross roads without crosswalks in the smaller streets.

3.5. Safe crosswalks
Provide wide crosswalks on the larger roads to slow down traffic and make safe crossing possible. The sides of the crosswalks should be easily visible and free of elements, such as parked cars or trees.

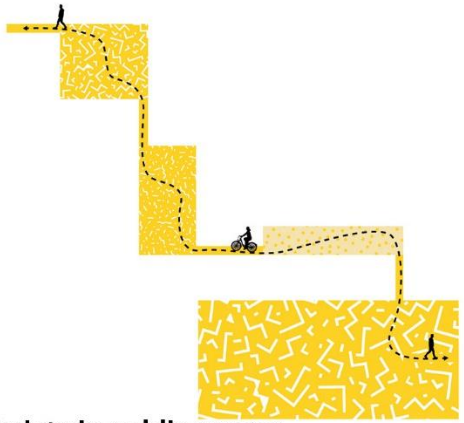


3.6. Changes in surface material
Implement changes in surface material where the role of the car changes. By changing the surface material, the car becomes a guest rather than the main user of the road and helps slowing down traffic.

Place-making
4. Variety and complexity

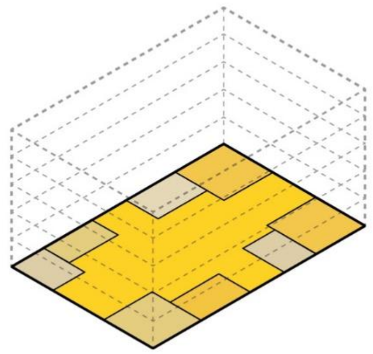


4.1. Neighborhoods with own identity
Create variety in the character of the different neighborhoods. This contributes to creating an ‘own identity’ and provides a more interesting urban environment.

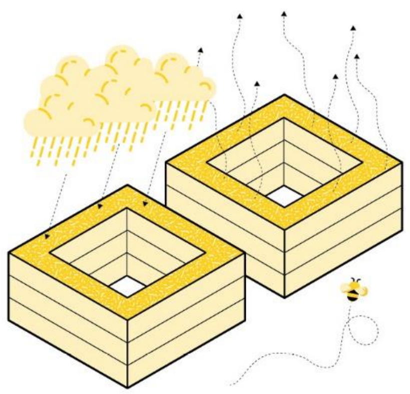


4.2. Variety in public spaces
Create public spaces with their own character. This contributes to creating an ‘own identity’ to the surrounding neighborhoods and provides a more interesting urban environment.

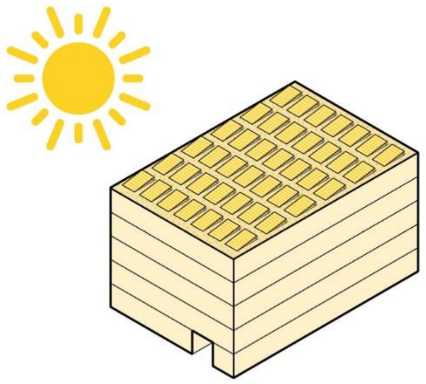
4.3. Variety in facades
Create a variety in facades by creating smaller building blocks and plots as well as providing similar guidelines in the guidelines of the detailed plan.



4.4. Placement of services
Locate smaller services so that they become visible in the ground floor, rather than larger services. This contributes to the variety and complexity of the ground floor and provides visibility to smaller services.



4.5. Green roofs
Implement vegetated roofs to the buildings. Vegetated roofs improve storm water management, reduce heat stress, insulate buildings, and contribute to biodiversity.

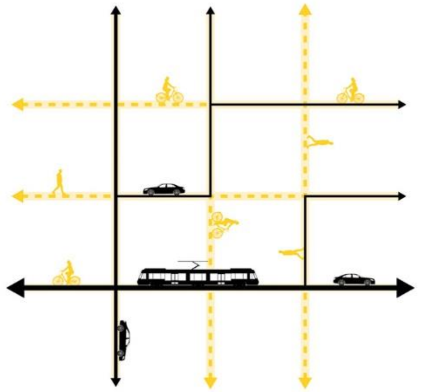


4.6. Solar panels
Implement solar panels, especially on larger roofs, to generate sustainable energy. The energy can, for example, be used to charge electric sharing bikes and cars.

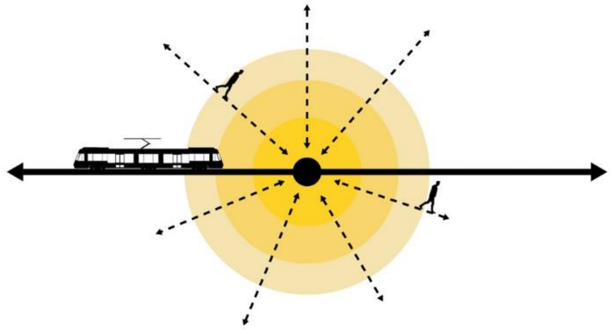
4.7. Reusable and sustainable materials
Make use of reusable or sustainable materials, such as brick or wood, in the construction of the buildings to reduce the amount of greenhouse gasses.

4.8. Freedom in architecture
Provide sufficient architectural freedom in the design of the buildings and stimulate innovation and new building techniques. Hand out plots to a large number of developers for more variation.

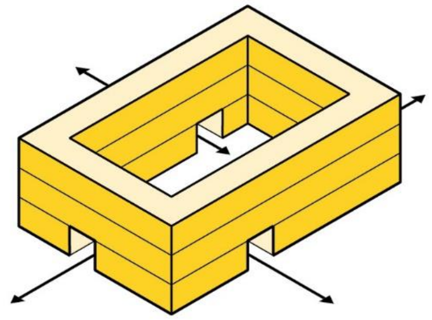
Place-making
5. Connections



5.1. Traffic network
Create a network that prioritizes connections for pedestrians and cyclists by cutting off motorized traffic. Reduce the amount of streets for cars without completely removing accessibility to individual building blocks.



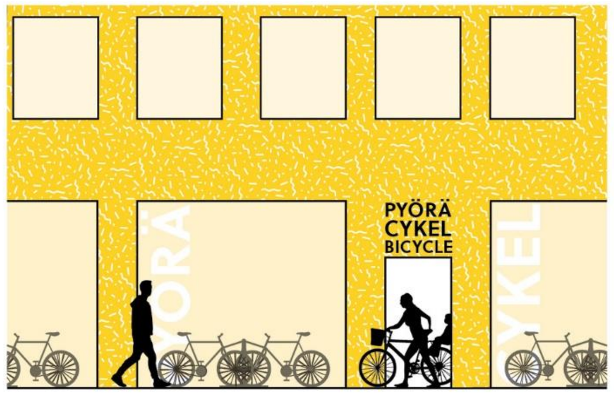
5.2. Transit stop as central point
Locate the transit stop so that it is easily accessible by pedestrians and becomes a central point in the neighborhood. The transit stop should form an important node in the pedestrian network.



5.3. Accessible building blocks
Create accessible building blocks to provide shortcuts for pedestrians and cyclists. This also contributes to the livability within the blocks.

Facilities/Logistics
6. Pedestrian/Cyclist orientation

6.1. Hierarchy in bicycle infrastructure
Implement safe bicycle infrastructure with a clear hierarchy. Connect important places with bicycle highways, locate separate bikeways along big roads, allow bicycles to use local roads, and create shared space where there is no motorized traffic.

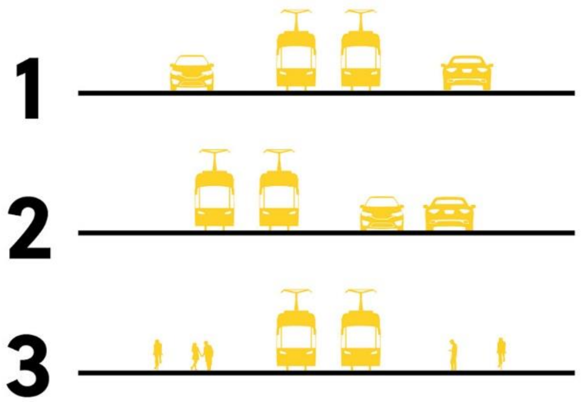


6.2. Residential bicycle parking
Provide sufficient residential bicycle parking. Locate the bicycle parking so that they are visible in the ground floor and, if possible, locate them so that they connect to non-motorized areas.

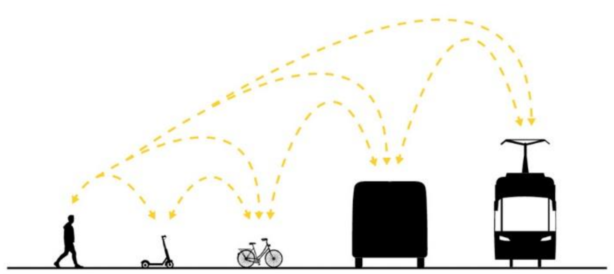
6.3. Sharing (cargo) bicycles
Implement a neighborhood (cargo) bicycle sharing program or implement the program used city-wide. Provide e-bikes for those who need additional support with cycling.

6.4. Wheelchair access
Ensure high quality wheelchair access to all ground floor facilities and public transit, making it easier for handicapped people to move through the area.

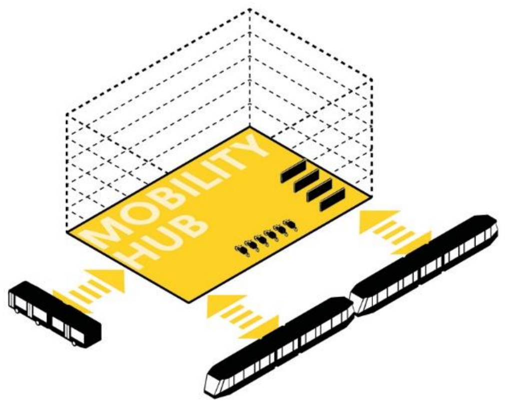
Facilities/Logistics
7. Transit in the urban pattern



7.1. Corridor layout
Select the right traffic layout for the main corridor and adjust functions and building blocks accordingly.



7.2. Stimulate multimodality
Stimulate multimodality by facilitating a multitude of modes of transport within the neighborhood so that it becomes easy to switch between them.



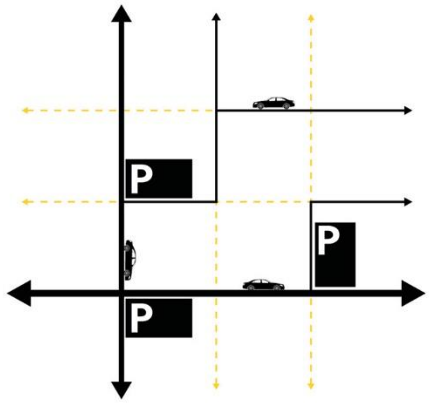
7.3. Mobility hubs
Implement mobility hubs in connection with transit stops throughout the neighborhood. The mobility hubs may differ in size and function depending on the importance of the stop.

7.4. Light rail stops as landmarks
Create a landmark status for every light rail stop. This can be done, for example, by construction canopies which also provide shelter from the weather. The stops may also contribute to the identity of the neighborhood.

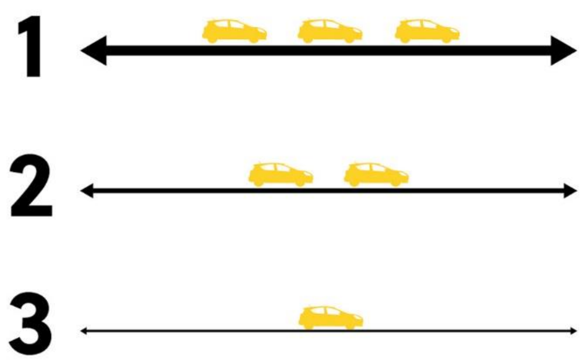
7.5. Autonomous transit
Prepare the infrastructure for autonomous transit in the future and use the neighborhood as a test site for smart mobility.

Facilities/Logistics
8. Car movement and parking

8.1. Centralized parking facilties
Create centralized parking facilities to prevent large surface parking lots and parking decks. The parking facilities may also be used for access to the services and should be flexible to be converted when demand for parking declines.

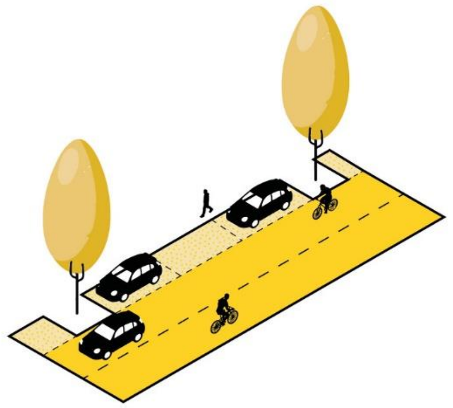


8.2. Parking facilties along main street
Locate the parking facilities in close connection to the main streets, reducing the need for driving through the smaller streets.

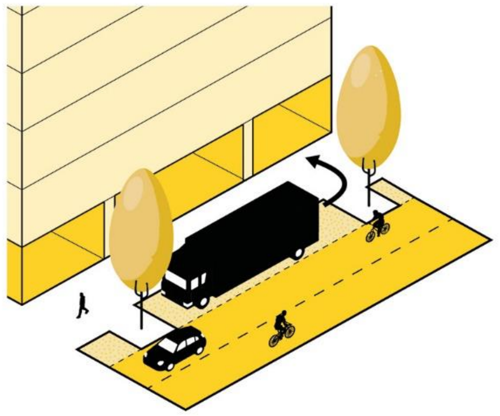


8.3. Hierarchy in car infrastructure
Create a clear hierarchy in car infrastructure, making it clear to the driver what role the car has in the street.

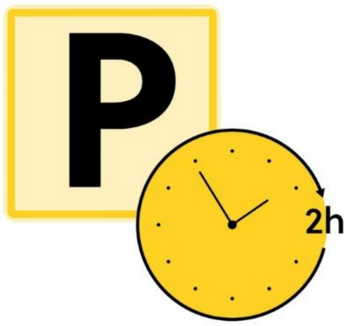
8.4. Shared cars
Implement a neighborhood car sharing program or implement the program used city-wide. Make use of electronic vehicles rather than traditional vehicles.



8.5. On-street parking
Provide, but limit, on-street visitor parking. Use porous surface materials, such as grass tiling, for the parking spaces, so that it contributes to the storm water system and the quality of the street.



8.6. Delivery access
Provide sufficient delivery spaces for commercial services in the streets to prevent complicated built solutions and blockage of sidewalks. Use the same surface material as is used in the other parking spaces.



8.7. Limited parking time
Limit the parking times for visitor parking. Decrease the maximum parking time closer to the services to direct visitors to the larger parking facilities.