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Promoting Sustainable Mobility in Urban Areas – the Role of Residential Parking

A Multiple Case Study of 13 Homeowner Associations in Gothenburg, Mölndal and Partille

Master's thesis in Design and Construction Project Management

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DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
DIVISION OF CONSTRUCTION MANAGEMENT

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ABSTRACT

A well-functioning transportation infrastructure that meets individual and societal mobility needs without relying on private cars is a critical component of the effort to create sustainable development in urban areas. Research shows that the availability of residential parking affects trip frequency, car ownership, mode preference and can potentially minimize private car use. In this setting, it is important for property owners to be considerate of factors that may affect residential car parking demand as well as resident's willingness to use more sustainable modes of transportation. Therefore, this thesis aims to examine the role of residential parking in the work to promote sustainable mobility in urban areas. To realize the aim, an analysis of the current parking situation at 13 homeowner associations in Gothenburg, Mölndal and Partille were conducted and combined with existing research on the topic. Various factors that are thought to influence residents' car and bicycle parking demand were examined.

We conclude that the resident's mobility condition affects their parking demand. The results indicate that high parking requirements, absence of carsharing, and relatively long travel time to city center by public transportation contributes to a higher residential car parking demand. Car parking located farther away from the residence as well as restricted car parking that only allows residents to rent one parking space per apartment can instead reduce the residential car parking demand. In terms of factors that influence residents' demand for bicycle parking, we observed that the bicycle parking demand increases when the residence is located relatively close to the city center, yet, most bicycle parking spaces are oversized.

To contextualize the results, the development of Backaplan was used were the findings from the study were theoretically implemented to generate recommendations on how the area's mobility can promote sustainable development. It is clear that residential parking plays an important role in the work to promote sustainable mobility. In future urban areas, such as Backaplan, residential parking should be located further away than other more sustainable modes of transportation in order to make private car ownership less appealing. As a consequence, public transportation should be closer to a residence than a car parking lot.

Key words: sustainable mobility, residential parking, parking requirement, mobility services, future car ownership

Främja Hållbar Mobilitet i Tätortsområden – Parkeringens Roll vid Flerbostadshus

En Fallstudie av 13 Bostadsrättsföreningar i Göteborg, Mölndal och Partille

Examensarbete inom Mastersprogrammet Organisation och Ledning i Bygg- och Fastighetssektorn

JENNY ANDERSSON

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SAMMANFATTNING

En väl fungerande transportinfrastruktur som tillgodoser individuella och samhälleliga mobilitetsbehov utan att förlita sig på privata bilar är en viktig del av arbetet med att skapa hållbar utveckling i stadsområden. Studier visar att tillgången på parkeringar vid flerbostadshus påverkar färdmedelsval samt resfrekvens och kan potentiellt minimera användningen av den privata bilen. I denna kontext är det viktigt för fastighetsägare att ta hänsyn till faktorer som kan påverka efterfrågan på parkering samt även de boendes vilja att använda mer hållbara transportsätt. Därför syftar denna studie till att undersöka parkeringens roll vid flerbostadshus i arbetet för att främja hållbar rörlighet i tätortsområden. För att förverkliga målet genomfördes en analys av den aktuella parkeringssituationen vid 13 bostadsrättsföreningar i Göteborg, Mölndal och Partille och kombinerades med befintlig forskning om ämnet. Olika faktorer som tros påverka invånarnas efterfrågan på bil- och cykelparkering undersöktes.

Vi drar slutsatsen att de boendes mobilitetförutsättningar påverkar deras parkeringsbehov. Resultaten tyder på att höga parkeringskrav, avsaknad av bilpool och relativt lång restid till stadens centrum med kollektivtrafik bidrar till en högre efterfrågan på bilparkering. Bilparkering som är placerad längre bort från bostaden samt begränsningar som endast tillåter boende att hyra en parkeringsplats per lägenhet kan istället minska efterfrågan på parkering. Gällande faktorer som påverkar de boendes efterfrågan på cykelparkering observerade vi att; behovet för cykelparkering ökar när bostaden ligger relativt nära stadens centrum, dock så är de flesta cykelrummen överdimensionerade.

För att kontextualisera resultaten användes utvecklingen av Backaplan. Resultaten har teoretiskt implementeras för att generera rekommendationer om hur områdets mobilitet kan främja hållbar utveckling. Det är tydligt att parkering för bostäder spelar en viktig roll i arbetet för att främja hållbar mobilitet. I framtida bostadsområden, såsom Backaplan, bör bostadsparkering placeras längre bort än andra, mer hållbara transportsätt, så att den privatägda bilen blir mindre attraktiv. Till följd av detta bör kollektivtrafiken vara närmare placerad ett boende än vad en bilparkering är.

Nyckelord: hållbar mobilitet, parkering vid flerbostadshus, parkeringstal, mobilitetstjänster, framtidens bilägande

Contents

Preface

This master's thesis has been the pinnacle of Chalmers University of Technology's master's program in Design and Construction Project Management. The study was conducted in collaboration with the housing company Riksbyggen.

We would like to thank everyone who have contributed to this research, especially our supervisors. First, we would like to express our gratitude to our supervisor at Chalmers University of Technology, Frances Sprei, for her unwavering support and invaluable guidance throughout the thesis process. Secondly, we would like to thank our supervisor at Riksbyggen, Charlotta Brolin, for the opportunity to write about this meaningful topic. This thesis would not have been possible without your time and resources.

Finally, we would like to thank Chalmers University of Technology for these rewarding and enjoyable five years. This education has provided us with invaluable experience and knowledge, and we are confident that it has laid a strong foundation for our future careers.

Gothenburg, May 2021

Jenny Andersson and Elin Nilsson

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Introduction

This chapter lays the foundation for the research subject by introducing the connection between sustainable mobility and residential parking and why it is a topic of interest. Further, the thesis's aim, research questions and delimitations are presented, as well as an ethical statement of the topic and the structure of the thesis.

1.1 Background

Mobility, movement, is fundamental to people's everyday life and to the functioning of societies and economies (Merriman, 2009). The use of private cars is at large the most dominant and preferred way to be mobile in a vast number of cities as it enables people to travel in a convenient and comfortable way (Kent, 2013). However, according to the European Commission (2019), it is necessary for travelers to have accessible, healthier and cheaper alternatives than the private car, as it is associated with global ecological, social and physical harm (Kent, 2013). Therefore, there is a need to shift emphasis to sustainable mobility and use modes of transportation such as cycling and public transportation, that are not as harmful to the environment.

Despite the fact that the car is parked for the majority of the day, most research has focused on its motion (Christiansen, Fearnley, Hanssen and Skollerud, 2016). The limited research that actually exists on parked cars mostly concern destination parking, meaning parking connected to work, shopping malls or downtown areas. However, several studies indicate that residential car parking has an effect on trip frequency, car ownership and mode choice, thus, parking is perceived as a vital tool for mobility management and needs to be further investigated (Sprei, Hult, Hult and Roth, 2020; Christiansen et al., 2016; Boverket, 2020).

In Sweden, The Planning and Building Act (PBL 2010:900) states that municipalities must ensure adequate parking for new construction of houses. This is typically accomplished by the municipalities establishing a parking requirement span, which refers to the amount of parking spaces appropriate for a property owner to construct. Gothenburg is one of the municipalities that works with flexible parking requirements, indicating that the developer can influence the amount of car parking spaces by providing other mobility services (Boverket, 2018a; Göteborgs Stad, 2019a). However, studies show that the current parking requirements are outdated and rarely correctly reflect the real need for parking. As a response, The Committee of Inquiry in Sweden (SOU 2021:23) proposes amendments to the The Planning and Building Act which states that the car and number of residential car parking spaces should not have a special position in legislation. It is suggested that the transportation system should meet the individual's and society's mobility needs without the use of private cars. Yet, Sweden has an increasing car dependence (Nykvist and Whitmarsh, 2008), indicating that the individual's and society's mobility needs might be heading towards an unsustainable direction. To break the trend and encourage the creation of future urban housing that facilitates sustainable mobility it's not just a matter of switching modes of transportation (Høyer, 2000); it is also a matter of evaluating what influences residents' choice of transportation.

In this setting, it is important for the property owners to assess what factors that can influence residents to use more sustainable modes of transportation. Riksbyggen is a co-operative association developing homeowner associations (Bostadsrättsföreningar) housing (Riksbyggen, 2019a). Riksbyggen plans to develop residential buildings in the Backaplan area in Gothenburg (Riksbyggen, 2019b). An area that will be densified since around 7,000 houses, utilities, offices and city trade will be developed within the next 20 years, which will involve challenges and uncertainties regarding future mobility (Göteborgs stad, 2019b). By studying factors that influence residents' demand for car and bicycle parking, property owners such as Riksbyggen could gain a better understanding of how to engage and encourage residents to choose more sustainable modes of transportation. Ultimately, designing future urban areas with measures that contribute to reduced car use and ultimately benefit the transition to sustainable mobility.

1.2 Aim and Research Questions

The aim of this thesis is to examine the role of residential parking in the work to promote sustainable mobility in future urban areas. In order to realize the aim, an analysis of the current parking situation at 13 homeowner associations is conducted to identify factors that influence parking demand disparities.

To fulfil and support the aim of the thesis, four research questions were established:

> *RQ1: How does the car and bicycle parking supply at the examined homeowner associations correspond to the residents' car and bicycle parking demand?*
>
> *RQ2: How does the car and bicycle parking demand at the examined homeowner associations correspond to the municipality of Gothenburg's current guidelines regarding car and bicycle parking?*
>
> *RQ3: How does the carsharing and bikesharing usage differ between the examined homeowner associations, and what factors influence usage?*
>
> *RQ4: How does the prerequisites for parking and mobility services in connection to residential buildings affect residents' car and bicycle parking demand?*

1.3 Delimitations

This thesis includes a case study of 13 homeowner associations developed by Riksbyggen in Gothenburg, Mölndal and Partille. All empirical data is therefore collected from these homeowner associations. Although some of these cases are located in surrounding municipalities, only Gothenburg's parking requirement guidelines are addressed in this study.

The study only examines parking connection with housing; thus, it will not consider parking in connection with service or other business. The parking spaces refers exclusively to car and bicycle parking that are confirmed to belong to a housing association and are intended for residents, not visitors.

Furthermore, this thesis in regard to the topic of sustainable mobility mainly address the ecological aspect.

1.4 Ethical Statement

The discipline of ethics deals with dilemmas of what is right and wrong as well as with moral responsibility and obligations (Merriam-Webster, 2021). According to Resnik (2020) it is of great importance to raise consciousness about ethical problems while conducting research. Considering this thesis' topic of sustainable mobility in a broader context, some ethical considerations need to be acknowledged.

An essential aspect of moving towards sustainable mobility is reducing people's private car use. Residential parking is perceived as a vital tool in promoting sustainable mobility as it is thought to influence private car ownership, trip frequency and mode choice. Using residential parking to influence and steer residents towards other forms of transportation possess ethical and moral concerns. It can be debated whether it is right to restrict people's mode choices as it can be argued that every individual should be able to make their own decisions on how to be mobile, rather than it being decided by municipalities or property owners. Although the intention is to encourage sustainable development, it should naturally not be done at any cost. Another consideration for the topic of this thesis is the technical knowledge that certain mobility services require. It may be considered unfair and unreasonable to force elderly to adopt this digitalization.

It is evident that the subject of sustainable mobility raises numerous ethical issues. The aftermath of this thesis is however considered beneficial for sustainable development rather than causing any harm, and the positive outcomes are perceived to outweigh the negative ones.

1.5 Structure of the Thesis

Chapter 1 – 'Introduction', lays the foundation for the research subject by providing a background to sustainable mobility and residential parking, as well as introducing the thesis aim, research questions and delimitations.

Chapter 2 – 'Theoretical Framework', aims to present existing research in the field of mobility and residential parking. The chapter establishes a theoretical framework which is applied to the analysis and discussion later on.

Chapter 3 – 'Methodology', describes how this thesis has been conducted by presenting the research process and research design. Further, the data collection and the data analysis are described. Additionally, an ethical consideration of the methodology and a reflection on the quality of study is presented.

Chapter 4 – 'Results: Multiple Case Study', presents the findings from the multiple case study.

Chapter 5 – 'Analysis and Discussion of Multiple Case Study', compares, analyses and discuss the findings from the multiple case study with support from the theoretical framework.

Chapter 6 – 'Applying the Result on the Development of Backaplan', aims to contextualize the findings from the multiple case study and the literature. To understand Backaplan's specific mobility conditions, the chapter begins with a background to the development.

Chapter 7 – 'Conclusion', answers the thesis research questions and presents suggestions for future studies.

2 Theoretical Framework

The aim of this chapter is to establish a theoretical framework that can be applied to the multiple case study and to the development of Backaplan. Initially, the concept of sustainable mobility is presented followed by a description of how residential parking can be used as a tool for limiting car use. Then, parking requirements in Sweden and Gothenburg are explained and alternative modes of transportation other than the private car is presented. Lastly, indications for future car use is reviewed.

2.1 Sustainable Mobility

The word mobility can refer to movement and the ability to physically move freely or to be easily moved (Cambridge Dictionary, 2021). Mobility in the context of this thesis is related to the transport sector, i.e. mobility in the form of transportation of individuals or goods in a society. Sustainable mobility is "a mobility in accordance with the principles and requirements of sustainable development" (Høyer, 2000). Sustainable development is defined by the World Commission on Environment and Development (1987) as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The concept of sustainable development emphasizes three fundamental components: social equity, environmental protection and economic growth.

Sustainable mobility can then be defined as “the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future” (World Business Council for Sustainable Development, 2004). In many cities, the use of private cars is the most dominant and preferred way to be mobile as it bridges distances and enables people to travel in a convenient and comfortable way (Kent, 2013). However, there is a prevailing consensus that the use of private cars needs to be limited (Khreis and Nieuwenhuijsen, 2016). The car is associated with global ecological, social and physical harm that requires urgent attention (Kent, 2013). The car emissions contribute to both air and noise pollution, as well as to global climate change by generating CO2. According to a report from IVA (2019), passenger cars in Sweden account for 67 percent of road traffic's carbon dioxide emissions.

Achieving sustainable development requires fundamental changes in behavioral patterns and consumption (Høyer, 2000). To achieve sustainable mobility, it is therefore not enough with technological progress, technical measures and environmentally friendly vehicles, it takes more than switching between different modes of transport (Høyer, 2000).

2.2 Residential Parking as a Tool for Limiting Private Car Use

As every car journey starts and ends in a parking space (Gunnarsson-Östling, 2020) and since the car is parked 95 percent of the time on average (Shoup, 2018), parking policies can be an effective way to influence people’s travel behavior. Residential parking has an effect on trip frequency (Sprei et al., 2020), car ownership (Christiansen et al., 2016; Sprei et al., 2020) and mode choice (Boverket 2020; Sprei et al., 2020), thus, a vital tool for mobility management and limiting car use. According to a study conducted in Norway where residents were questioned about their parking arrangements, Christiansen et al., (2016) found a positive relationship between parking availability and car ownership. People who have access to an owned or reserved parking space are three times more likely to own a car than those who do not. The study by Christiansen et al., (2016) also states that longer distances between home and residential parking substantially lower the car's modal share in favor for walking and public transportation. Respondents stated they could consider a maximum distance of 155 meters between their home and car parking on average. The cost for renting a parking space is another factor influencing people's travel behavior (Ostermeijer, Koster and van Ommeren, 2019). A study conducted in the Netherlands showed that the cost for parking space in the city center is four times higher than in the periphery, accounting for about 30% of the disparity in total car ownership rates between these areas (Ostermeijer et al., 2019).

2.3 Car Parking Requirement in Sweden

In Sweden, guidelines from the municipalities govern the number of residential parking (Boverket, 2018b). The Planning and Building Act (PBL 2010:900) states that municipalities must ensure suitable space for parking for new construction of houses. This is usually done by setting a parking requirement which states the number of parking spaces that is required for new construction and rebuilding. The parking requirement is specified as the amount of parking spaces per apartment or per 1000 m2 gross floor area. The property owner is primarily responsible for securing space for parking, but the municipality is obliged by the law to ensure that the parking requirement is met before granting a building permit.

Sweden has since the 1950s used minimum parking requirements, meaning that municipalities mandate property owners to provide a minimum amount of residential car parking spaces (Johansson and Henriksson, 2018). Minimum standards remain the norm for residential car parks in both European and U.S. cities (Guo and Li, 2014). However, studies show that these requirements are outdated and rarely correctly reflect the real need for parking (Antonson, Hrelja and Henriksson, 2017; Fastighetsägarna, Hyresgästföreningen and Naturskyddsföreningen, 2020; Christiansen et al., 2016; Guo and Li, 2014). Additionally, as a way of competing for tenants, property owners can intentionally oversupply parking and can therefore help generate a demand instead of satisfying a need that exists (Guo and Li, 2014).

In an interview study with five property owners in Södertälje, everyone agrees that they generally want to build less car parking than what the municipality's minimum requirement states (Envall and Nissan, 2013). Criticism has also been leveled at the fact that parking cost for car owners is subsidized by non-car owners in new building projects (Envall and Nissan, 2013; Boverket, 2018b). Bundling the cost of parking spaces into the cost of development can be seen as an injustice between car owners and non-car owners. In terms of actual construction costs for parking spaces, Malmö Stad (2020) states that the monthly costs for one car parking space are 140 SEK for ground parking, 1200 SEK for parking facilities and between 1850-2500 SEK for underground car parks. Naturally, the costs are approximately and varies depending on factors such as location.

2.3.1 Parking Requirements in Gothenburg

As a response to the outdated minimum parking requirements, several municipalities, Gothenburg included, have started using flexible car parking requirements (Boverket, 2018a). Flexible parking requirements indicate that the developer can be involved and influence the amount of car parking spaces. Providing mobility services that facilitate alternative modes of transport and reduce the need for car ownership for the residents, can result in the developer being allowed to build fewer parking spaces than the minimum policy requires.

Göteborgs Stad's (2019a) report *Guidelines for mobility and parking in the city of Gothenburg* provides recommendations for appropriate mobility measures in Gothenburg, including the flexible car parking requirements. These guidelines ensure that mobility assessments are handled in similar and appropriate ways. The work process for deciding the car parking requirements for residential buildings (minimum of three apartments) in Gothenburg follows four steps resulting in a project specific solution for mobility measures, and the amount of parking spaces to be provided.

The first step determines which standard parking span should form the basis for the assessment of the parking requirements per apartment. Gothenburg is divided into five zones (A-E) with different requirements and the geographical location therefore determines in which span the assessment will originate, see Figure 1. The standard span's upper value serves as the starting value for the following steps.

Figure 1. Normal span for parking requirements for residential building in Gothenburg. Adapted from Göteborgs Stad (2019a).

The subsequent three steps can adjust the parking requirement per apartment that is set in step one. The regulation can vary based on the zone the residential building is located, illustrated in Figure 2.

	Analysis step 1	Analysis step 2		Analysis step 3	Analysis step 4	
Zone	Starting value	Large district center	Situation assessment	Project specific conditions	Basic	Star
A	0,5	→	→↘ 0,05	↗↔↘ 0,05	→↘ 0,05	→↘ 3x 0,05
B	0,6	→	→↘ 0,05	↗↔↘ 0,05	→↘ 0,05	→↘ 3x 0,05
C	0,8	↘ 0,05	→↘ 0,1	↗↔↘ 0,05	→↘ 0,05	→↘ 3x 0,05
D	1,0	↘ 0,1	→↘ 0,1	↗↔↘ 0,1	→↘ 0,05	→↘ 3x 0,05

Figure 2. Gothenburg parking requirements and potential deductions and additions for residential buildings. Adapted from Göteborgs Stad (2019a). The authors' own translation.

The second step regards a situation assessment where the specific area around the building is evaluated in more detail with emphasis on the areas' weighted accessibility to public transportation, services, bicycle infrastructure and other urban activities. For the zones C and B, deduction can be given if the building has a direct proximity to a large district center. The third step concerns the project specific conditions where the assessment is focused on, for example, the distribution of the apartments and the potential for shared use of parking spaces.

The fourth step is a voluntary offer to the property owner to further reduce the parking requirement. The property owner can provide the residents with mobility services that reduce the need for a private car. This step requires an agreement between the property owner and the municipality of Gothenburg which is included in the building permit application and remains in effect until the municipality determines that the steps are helping to accelerate the transition to sustainable transportation. The measures are implemented by the property owner, but it is the housing cooperatives or tenants' associations responsibility to ensure that the mobility services are monitored and evaluated.

Set measures for mobility solutions can be found in the guidelines in two different packages, the basic-package and the star-package, see Figure 2. Within the basic package, all eight measures must be implemented to achieve a deduction of 0.05 on the project's parking requirement. There are fourteen measures in the star-package where seven of them are marked with a star. These are more demanding than in the basic-package and provide strong incentives for sustainable travel. Deductions through the star-package are given in three steps and can first be given if the developer has met the requirements for the basic package. If the developer performs all measures in the basic package and six measures from the star package, where at least three are marked with a star, a full deduction of 0.2 is given, see Figure 2. There is also an opportunity within the star package for developers to come up with their own incentives that can reduce the car use for tenants. It is then the municipality of Gothenburg that assesses whether the measure can be regarded as a star measure.

2.3.2 Zero Parking Requirement

For a new residential building in zone A in Gothenburg, the lowest parking requirement a developer can achieve is 0.2 (Göteborgs Stad, 2019a). However, it is possible to reduce the parking requirement to zero. The City of Gothenburg has guidelines if a new residential building can be granted a zero parking requirement, for example that the project comprises a maximum of 30 apartments and that the developer provides the basic package with mobility measures. Yet, several municipalities have launched pilot projects of so-called car-free housing, in which parking guidelines are ignored and other mobility measures are assumed to fully replace the need for residential parking (Romson, Ivansson and Holm, 2020). The research project HOA Viva in Gothenburg is an example of this, where there are no parking spaces offered to the residents (Olsson Jeffery, 2021).

Romson et al., (2020) speculates about the long-term effects and what the potential outcome of a car-free residential area could be. Mobility measures may contribute to residents not having their own car. According to a survey conducted by Lund (2020), where 27 residents at HOA Viva answered questions regarding their travel behavior, the average car ownership in HOA Viva is 0.18 cars per person. The corresponding figure for Gothenburg as a whole was 0.28 cars per person in 2018, indicating that the car ownership in Viva is significantly lower than the average (Lund, 2020). However, an additional outcome of a car-free residence could be that residents have their cars parked in the immediate vicinity of the residence such as on the street or in a car park. The survey conducted by Lund (2020), found that slightly more than half of those questioned drive their own car at least 2-3 times a month and park it on the street near HOA Viva.

2.4 Alternative Modes of Transportation other than the Private Car

The most common way to achieve reduced parking requirements for developers or housing owners is to offer different mobility services to the residents, principally various forms of bicycle measures and carsharing (Hult, 2017). Tickets for public transportation is another measure (Göteborgs stad, 2019a). Additionally, physical locations that connect a variety of transportation modes, so called mobility hubs, are essential in order to facilitate more environmentally friendly modes of transportation (Schemel, Niedenhoff, Ranft, Schnurr and Sobiech, 2020). The subsequent chapter will further describe the bicycle as transportation mode, carsharing, public transportation and mobility hubs.

2.4.1 The Bicycle

Many of the detrimental consequences of car usage, such as greenhouse gas emissions, traffic collisions, lack of physical activity, social inequality and lack of accessibility, can be remedied by cycling (Martens, 2007). The city of Gothenburg's ambition is that cycling will triple by 2025 compared to 2011, and that the city will be seen as bike-friendly by three out of four people (Trafikkontoret, 2017). Statistics from Trafikkontoret (2020) show that bicycles account for 9% of daily travel in Gothenburg, while the car accounts for 48%, public transport for 24% and pedestrians for 19%.

According to a study conducted by Cykelfrämjandet (2020), cyclists in Gothenburg are dissatisfied with the city's current bicycle infrastructure, especially in terms of protection and accessibility.

One study from Malmö explored cyclists' needs and preferences in three residential areas located in Malmö (Andersson, 2017). By conducting a survey, the author found that the research population preferred indoor bicycle storage compared to outdoor bicycle parking as the perception of security was higher and the risk of theft was deemed lower by the participants.

2.4.1.1 Bicycle Parking Requirement in Gothenburg

Göteborgs Stad’s (2019a) report *Guidelines for mobility and parking in the city of Gothenburg* also includes recommendations for appropriate bicycle parking requirements. The work process for deciding the bicycle parking requirements for residential buildings in Gothenburg follows three steps; the standard span, situation assessment and project specific conditions. The bicycle parking requirements starting point is 2.5 parking spaces per apartment if the apartments have an average size distribution, which means that 55 percent are one- or two-bedroom apartments and 15 percent are at least four-4-bedroom apartments. This applies to all residential buildings in Gothenburg with more than two apartments, regardless of the zone the building is located in.

In step two, the parking requirements can increase if the car parking spaces connected to the building are limited and/or if the location provides good conditions for cycling. However, the parking requirements can be reduced if the conditions for accessing the building with a bicycle is poor and there is no possibility for improvement. In step three, the parking number for bicycles can be increased if a predominant part of the apartments are large. If a predominant part of the apartments are small, the parking number can be reduced. According to the guidelines, a property owner can achieve a minimum parking requirement of 2.0 per apartment and a maximum of 3.0, however guest parking is not included.

2.4.1.2 Bikesharing

Bikesharing is an example of “sharing economy”, indicating an economic system with the fundamental idea of people sharing services or possession, for money or for free, by using the internet for organizing (Cambridge Dictionary, 2019). Bikesharing implies shared use of a bicycle fleet where individuals can use bicycles on an on-demand and temporary basis (Shaheen, Guzman and Zhang, 2010). This enables people to cycle without worrying about storage, parking, high purchase costs or maintenance costs (Shaheen et al., 2010). Developers or housing owners can offer bikesharing to their residents to achieve reduced car parking requirements, bicycle fleets that may consist of both “ordinary bicycles” or “special bicycles” such as cargo bicycles (Göteborgs Stad, 2019a).

Despite the fact that several studies have been devoted to evaluating bikesharing, evidence on the benefits are still limited (Teixeira, Silvia and Moura e Sá, 2020). There are some arguing that bikesharing can compete with the car and decrease its modal share, and that bikesharing through synergies with other modes of transportation, such as public transportation, can to some extent replace the car (Teixeira et al., 2020).

2.4.2 Carsharing

Just like bikesharing, carsharing is an example of "sharing economy" and implies people to temporarily and locally rent a car on an on-demand basis (Münzel, Boon, Frenken, Blomme and van der Linden, 2019). Carsharing enables individuals to use a car when needed, and throughout one day, several different members can have access to a shared-used car (Martin, Shaheen and Lidicker, 2010). Carsharing differs from traditional car rental as it does not require pick up at a rental station and it differs from vehicle leasing since leased cars are not being shared on a daily basis (Frenken, 2013). Developers in Gothenburg can decrease the parking requirement by providing incentives and prerequisites for carsharing (Göteborgs stad, 2019a).

Offering carsharing for residents may result in reduced need for private car ownership (Vaca and Kuzmyak, 2005; Martin et al., 2010). There are studies indicating that carsharing can reduce household car ownership with between 40 to 60 percent (Vaca and Kuzmyak, 2005). A study by Martin et al. (2010) suggests that carsharing members in North America minimized their car ownership from 0.47 vehicles per household to 0.24 by switching to carsharing. The shift from owning a car to instead using carsharing was most seen in one-car households. Furthermore, since you pay as you go and the costs are linked to use, carsharing implies variable costs, which can encourage people to limit their driving (Vaca and Kuzmyak, 2005). The variable cost carsharing implies may also be a reason why carsharing is generally not used for commuting or for full days of renting as it becomes too expensive (Martin et al., 2010). Indicating that households that require a car for trips or commuting will most likely own a vehicle regardless of access to carsharing (Martin et al., 2010). Likewise, findings from a study done in Sweden shows that carsharing is more of a complement to the existing private car use rather than replacing it (Bocken, Jonca, Södergren and Palm, 2020).

Vaca and Kuzmyak (2005) questions if carsharing will really influence individuals' travel behavior on a large scale, since carsharing is mainly attractive to those who rarely drive cars. Additionally, the idea of sharing economy is more appealing to younger people (Rudmin, 2016; Benoit, Baker, Bolton, Gruber and Kandampully, 2017). Older people appear to be less willing to change their driving behaviour and seem to find it more difficult to use digital applications of carsharing platforms (Rudmin, 2016). Likewise, a survey conducted in London, Paris and Madrid showed that people under the age of 45 are much more likely to use car sharing services (Prieto, Stan, Baltas and Lawson, 2019). Further, a study conducted in Seoul showed that carsharing demand is larger in areas with a higher proportion of young residents in their 20s and 30s (Kang, Hwang and Park, 2016). To help promote carsharing usage, the study also suggests that carsharing should utilize city owned public parking facilities. However, according to the The Committee of Inquiry in Sweden (SOU 2020:22) there is currently no legal support in Sweden for leaving carsharing vehicles parked on public property.

2.4.3 Public Transportation

There is a significant body of research on public transportation, indicating its importance in terms of sustainability, especially the economic and ecological dimension, but also in terms of social sustainability (Stjernborg and Mattisson, 2016). Thus, public transportation can generate benefits to societies and is an important mode of transport to create mobility (Stjernborg and Mattisson, 2016). According to Redman, Friman, Gärling and Hartig (2012) public transportation together with walking and cycling is a more sustainable option to the use of private cars. As carsharing generally is not used for full days of renting (Martin et al., 2010), public transportation is also an alternative for daily work commuting. Tickets for public transportation is a mobility service that developers or property owners can offer to their residents (Göteborgs Stad, 2019a). Residents can receive one free public transportation card per apartment, valid either 30, 90 or 365 days. The purpose is to establish a habit among the residents to use public transportation as well as to make car ownership feel redundant as the residents have gotten their collective travel paid for. Studies show that if residents want to continue to use public transport and invest in a mobility tool such as a season ticket, it is a significant financial investment and therefore a powerful incentive to actually use that mode instead of the car (Loder and Axhausen, 2018).

Weinberger (2012) argues that if residents' parking requirement is generous, people tend to use the car for destinations that are relatively well integrated with public transport. In addition, the study by Loder and Axhausen (2018) states that if the provision of public transport is good and comparatively more accessible than the car as a mode of transport, the likelihood of car ownership is reduced. The study by De Gruyter, Truong and Taylor (2020), found that it is more necessary to consider the supply of public transport (frequency and quality) rather than the distance to transit. According to a study conducted in the Netherlands, the travel time of public transportation compared to alternative modes has a significant impact on its market share (CE Delft, 2018). For example, when the travel time by public transportation is twice as long as by car, the public transportation market share drops under 30%. When the travel time by public transportation is 1.5 times higher than when travelling by car, the public transportation market share instead grows to over 60%.

2.4.4 Mobility Hubs

The concept of mobility hubs is described by Schemel et al. (2020) as a physical place that connects and provides a variety of transport modes (such as bikesharing, carsharing, public transportation, information, charging and bike repair) as well as acting as a seamless interchange between the different modes of transportation. According to Schemel et al. (2020), Mobility hubs are essential in order to meet the current as well as the prospective mobility demand, while also facilitating the transition to a low-carbon transportation system. By providing alternative mobility modes in combination with the hub's design and location, the hub can nudge people to change their travel behavior. In comparison to other less environmentally friendly modes of transportation, mobility hubs can make environmentally friendly modes easier, more convenient and more appealing.

2.5 Mobility as a Service

Mobility as a Service, or MaaS, is a recently emerged mobility concept that has the potential to be a game-changer when it comes to how people travel and conceive mobility (Storme, De Vos, De Paepe and Witlox, 2020). The concept is defined by Hietanen (2014) as a distribution model for transportation services that merges various available mobility services and transport modes (such as bikesharing, carsharing, public transportation and taxi) into a single mobility package. The key idea of MaaS is to offer tailored mobility solutions based on travelers' individual needs, through a single digital interface (Hietanen, 2014), with the aim to improve and smoothen the users' everyday travel (Storme et al., 2020). The desired outcomes from MaaS are according to Butler, Yigitcanlar and Paz (2021) associated with increased trip awareness, enhanced social equity, reduced distance traveled, reduced parking and reduced vehicle ownership. The emergence and development of MaaS is also an important driving force for increased use of carsharing (Boyer, Schnurr and Andersson, 2020). Likewise, Storme et al. (2020) describes that, as MaaS claims to decrease private car ownership, it promotes vehicle sharing and multimodality as well as more active travelling such as walking and cycling. Hence, MaaS can contribute to solving environmental issues such as carbon emissions and air pollution, and to a transition towards a more sustainable mobility system. There is however limited research on how and to what extent MaaS will affect future car use and car ownership (Liljamo, Liimatainen, Pöllänen and Viri, 2021).

Liljamo et al. (2021) tries to fill the gap by investigating how public transportation, MaaS and automated vehicles can impact car ownership in Finland, as well as how people's willingness for car ownership may change in the future. According to the findings, 58 percent have no need or do not want to own a car if MaaS is available, hence, implementation of MaaS may result in decreased car ownership. In addition, the study concludes that new mobility systems such as MaaS need to meet people's mobility requirements while offering economic benefits to decrease car ownership. There are however those who differ in opinion. Storme et al. (2020) points out that expectations regarding the future use of MaaS often lack sufficient empirical support and nuance as they are pitched by commercial organizations or are think pieces. Their study instead suggests that it cannot be assumed that MaaS will radically reduce car distance travel and car ownership. The results rather indicate how MaaS could be a complement to a private car and not a substitute, thus, MaaS could potentially have an effect on individuals' travel behaviour and potentially even generate additional car trips.

The pilot project HOA Viva is currently offering a MaaS concept to their residents' where a number of different mobility services, such as public transportation, carsharing and bikesharing, are compiled in an application (Lund, 2020). In addition to the application, the concept also includes personal counselling, support and campaigns to help the residents find the best possible mobility solution. The overall aim with MaaS at HOA Viva is to create a simple and flexible alternative to private car ownership that covers the residents' everyday travel needs. According to Smith (as cited in Olsson Jeffery, 2021) the MaaS concept at HOA Viva helped the residents accept that there was no residential parking. Additionally, those who still own a private car at HOA Viva need to park a distance away from the residence, this inconvenience made them interested in the mobility services included in the MaaS concept.

MaaS has only been operated as pilot projects in Sweden, but there are plans for commercializing MaaS applications (Boyer et al., 2020). It is however hard to predict at what rate MaaS to a greater extent will develop and establish in Sweden since it according to Arby (as cited in Olsson Jeffery, 2021) depends on factors such as quality, easy operation for the consumer, value for money and the working business models. Implementing MaaS on the Swedish market does also require great changes in both behavior and infrastructure as well as innovation in several areas (Olsson Jeffery, 2021). Additionally, Arby (as cited in Olsson Jeffery, 2021) points out that it is hard to distinguish between long-term and short-term trends right now, as the ongoing pandemic most certainly will have long-term effects.

2.6 Indications for Future Car Use

The residences developed today and in the near future are expected to last a long time, thus, the design must suit the future. Developing an underground car park with a certain number of car parking spaces may become unsustainable if car ownership declines and they are not fully utilized. Particularly because, when not in use as a garage, residential underground car parks typically have a limited area of use (Broere, 2016). As a result, future indications of both parking policies as well as people's travel behavior must be considered when developing new residential houses.

2.6.1 Residential Parking

In policy terms, Gothenburg has set an ambitious goal to reduce CO2 emissions by 16% each year in order to fulfil Västra Götaland's part of the Paris Agreement (Anderson, Schrage, Stoddard, Tuckey and Wetterstedt, 2019). An efficient transportation system is seen as a prerequisite for achieving societal goals, such as economic growth and sustainable development (Regeringskansliet, n.d). Hence, it is important to look at alternatives to the car as a mode of transport rather than car usage. Also referring to Sweden's goal to reduce greenhouse gas emissions from the transport sector by at least 70 percent between 2010 and 2030, and to become climate neutral by 2045 (Kungl. Ingenjörsvetenskapsakademien, 2019).

To facilitate an efficient transportation system, The Committee of Inquiry in Sweden (SOU 2021:23) has recently presented a report that proposes amendments to the The Planning and Building Act (PBL 2010:900). As mentioned, The Planning and Building Act (PBL 2010:900) states that the Swedish municipalities must ensure suitable space for parking for new construction of houses. The new report suggests that the car should not have a special position in legislation and that it is not necessary for each plot to have a certain number of parking spaces available. Instead should carsharing, bikesharing, infrastructure for home deliveries and other forms of mobility solutions be within reach for the residents. The main purpose should be to meet the individual's and society's mobility needs, instead of focusing on the amount of parking spaces that new construction requires. Implementing this new proposal can entail decreased costs for the residents, developers and municipalities as well as larger land areas can be used for greenery and housing. Additionally, positive effects of the proposal include reduced environmental impact, better use of the existing infrastructure and that the need for passenger and goods transport can be kept at a lower level.

2.6.2 Travel Behaviour

While the climate goals call for a shift to more sustainable modes of transport, it is necessary to study people's needs for a car and thus residential parking, as well as future indicators of how this might change. Envall and Nissan (2013) conclude that the parking solution must consider that the residents' needs as well as travel behavior may change character over time. Car ownership is growing in Sweden, demonstrating a trend towards higher car dependence (Nykvist and Whitmarsh, 2008). According to a study, this increase is largely due to the fact that the proportion of households with two cars is increasing (Trafikanalys, 2015).

It is hard to predict what the future may hold in regard to the future of mobility. Achieving sustainable mobility takes, just as Høyer (2000) argues, more than just switching between different modes of transport. When the car was first introduced it did not take long until it dominated the transportation market, as the transition from horse to car a century ago went fairly rapidly (Nakicenovic, 1986). Sprei (2017) claims in her article that the socio-technical system surrounding the car today is a more complicated, indicating that the transition from private car ownership to more sustainable options is harder to achieve in comparison to the evolution of the car. According to Sprei (2017) technological advancements are not enough in order to meet the citizen mobility needs. To eradicate the dominant private car ownership, the alternatives must create a transportation system that can guarantee sufficient mobility and accessibility. Also, an integral part of this transition is change in travel behavior (Banister, 2008).

3 Methodology

This chapter aims to describe how this study has been conducted in order to answer the research questions and includes the research process, research design, data collection, data analysis, ethical consideration of methodology and a reflection of the quality of the study.

3.1 Research Process

The topic of sustainable development and residential parking in this master thesis was originally proposed by Riksbyggen. The authors who contributed equally to the study explored the subject further. The main method employed in this thesis is a multiple case study where the findings are applied on the development of Backaplan. A literature review was initially carried out in order to establish a relevant foundation of expertise. This chapter delves further into how the process was carried out.

3.1.1 Literature Review

The literature review was conducted to establish a theoretical background to the subject of sustainable mobility and residential parking as well as to provide context to the development of Backaplan. It also aims to identify and generate knowledge about the existing research in the field (Rowley and Slack, 2004). The literature review began prior to the planning phase of the thesis and proceeded in parallel with the multiple case study, as it aimed to systematically complement the results from the studies with conceptualized meaning (Dubois and Gadde, 2014).

3.1.2 Multiple Case Study

A multiple case study is a valuable source of reference for building on existing literature (Bryman and Bell, 2015). The multiple case study is suitable as it is well-suited for information-rich cases (Yin, 2009) and allows understanding of the cases similarities and differences (Baxter and Jack, 2008). The aim of the multiple case study is to build theoretical premises that serve as a tool for making assertions regarding circumstances similar to the ones being studied (Yin, 2013).

The multiple cases study consists of 13 homeowner associations, further referred to as HOAs, developed by Riksbyggen in Gothenburg, Mölndal and Partille, see Table 1. The cases were selected by Riksbyggen due to their geographical spread and recent development, see Figure 3. All HOAs are located in urban areas, meaning coherent settlements with at least 200 inhabitants (SCB, 2020), thus the conditions regarding service and activities have been assumed to be the same. Data was collected regarding the HOAs parking supply and occupancy as well as their mobility prerequisites.

Table 1. The 13 homeowner associations examined.

Tuve	Sannegården	Eriksberg	Munkebäck	Guldheden	Mölndal	Partille
Ljuspunkten Ljusglimten (+55)	Akterspegeln Kajutan	Salteriet Albertina	Munkebäcksäng Munkebäckslund (+55)	Viva	Tigeröga Grandalia Rosenrot (+55)	Kronhöjden

The cases are located relatively close to each other within the examined areas. Three of the cases are Riksbyggens' concept for senior housing, Bonum. The apartments in these associations can only be owned by people over the age of 55 thus named "+55" (Bonum, 2019).

The result from the multiple case study is presented in Chapter 4.

3.1.3 The Development of Backaplan

To contextualize the findings from the literature review and the multiple case study and understand how to promote sustainable mobility in urban areas, the results were applied on the development of Backaplan where Riksbyggen plans to develop residential buildings. Backaplan has similar conditions as the cases in the multiple case study since Backaplan is located in an urban area, see Figure 3. Also, the area aims contribute to a more sustainable society by not promoting the car as the main mode of transportation (Sundberg and Mattsson, 2019). The collected literature on the development of Backaplan laid the groundwork for how the findings could be applied to the area's specific conditions. The implementation aims to generate recommendations on how the area's mobility can promote sustainable development.

The background to the development of Backaplan and the mobility recommendations are presented in Chapter 5.

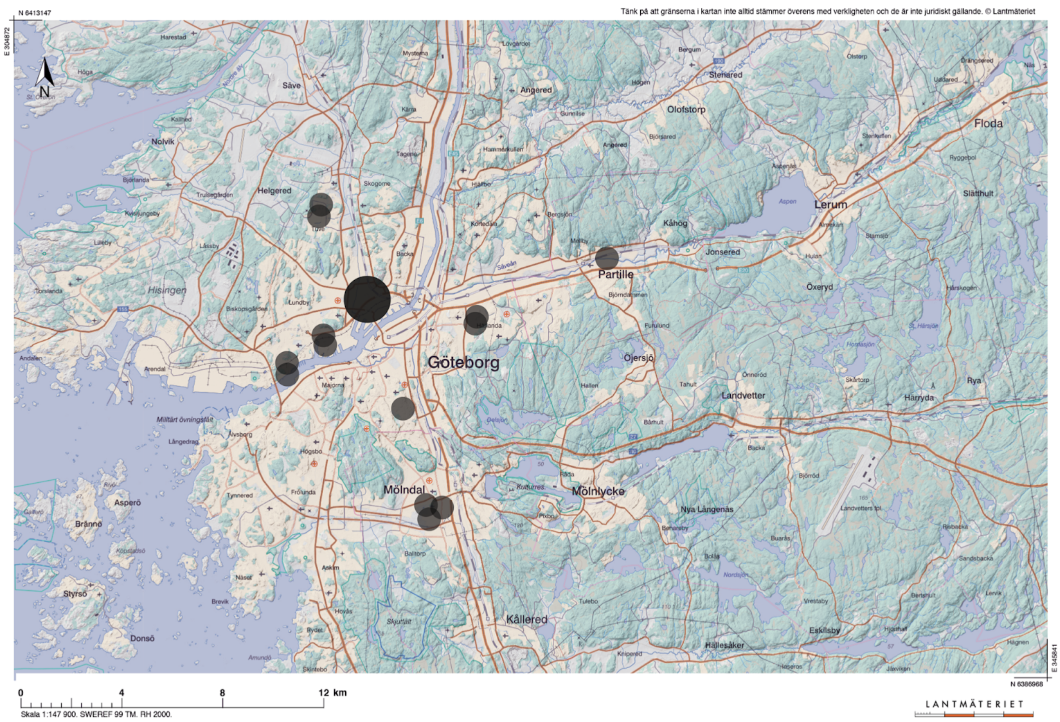

Figure 3. Map of the HOAs examined. The big dot represents where the development of Backaplan will be located. ©Lantmäteriet (2021).

3.2 Research Design

This thesis has a mixed method research design, meaning a combining of qualitative and quantitative approaches (Creswell, 2006). According to Bryman and Bell (2015), quantitative research is characterized by collecting information, transforming it into data, comparing it and then interpreting the results of the analysis. Embracing a quantitative research approach can be seen as a prerequisite in the multiple case study as it seeks to contrast the cases. Applying the results on the development of Backaplan has a more qualitative approach since it aims to create a deeper understanding of a specific area (Björklund and Paulsson, 2014).

The quantitative results from the multiple case study were analysed and contextualized through a qualitative approach when applying the results on the development of Backaplan. According to Creswell (2006), this is one of the benefits of mixed methods since it enables researchers to answer questions that are difficult to explain if you only used one approach. Saunders, Lewis, and Thornill (2016) also claim that mixed methods may enable the generalizability of a study. The mixture of the two different approaches can be seen as embedding one dataset into the other, as illustrated in Figure 4, meaning that the data in the multiple case study have a supportive role when analysing the development of Backaplan (Creswell, 2006).

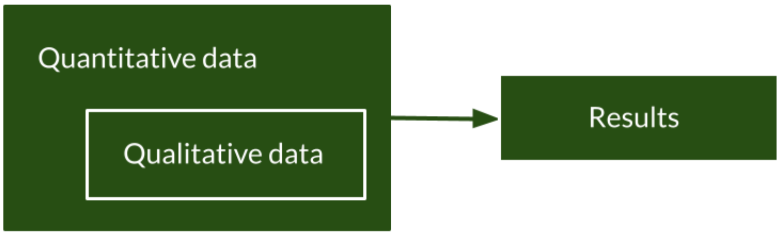

Figure 4. Illustration of mixed method with embedded qualitative data. Adapted from Creswell (2006).

The mixed method research design is well suited as it allows a combination of both inductive and deductive thinking (Creswell, 2006). Therefore, this study has an abductive approach, meaning that the progression of the study moved back and forth between literature and empirical data (Bryman and Bell, 2015).

3.3 Data Collection

The data of this study consists of both primary and secondary data. Some empirical findings are made from observations, indicating primary data that is collected for the purpose of being used in this study (Björklund and Paulsson, 2014). However, the majority of the literature as well as the empirical findings are obtained from secondary data, such as literature and documents that have been produced for an aim other than this study (Björklund and Paulsson, 2014). Using secondary data creates more time for data analysis and new interpretations of the results (Bryman and Bell, 2015). Additionally, the use of multiple data sources improves the reliability of results as well as conclusions (Antonson et al. 2017).

3.3.1 Literature Review

Scientific publications, books, reports and student literature gathered from electronic databases such as Google Scholar, Scopus and Chalmers library website, as well as from Chalmers library, were included in the literature review. Several search keywords were used in research databases to develop knowledge of theoretical concepts. Keywords such as *sustainable mobility, parking requirements, future car ownership* and *mobility services.*

3.3.2 Multiple Case Study

The multiple case study consists of collecting case specific descriptive parameters which are illustrated in Table 2. The parameters are collected through secondary data, observations and by estimations of travel times. The same parameters were collected from all HOAs to allow comparison.

Table 2. Explanation of descriptive parameters.

Descriptive parameters	Explanation
Year of moving in	The year of which the residents moved in
Number of apartments	Number of apartments at each HOA
Apartment sizes	Apartment sizes stated as number of rooms
Number of car parking spaces	Number of available car parking spaces for the residents
Monthly cost for parking	The monthly fee for renting a car parking space
Residents queuing for parking	Number of residents in queue for car parking
Number of bicycle parking spaces	Number of available indoor bicycle parking spaces for the residents
Available mobility services	Available mobility services at each HOA
Mobility services usage and utilization rate	Number of bookings, unique users and to what extant the mobility services are used in relation to their availability
Number of Bicycles observed	The number of bicycles observed in the HOAs indoor bicycle parking
Travel time to the city by car	Travel time from the HOAs to the city center of Gothenburg by car
Travel time to the city by bike	Travel time from the HOAs to the city center of Gothenburg by bike
Distance to public transportation	The distance in meter to the nearest public transportation stop
Travel time to the city by public transportation	Travel time from the HOAs to the city center of Gothenburg by public transportation

3.3.2.1 Secondary Data

The descriptive parameters that were gathered through secondary sources are listed in Table 3, as well as the source from which they were obtained.

Table 3. *Source from which the descriptive parameters were obtained.*

Descriptive parameter	Obtained from
Year of moving in	Riksbyggen
Number of apartments	Riksbyggen
Apartment sizes	Buildings permit documents from Gothenburg's city planning office
Number of car parking spaces	Riksbyggen
Monthly cost for car parking	Riksbyggen
Residents queuing for car parking	Riksbyggen
Number of bicycle parking spaces	For the HOAs in Gothenburg: Buildings permit documents from Gothenburg's city planning office For the HOAs in Mölndal: the detailed development plan from the city of Mölndal's website For HOA in Partille: Unable to obtain
Available mobility services	Riksbyggen
Mobility service usage and utilization rate	Carsharing and bikesharing companies

3.3.2.2 Observations

Bicycle parking observations were done on site at six of the HOAs, selected by Riksbyggen. Table 4 presents the HOAs were observations were conducted as well as the time and date of the observations. The observations aimed to get a perception about the current bicycle supply and demand. The HOAs property managers were contacted to make the site visits and observations possible.

Table 4. Location, time and date for the bicycle parking observations.

Descriptive parameter	Done at	Time and date
Number of bicycles observed	HOA Kajutan	8:00 a.m., 2021-03-19
	HOA Akterspegeln	8:10 a.m., 2021-03-19
	HOA Albertina	8:20 a.m., 2021-03-19
	HOA Ljusglimten (55+)	9:20 a.m., 2021-03-19
	HOA Ljuspunkten	9:40 a.m., 2021-03-19
	HOA Viva	10:40 a.m., 2021-03-22

Merely HOAs with a year of move-in that was no later than 2017 were included in the observations for bicycle parking. To only include certain HOAs in the observations was initiated by Riksbyggen as it was considered that the bicycle rooms in the newly moved in associations would not be sufficiently established among the residents. HOA Ljuspunkten is an exception to this, since the year of moving in was 2018. HOA Ljuspunkten were included since it is located directly next to HOA Ljusglimten, and Riksbyggen deemed it interesting to compare those two since one of them is a 55+ housing. HOA Viva was also an exception since it was finished in 2019. HOA Viva is a pilot project and Riksbyggen considered it interesting to compare HOA Viva's parking situation with the other associations.

3.3.2.3 Estimated Travel Time

Table 5 presents how the travel times to the city center of Gothenburg were estimated by car, bicycle and public transportation.

Table 5. Measured distances and tools for estimation.

Descriptive parameter	Distance	Measure tool
Travel time to the city by car	HOA to Nordstan's parking garage	Google maps directions tool
Travel time to the city by bicycle	HOA to Brunnsparken	Google maps directions tool
Distance to public transportation	HOA to nearest stop	Google maps directions tool
Travel time to the city by public transportation	HOA to Brunnsparken or Nordstan	Västtrafiks planning tool

The travel time by public transportation is based on the route that generated the shortest travel time.

3.4 Data Analysis

The multiple case study had a comparative design when the data collected were analysed, meaning that the cases were studied in more or less identical ways (Bryman and Bell, 2015). First, case descriptions were created by compiling the collected descriptive parameters into tables. Secondly, further descriptive parameters were generated by simpler calculations to interpret the collected data.

The *parking requirement* for both car and bicycle are calculated by dividing the number of available parking spaces that belongs to a HOA by the number of apartments, see (1). To evaluate how much of the parking space that is actually used, the *parking occupancy rate* is calculated by dividing the number of occupied parking spaces by the number of available parking spaces, see (2). An estimation of the resident's *car parking demand* is formulated, where the number of residents in queue for a parking space is added to the number of occupied parking spaces and divided by the number of sold apartments, see (3). An estimation of the *bicycle parking demand* is also developed at the six HOAs where bicycle parking observation was done. The estimation considers the number of bicycles observed in the storage area divided by the number of sold apartments, see (4). The estimated car and bicycle parking demand enables an understanding of the resident's actual need for parking. Additionally, the transportation demand depends on the number of users, in this case the number of residents in each HOA. As the number of residents living in each association is unknown, an *average apartment size* is calculated in order to perform a more reliable study, see (5).

Parking requirement: $$\frac{Number\ of\ available\ parking\ spaces}{Number\ of\ apartments} \quad (1)$$

Parking occupancy rate: $$\frac{Number\ of\ occupied\ parking\ spaces}{Number\ of\ available\ parking\ spaces}\ x\ 100\% \quad (2)$$

Estimated car parking demand: $$\frac{Number\ of\ occupied\ parking\ spaces + queue}{Number\ of\ sold\ apartments} \quad (3)$$

Estimated bicycle parking demand: $$\frac{Number\ of\ bicycle\ observed}{Number\ of\ sold\ apartments} \quad (4)$$

Average apartment sizes: $$\frac{Apartment\ sizes}{Number\ of\ apartments} \quad (5)$$

Third, working hypotheses were set up and tested in order to get an idea of potential patterns that transcends the cases. Hypothesis testing is a common method in quantitative research studies aiming to conduct statistical analyses and processing (Bridgmon and Martin, 2012) and includes comparing data with various statements of prediction and assumptions (Trochim, 2006). Additional tables were then compiled based on the hypotheses, yet the disposition is reorganized for a better structure. Lastly, any correlations and constant associations derived from the findings were discussed and reflected upon with support from the theoretical framework.

3.5 Ethical Consideration of Methodology

According to Bryman and Bell (2007), the representation of primary data findings should be done in an honest way, meaning that no misleading data is illustrated. The reporting of data is done with integrity and honesty. No personal information has been managed to protect the residents' privacy. The purpose of gathering information has always been clarified when requesting it. Individuals who provided the data are kept anonymous and are not presented in the study. Additionally, the authors declare no financial support from any organization for the submitted work.

3.6 Quality of Study

According to Björklund and Paulsson (2014) validity, reliability and objectivity are the three measures to ensure credibility of a study and must always be considered. Validity refers to the absence of either methodological or systematic errors. Reliability implies to what degree the measuring instruments are operationally accurate and if the same values would be obtained if the study was repeated. Objectivity refers to which extent values have affected the research. To ensure credibility, the cases, methods, and results have all been described and handled in the most transparent, truthful, and equitable manner possible to verify the study's authenticity. When no clear connections have been confirmed in the analysis, it has been considered scientifically just as important and has been included in the study.

However, the authors are aware of possible deficiencies in the thesis. The study mainly consists of secondary data, meaning that the information might be biased or not completely comprehensive (Bryman and Bell, 2015). When reviewing literature, it is not always established which method has been used and how information and data has been collected. Nor is it always justified for what purpose the information has been collected. Although the collected data was controlled, the figures did vary depending on the sources, implying margins of error. The travel time and distances are approximate, and the actual travel time may depend on factors such as time of day or current traffic situation. Also, the time for observations of bicycle rooms had to be adapted to property managers at the respective HOA. Making further observations at various times of the day may have increased the study's validity and reliability. For example, conducting an observation during the day and another during the evening to be able to draw a conclusion on how much bicycles are actually used. Furthermore, the study did not consider that residents have bicycles elsewhere than in bicycle storage.

Additionally, the data collection was carried out during the covid-19 pandemic, which has affected residents travel behavior (Göteborgs Stad, 2021). If data were collected under normal circumstances with no restrictions, such as no traveling and working from home, a more complete result could be obtained. Therefore, caution is required when interpreting the findings from the multiple case study.

4 Results: Multiple Case Study

The following chapter presents the result from the multiple case study, consisting of 13 homeowner associations, HOAs, located in Gothenburg, Mölndal and Partille.

4.1 Case Specific Prerequisites

Table 6 presents an overview over the examined HOAs.

Table 6. Overview of the HOAs.

Area	Homeowner Association	Year of moving in	Number of apartments	Average apartment size
Tuve	Ljuspunkten	2018	72	2.6
	Ljusglimten (55+)	2017	47	3.0
Sannegården	Akterspegeln	2015	85	2.6
	Kajutan	2017	22	2.5
Eriksberg	Salteriet	2018	61	2.6
	Albertina	2016	89	2.4
Munkebäck	Munkebäcksäng	2020	79	2.6
	Munkebäckslund (55+)	2020	66 (of which 15 are not sold)	2.9
Guldheden	Viva	2019	132	2.3
Mölndal	Tigeröga	2018	26	1.6
	Grandalia	2019	69	2.4
	Rosenrot (55+)	2018	50	2.8
Partille	Kronhöjden	2019	74 (of which 1 is not sold)	2.7
Average	-	-	67	2.5

4.2 Case Specific Car Parking Situation

Table 7 presents the collected and calculated data regarding the HOAs car parking.

Table 7. The HOAs car parking situation.

Area	Homeowner Association	Number of parking spaces	Cost for paring/month	Parking requirement	Parking occupancy rate	Residents queuing to parking	Estimated parking demand
Tuve	Ljuspunkten	58	800 SEK	0.8	100% to underground car park, 33% to ground parking	15 queuing to the underground car park	1.0
	Ljusglimten (55+)	30	800 SEK	0.6	100%	5	0.7
Sannegården	Akterspegeln	55	1100 SEK	0.6	100%	8	0.7
	Kajutan	14	1100 SEK	0.6	57%	0	0.4
Eriksberg	Salteriet	47	1100 SEK	0.8	100%	26	1.2
	Albertina	59	1100 SEK	0.7	100%	38	1.1
Munkebäck	Munkebäcksäng	42	1100 SEK	0.5	100%	8	0.6
	Munkebäckslund (55+)	46	1100 SEK	0.7	87%	0	0.8
Guldheden	Viva	-	-	-	-	-	-
Mölndal	Tigeröga	5	1250 SEK	0.2	100%	0	0.2
	Grandalia	45	1250 SEK	0.7	67%	0	0.3
	Rosenrot (55+)	40	1250 SEK	0.8	60%	0	0.5
Partille	Kronhöjden	60	950 SEK	0.8	100% to underground car park and 25% to parking deck	5 queuing to underground car park	0.6
Average	-	42	1075 SEK	0.7	-	-	0.7

The column in Table 7 named "number of parking spaces" refers to all of the parking spaces that belong to each HOA. All associations offer parking spaces in an underground car park. HOA Akterspegeln and HOA Kajutan share an underground car park, located under HOA Akterspegeln. The residents at HOA Kajutan must exit the building and walk approximately 60 meters to their car parking. Furthermore, when residents of Mölndal's HOAs moved in, they were only allowed to rent one parking space per apartment. Three of the HOAs offer additional parking options. Residents of HOA Ljuspunkten have access to additionally 10 ground parking spaces, and residents of HOA Kronhöjden have access to 20 parking spaces on a parking deck situated approximately 300 meters away. Residents of HOA Albertina have the possibility to rent parking spaces at Eriksbergsdockan's garage nearby through an external company. Furthermore, the users of the additional parking spaces in HOA Ljuspunkten and HOA Albertina are not considered as residents queuing for the underground parking spaces. However, at HOA Kronhöjden, the five residents who occupy the additional parking spaces are known to represent the five residents in the queue for the underground parking spaces.

4.3 Case Specific Bicycle Parking Situation

Table 8 presents the collected and calculated data regarding the HOAs bicycle parking.

Table 8. The HOAs bicycle parking situation.

Area	Homeowner Association	Number of bicycle parking spaces	Parking requirement	Number of bicycles observed	Parking occupancy rate	Estimated bicycle parking demand
Tuve	Ljuspunkten	215	3.2	56	26%	0.8
	Ljusglimten (55+)	126	2.7	36	29%	0.8
Sannegården	Akterspegeln	100	1.2	89	89%	1.0
	Kajutan	41	1.7	28	68%	1.3
Eriksberg	Salteriet	126	2.1	-	-	-
	Albertina	111	1.2	72	65%	0.8
Munkebäck	Munkebäcksäng	127	1.6	-	-	-
	Munkebäckslund (55+)	124	1.9	-	-	-
Guldheden	Viva	268	2.0	95	35%	0.7
Mölndal	Tigeröga	NA	1.5	-	-	-
	Grandalia	NA	1.8	-	-	-
	Rosenrot (55+)	NA	2.0	-	-	-
Partille	Kronhöjden	NA	NA	-	-	-
Average	-	138	1.9	63	52%	0.9

There is one thing worth noting regarding the HOAs bicycle parking; during the observation of the bicycle storage room it was revealed that some of the HOAs have had burglary issues in the bicycle storage rooms. At HOA Viva, there have been thefts that has included electric bicycles and associated batteries (C. Brolin, personal communication, March 22, 2021). At HOA Akterspegeln, notes where attached to the bicycle storage room with warnings about thefts.

4.4 Case Specific Travel Times to City Center

Table 9 presents the estimated travel times from the HOAs to the city by car, bicycle and by public transportation.

Table 9. Travel times to the city center.

Area	Homeowner Association	Travel time to the city by car	Travel time to the city by bike	Distance to public transportation (nearest stop)	Travel time to the city by public transportation
Tuve	Ljuspunkten Ljusglimten (55+)	15 min	29 min	50 m (Tuve centrum) 100 m (Tuve centrum)	22 min
Sannegården	Akterspegeln Kajutan	10 min	11 min with ferry or 17 min over Göta Älv bridge	200 m (Sannegårdshamnen) 150 m (Sannegårdshamnen)	13 min
Eriksberg	Salteriet	13 min	19 min with ferry or 25 min over Göta Älv bridge	220 m (Bockkranen)	21 min
	Albertina	11 min	18 min with ferry or 24 min over Göta Älv bridge	150 m (Eriksbergsdockan)	20 min
Munkebäck	Munkebäcksäng Munkebäckslund (55+)	8 min	16 min	200 m (Ättehögsgatan)	16 min
Guldheden	Viva	14 min	12 min	350 m (Doktor Fries torg)	13 min
Mölndal	Tigeröga Grandalia Rosenrot (55+)	13 min	27 min	400 m (Mölndals innerstad) 300 m (Mölndals innerstad) 350 m (Mölndals innerstad)	21 min
Partille	Kronhöjden	13 min	31 min	220 m (Partille centrum)	12 min
Average	-	12 min	21 min (based on the fastest option)	220 m	18 min

4.5 Case Specific Mobility Services

Table 10 presents the collected data regarding the HOAs available mobility services.

Table 10. Available mobility services.

Area	Homeowner Association	Mobility service
Tuve	Ljuspunkten Ljusglimten (55+)	- -
Sannegården	Akterspegeln Kajutan	- -
Eriksberg	Salteriet Albertina	- -
Munkebäck	Munkebäcksäng Munkebäckslund (55+)	Carsharing: Shares 2 vehicles
Guldheden	Viva	Carsharing: 3 vehicles Bikesharing: 5 electric bicycles 3 electric cargo bicycles Service room
Mölndal	Tigeröga Grandalia Rosenrot (55+)	Carsharing: Shares 3 vehicles Free public transportation card
Partille	Kronhöjden	-
Average	-	-

As shown, 6 out of 13 HOAs offer mobility services. All six HOAs offer carsharing, HOA Viva also provides various bicycle services, and the HOAs in Mölndal provide public transportation cards. The carsharing at HOA Munkebäcksäng, HOA Munkebäckslund, and HOA Viva is provided by the same company, while the HOAs in Mölndal are supplied by a different carsharing enterprise. The free public transportation cards in Mölndal entails one 365-day period ticket per apartment, valid in Gothenburg and surroundings.

4.6 Mobility Service Usage

As presented in Table 10, the HOAs in Munkebäck, HOA Viva and the HOAs in Mölndal offers a variety of mobility services. The data gathered regarding the use of these services is presented in the following section.

4.6.1 Carsharing

Figure 5 presents the number of bookings for a carsharing vehicle in the HOAs Munkebäcksäng, Munkebäckslund and Viva. The statistics for HOA Viva are from the time period 2020-05-01 - 2021-03-31, while the statistics for the HOAs in Munkebäck are from the time period 2020-10-01 - 2021-03-31. In addition, Figure 6 presents the number of unique users each HOA has during the same time period.

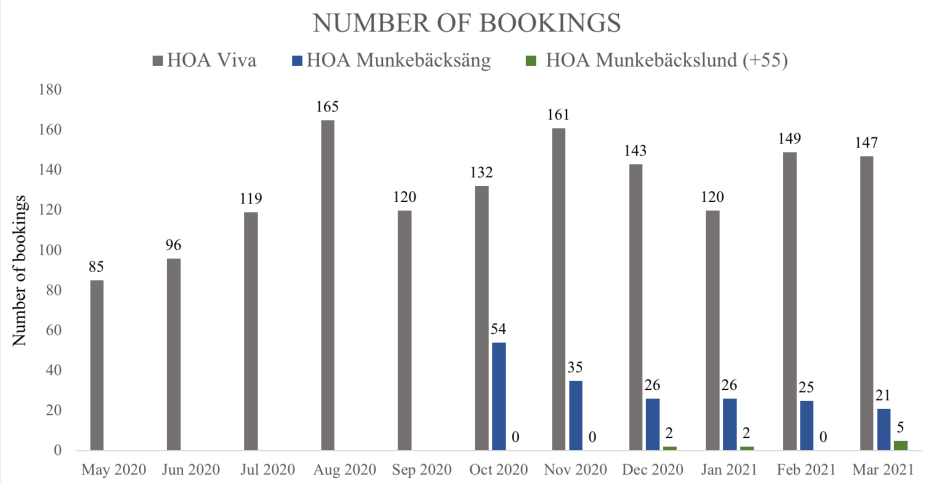

Figure 5. Number of bookings for a carsharing vehicle.

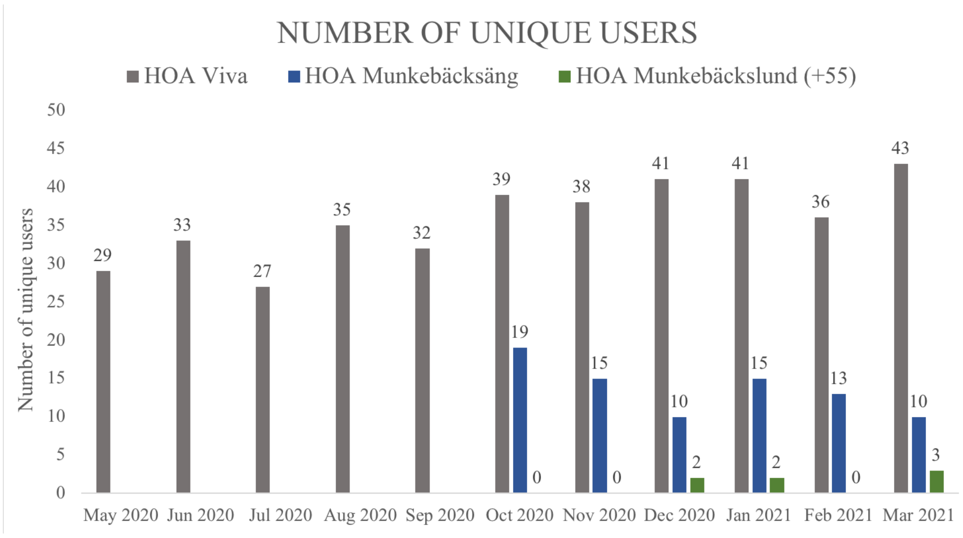

Figure 6. Number of unique users of carsharing.

Regarding the carsharing usage at the HOAs in Mölndal, there is no data available for the number of bookings or number of unique users. Table 11 presents the number of residents that have signed up for carsharing, i.e. members connected per HOA

Table 11. Signed up residents for carsharing at the HOAs in Mölndal.

Area	Homeowner Association	Number of residents signed up for carsharing
Mölndal	Tigeröga	1
	Grandalia	3
	Rosenrot (55+)	6

4.6.2 Bikesharing

Figures 7, 8, 9 and 10 below present the monthly electric bikesharing and the electric cargo bikesharing usage at HOA Viva during the time period 2020-05-01-2021-03-31. Figure 7 presents the monthly number of bookings for electric bikesharing as well as monthly number of unique users. Figure 8 presents the monthly number of bookings for electric cargo bikesharing at HOA Viva together with the number of unique users. Figure 9 depicts the average monthly utilization rate for electric bikesharing, which indicates to what extent the electric bicycles are used in relation to their availability. Lastly, Figure 10 shows the average monthly utilization rate for the electric cargo bicycles.

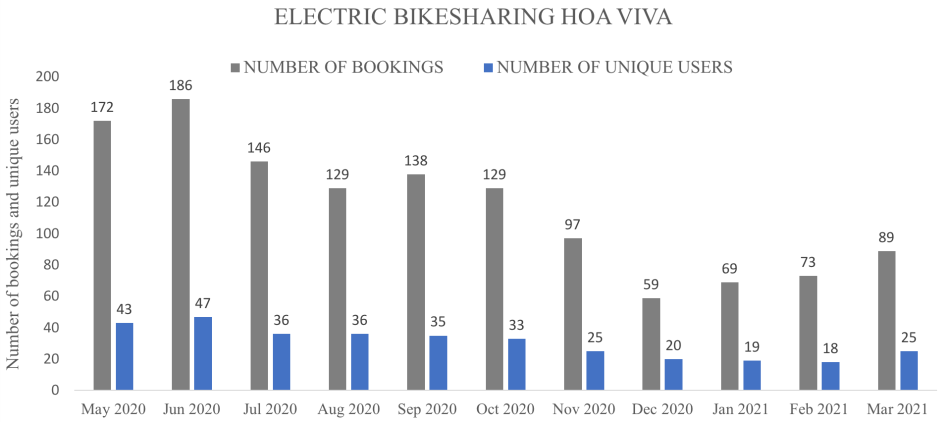

Figure 7. Electric bikesharing at HOA Viva.

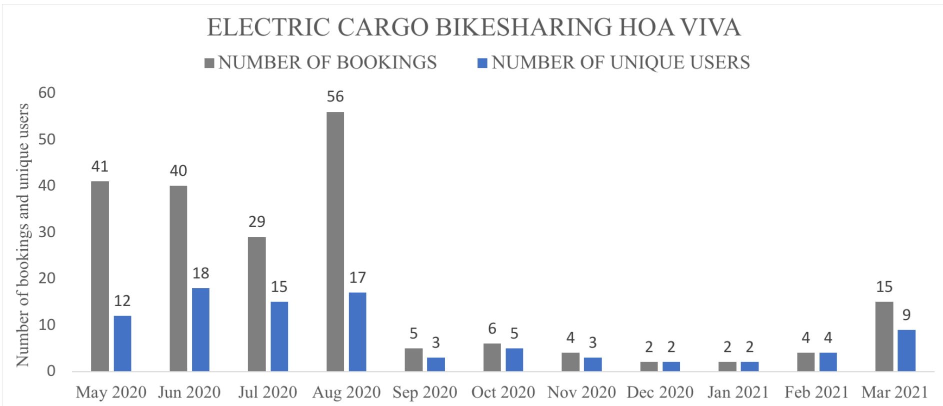

Figure 8. Electric cargo bikesharing at HOA Viva.

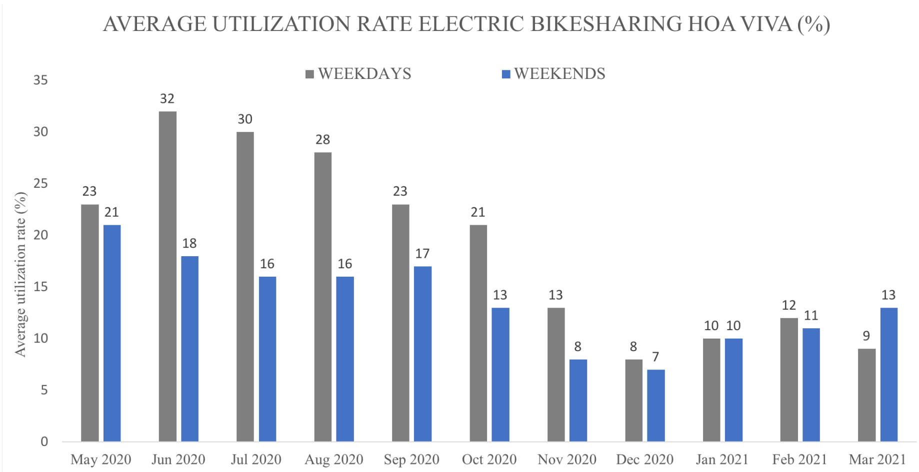

Figure 9. Electric bikesharing average utilization rate at HOA Viva.

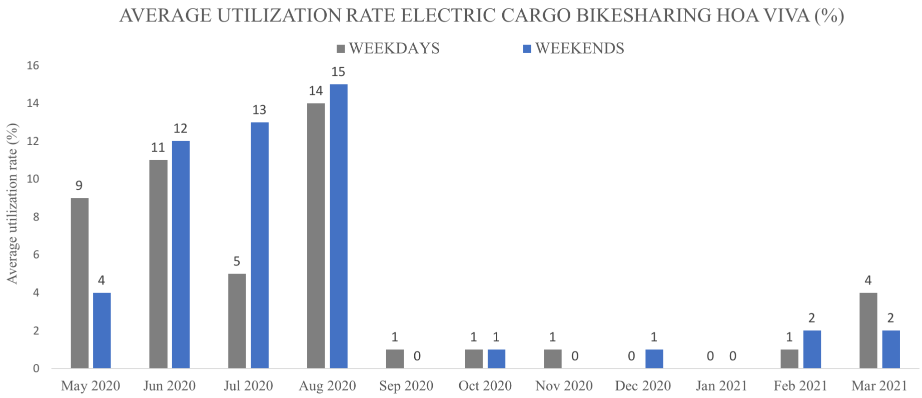

Figure 10. Electric cargo bikesharing average utilization rate at HOA Viva.

5 Analysis and Discussion of Multiple Case Study

The tables and figures presented in previous chapter are in the following section analyzed and discussed with support from the theoretical framework. To begin with, the HOAs case specific characteristics are analyzed in relation to the estimated car parking demand. The estimated car parking demand is then compared to Gothenburg's current guidelines to examine the accuracy of the guidelines. The analysis and discussion for the bicycle situation is then presented with a similar disposition. Finally, the correlation between car and bicycle parking is analyzed in order to identify travel behaviors that transcend the cases studied.

5.1 Car Parking

Table 12 compare the HOAs car parking with the number of apartments and average apartment size. Table 13 compare the estimated car parking demand with the travel time to the city center by various modes of transportation.

Table 12. Car parking and apartments conditions.

Area	Homeowner Association	Estimated car parking demand	Parking requirement	Parking occupancy rate	Monthly cost for parking	Number of apartments	Average apartment size
Tuve	Ljuspunkten	1.0	0.8	100% to underground car park, 33% to ground parking	800 SEK	72	2.6
	Ljusglimten (55+)	0.7	0.6	100%	800 SEK	47	3.0
Sannegården	Akterspegeln	0.7	0.6	100%	1100 SEK	85	2.6
	Kajutan	0.4	0.6	57%	1100 SEK	22	2.5
Eriksberg	Salteriet	1.2	0.8	100%	1100 SEK	61	2.6
	Albertina	1.1	0.7	100%	1100 SEK	89	2.4
Munkebäck	Munkebäcksäng	0.6	0.5	100%	1100 SEK	79	2.6
	Munkebäckslund (55+)	0.8	0.7	87%	1100 SEK	66 (of which 15 are not sold)	2.9
Guldheden	Viva	-	-	-	-	132	2.3
Mölndal	Tigeröga	0.2	0.2	100%	1250 SEK	26	1.6
	Grandalia	0.3	0.7	67%	1250 SEK	69	2.4
	Rosenrot (55+)	0.5	0.8	60%	1250 SEK	50	2.8
Partille	Kronhöjden	0.6	0.8	100% to underground car park and 25% to parking deck	950 SEK	74 (of which 1 is not sold)	2.7
Average	-	0.7	0.7	-	1075 SEK	67	2.5

Table 13. Car parking demand and travel times.

Area	Homeowner Association	Estimated car parking demand	Travel time to city center by car	Travel time to city center by bike	Travel time to city center by public transportation
Tuve	Ljuspunkten Ljusglimten (55+)	1.0 0.7	15 min	29 min	22 min
Sannegården	Akterspegeln Kajutan	0.7 0.4	8 min	11 min with ferry or 17 min over Göta Älv bridge	13 min
Eriksberg	Salteriet	1.2	13 min	19 min with ferry or 25 min over Göta Älv bridge	21 min
	Albertina	1.1	11 min	18 min with ferry or 24 min over Göta Älv bridge	20 min
Munkebäck	Munkebäcksäng Munkebäckslund (55+)	0.6 0.8	8 min	16 min	16 min
Guldheden	Viva	0	14 min	12 min	13 min
Mölndal	Tigeröga Grandalia Rosenrot (55+)	0.2 0.3 0.5	13 min	27 min	21 min
Partille	Kronhöjden	0.6	13 min	31 min	12 min
Average	-	0.7	12 min	21 min (based on the fastest option)	18 min

Although parking requirements and estimated parking demand differ when examining each association, the average for both is 0.7, see Table 12. Indicating that in general, the built car parking spaces for the HOAs examined correspond to the residents' demand.

The HOAs in Eriksberg and HOA Ljuspunkten in Tuve have the highest estimated car parking demand. Where the underground car park has full occupancy rate and there is generally a long queue, resulting in that the demand exceeds the set parking requirement, i.e. the offered parking spaces do not satisfy the need for residential parking. It is possible to conclude that the HOAs with the highest estimated car parking demand has an above-average travel time to the city center by public transportation, see Table 13. The results are supported by literature, which states that the longer it takes to travel by public transport compared to driving, the lower the market share for public transport (CE Delft, 2018). In the case of HOA Ljuspunkten, the travel time by public transportation is nearly twice as long as travel time by car, according to CE Delft (2018), this results in a 30% decrease in the public transportation market share. This statement cannot be applied to the HOAs in Mölndal and Partille that does not belong to the municipality of Gothenburg. As they are located in the middle of their municipality’s center, the need for travel to Gothenburg city center might be limited. Hence, the relatively low estimated parking demand for these HOAs might be explained by the residents' proximity to relevant services that do not necessitate the use of a car on a daily basis.

It is hard to determine why HOA Ljuspunkten has higher estimated parking demand than nearby HOA Ljusglimten. HOA Ljusglimten has 25 more apartments and a slightly larger average apartment size than HOA Ljuspunkten, as shown in Table 12. Also, the parking requirement for HOA Ljuspunkten is 0.2 higher than HOA Ljusglimten. What further distinguishes them is the fact that no one under the age of 55 is permitted to reside in Ljusglimten, which could have an effect on car ownership.

The HOAs in Mölndal and HOA Kajutan in Sannegården have the lowest estimated car parking demand. In Mölndal, this can be linked to the fact that residents were only allowed to rent one parking space per apartment when they moved in, a limitation that was not present in any of the other HOAs studied. Research show that the growing car ownership in Sweden is mainly due to the increasing proportion of households with two cars (Trafikanalys, 2015). The HOAs Kajutan and Tigeröga, which have low estimated car parking demand of 0.4 and 0.2, respectively, are both associations with fewer apartments than all other HOAs examined, see Table 12. It can also be deduced that the average apartment size in both HOA Tigeröga, HOA Grandalia and HOA Kajutan is lower than the overall average.

HOA Kajutan has a travel time to the city center that is below average for all modes of transportation, see Table 13. The same prerequisites apply to the nearby HOA Akterspegel, which has a remarkably higher estimated parking demand of 0.7. HOA Kajutan and HOA Akterspegel are distinguished by the latter's slightly larger average apartment size and a higher number of apartments, see Table 12. HOA Kajutan is also the only association where the residents must exit the building to access the underground car park. According to Christiansen et al. (2016), a longer distance to residential parking results in a substantial decrease in the car’s modal share, which may explain why residents at HOA Kajutan have a lower car ownership.

Table 12 shows that the cost for car parking varies between 800SEK and 1250SEK. However, no clear correlation between the estimated car parking demand and the price factor can be interpreted.

5.1.1 Carsharing's Impact on Car Parking Demand

Carsharing is the second most common measure to achieve reduced car parking requirements (Hult, 2017) and it is therefore interesting to examine the estimated car parking demand is affected by the provision of carsharing. Table 14 presents the HOAs that offer carsharing services to their resident.

Table 14. Car parking demand and available carsharing.

Area	Homeowner Association	Number of apartments	Estimated car parking demand	Carsharing
Tuve	Ljuspunkten	72	1.0	-
	Ljusglimten (55+)	47	0.7	-
Sannegården	Akterspegeln	85	0.7	-
	Kajutan	22	0.4	-
Eriksberg	Salteriet	61	1.2	-
	Albertina	89	1.1	-
Munkebäck	Munkebäcksäng	79	0.6	Shares 2 vehicles
	Munkebäckslund (55+)	66 (of which 15 are not sold)	0.8	
Guldheden	Viva	132	-	3 vehicles
Mölndal	Tigeröga	26	0.2	Shares 3 vehicles
	Grandalia	69	0.3	-
	Rosenrot (55+)	50	0.5	-
Partille	Kronhöjden	74 (of which 1 is not sold)	0.6	-
Average	-	67	0.7	-

As illustrated in Table 14, the absence of a carsharing service connected to the residential building is a feature identified for all HOAs with high estimated car parking demand. Likewise, both Vaca and Kuzmyak (2005) and Martin et al. (2010), states that carsharing can minimize the need for private car ownership. However, it is hard to ascertain if this is accurate for the HOAs studied as the estimated car parking demand is only reliable for the HOAs in Munkebäck. The associations in Mölndal have a car parking limitation and HOA Viva have a parking requirement set to zero. Yet, to obtain a clearer understanding of the conditions for a higher carsharing usage rate, it is interesting to examine how the HOAs carsharing usage differ.

The number of bookings for a carsharing vehicle and the number of unique users are illustrated in Figure 11 for the HOAs Viva, Munkebäcksäng and Munkebäckslund.

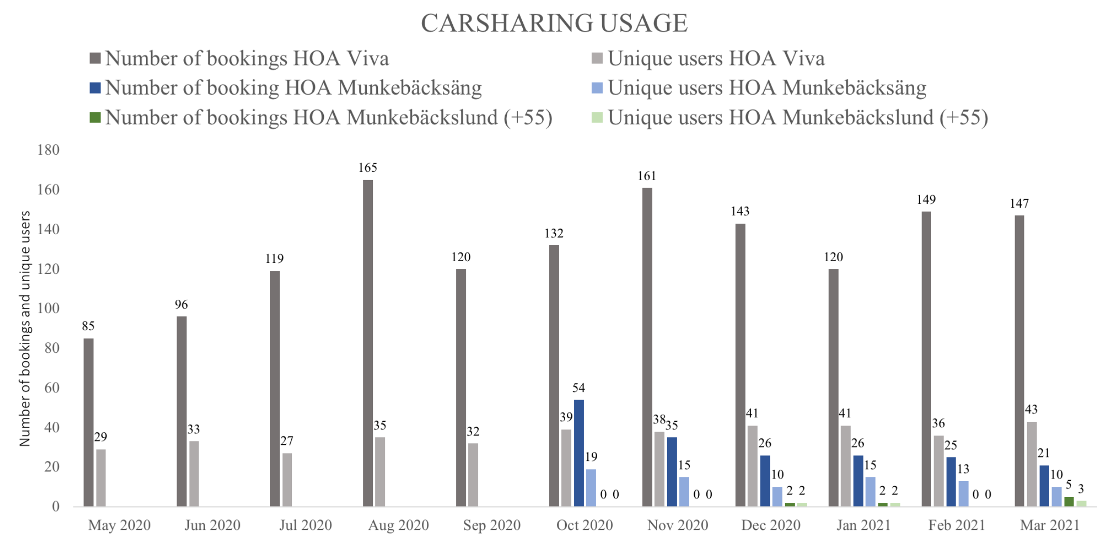

Figure 11. Carsharing usage.

Although the various number of apartments are considered, HOA Viva has the most extensive carsharing usage, see Figure 11. HOA Viva does not offer any car parking and a survey conducted among the residents showed that the car ownership among the residents is significantly lower than the average in Gothenburg (Lund, 2020). Although the number of residents that owns a car at the HOAs in Munkebäck are unknown, their parking requirement and estimated parking demand is around the average for the HOAs studied, implying that the car ownership may be around the average in Gothenburg. A lower proportion of car owners can be interpreted as a natural explanation why the carsharing is used more in HOA Viva than in the HOAs in Munkebäck, as carsharing is mostly appealing to those who rarely drive cars (Vaca and Kuzmyak, 2005).

The low carsharing usage in Munkebäckslund is significant, despite having lowest number of potential users (i.e. lowest number of apartments sold). This finding is supported by previous studies mentioned in the theoretical framework, that the idea of sharing economy is less appealing to older people and that they may find the usage of digital application of carsharing platforms more difficult to use (Rudmin, 2016; Benoit et al., 2017).

Illustrated in Figure 11, HOA Munkebäcksäng has the most unique users in relation to the number of bookings, of which it can be interpreted that the residents may try it but do not use it frequently. Likewise, (Martin et al., 2010) implies that the variable cost of carsharing can become too expensive and is therefore used more as a complement to the private car. In addition, the number of bookings has decreased at HOA Munkebäcksäng. It can be debated whether the residents tried out carsharing but did not find it particularly appealing. However, since the statistics are taken from a six-month period, further data must be analysed for a longer period of time before a conclusion can be drawn.

Regarding the carsharing usage at the HOAs in Mölndal, the only data available is the number of residents that have signed up for carsharing, i.e. members connected per HOA, see Table 11. It is worth noting that the numbers are low, and that the number of residents who have signed up is highest at HOA Rosenrot, which is a 55+ resident. These numbers, however, implies nothing about the actual use of carsharing.

5.1.2 Car Parking Demand in Relation to Gothenburg's Guidelines

As mentioned in the theoretical framework, guidelines from the municipalities govern the car parking requirements. The normal span illustrated in Figure 12 shows within which span a building's parking requirement should fall within the city of Gothenburg, depending on where the project is located.

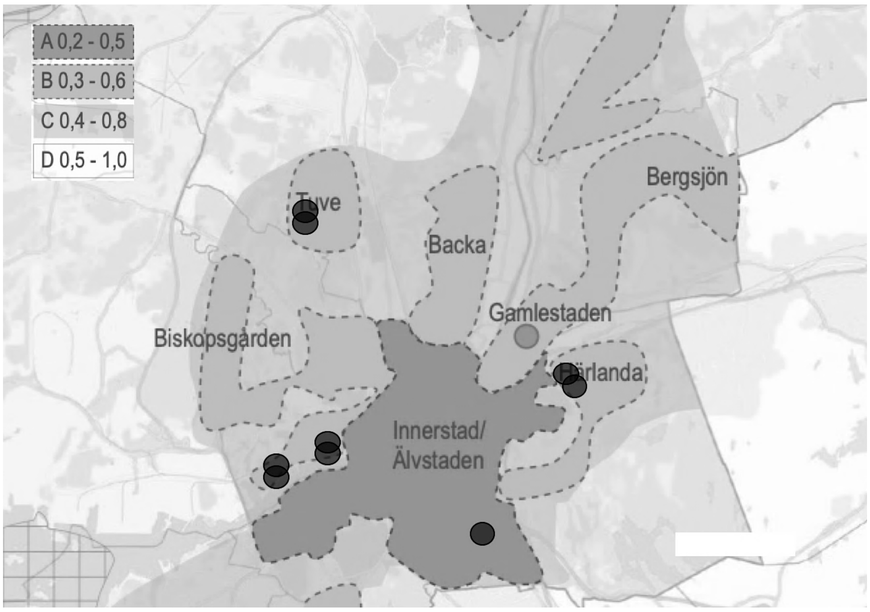

Figure 12. Normal span for parking requirements, with the HOA marked with black dots. Adapted from Göteborgs stad (2019a)

The guidelines were first implemented in 2019 thus were not applied when developing the HOAs studied. It is however interesting to compare HOAs estimated parking demand, to see if the guidelines are in line with the actual need. The markings in illustration 12 are approximate but correspond to the actual zone the HOAs are located. The majority of the HOAs studied are located in priority development areas and should have a parking requirement between 0.3-0.6. Four out of eight HOAs in these areas complies with what the normal span states in regard of their parking requirement, the HOAs in Sannegården, HOA Ljusglimten and HOA Munkebäcksäng. Although, when reviewing the residents parking demand, only two, HOA Kajutan and HOA Munkebäcksäng complies with the guidelines. Thus, it is likely that if property owners had followed today's guidelines when developing the HOAs studied, the majority of them would have had a lower parking supply. Whether this would result in less demand for parking spaces is unclear. According to previous studies, including Sprei et al. (2020), the residential parking supply affects both car ownership and usage. That is, a lower parking supply would reduce car use and thus affect the individual's choice of transport. However, as the analysis shows that residents' parking demand is often higher than the current guidelines, the responsibility may fall on property owners who also want to sell attractive apartments. A residence that does not offer car parking that meets the demand may be a cause for doubt for potential residents. A higher car parking demand than supply can also result in residents parking their cars on the street, as in the case of HOA Viva (Lund, 2020). Based on this, it is clear that other modes of transportation must be available so that residents feel comfortable changing their travel behaviours.

5.2 Bicycle Parking

Table 15 compares the HOAs' bicycle parking with the number of apartments and average apartment sizes. Table 16 compares the estimated bicycle parking demand with the travel time to the city center by various modes of transportation.

Table 15. Bicycle parking and apartment conditions.

Area	Homeowner Association	Estimated bicycle parking demand	Bicycle parking requirement	Bicycle parking occupancy rate	Number of apartments	Average apartment size
Tuve	Ljuspunkten	0.8	3.2	26%	72	2.6
	Ljusglimten (55+)	0.8	2.7	29%	47	3.0
Sannegården	Akterspegeln	1.0	1.2	89%	85	2.6
	Kajutan	1.3	1.7	68%	22	2.5
Eriksberg	Salteriet	-	2.1	-	61	2.6
	Albertina	0.8	1.2	65%	89	2.4
Munkebäck	Munkebäcksäng	-	1.6	-	79	2.6
	Munkebäckslund (55+)	-	1.9	-	66 (of which 15 are not sold)	2.9
Guldheden	Viva	0.7	2.0	35%	132	2.3
Mölndal	Tigeröga	-	1.5	-	26	1.6
	Grandalia	-	1.8	-	69	2.4
	Rosenrot (55+)	-	2.0	-	50	2.8
Partille	Kronhöjden	-	NA	-	74 (of which 1 is not sold)	2.7
Average	-	0.9	1.9	52%	67	2.5

Table 16. Bicycle parking demand and travel times.

Area	Homeowner Association	Estimated bicycle parking demand	Travel time to city center by car	Travel time to city center by bike	Travel time to city center by public transportation (Bus or tram stop)
Tuve	Ljuspunkten Ljusglimten (55+)	0.8 0.8	15 min	29 min	22 min (Tuve centrum)
Sannegården	Akterspegeln Kajutan	1.0 1.3	8 min	11 min with ferry or 17 min over Göta Älv bridge	13 min (Sannegårdshamnen)
Eriksberg	Albertina	0.8	11 min	18 min with ferry or 24 min over Göta Älv bridge	20 min (Eriksbergsdockan)
Guldheden	Viva	0.7	14 min	12 min	13 min (Doktor Fries torg)
Average	-	0.9	12 min	18 min	17 min

The figures in Table 15 indicate that the HOAs in Sannegården and Eriksberg have an above-average bicycle parking occupancy rate, whilst HOA Viva and the HOAs in Tuve have a below-average rate. The lower occupancy rates in the latter might be due to the above-average bicycle parking requirements, and thus a greater supply of bicycle parking. For example, HOA Ljuspunkten has a bicycle parking requirement of 3.2, which is the highest number of the HOAs studied, and has the lowest bicycle parking occupancy rate of 26%. HOA Akterspegel, on the other hand, has the highest occupancy rate of 89%, yet, together with HOA Albertina, the lowest bicycle parking requirement of 1.2. Higher parking requirements implies that the bicycle parking at HOA Viva and the HOAs in Tuve are designed to accommodate more bicycles per apartment than those in Sannegården and Eriksberg. That many of the HOAs' bicycle parking are not fully occupied indicates that the parking spaces satisfy the residents' needs. However, it also indicates that the bicycle parking's are to some extent oversized.

Since the parking requirements vary to a great extent between the HOAs, the occupancy rate can be considered quite misleading regarding the actual bicycle parking need. It is therefore interesting to compare the actual number of parked bicycles in relation to the number of apartments; this is presented in Table 15 as estimated bicycle parking demand. The HOAs estimated bicycle parking demand ranges between 0.7 at HOA Viva to 1.3 at HOA Kajutan, with an average value of 0.9. It could possibly be assumed that the demand varies due to the apartments' diverse size distributions. HOAs with larger apartments and, on average, more residents, may possess a higher number of bicycles per apartment. However, Table 15 presents the HOAs average apartment sizes, and it can be interpreted that above-average estimated bicycle parking demand does not correlate with large apartment sizes. For example, the HOAs in Tuve have the highest average apartment size but the lowest estimated bicycle parking demand. Nor can it be interpreted that the number of apartments affect the estimated bicycle parking demand. HOA Akterspegeln and HOA Kajutan has the highest estimated bicycle parking demand although one of them have an above average number of apartments and the other below average number of apartments.

Regarding the travel time to the city by various modes of transportation, HOA Akterspegeln and HOA Kajutan have an above average estimated bicycle parking demand and travel times by all modes of transportation that are below average, see Table 16. As a result, high estimated bicycle parking demand appears to correlate with a short travel time to the city center by car, bike and public transportation. The HOAs Ljuspunkten, Ljusglimten, Albertina and Viva have below average estimated bicycle parking demand, see Table 16. However, HOA Viva can be disregarded in this context since it previously been stated that the residents at HOA Viva have access to various mobility services, see Table 10. Thus, making it hard determining whether the low estimated bicycle parking demand at HOA Viva is attributable to available mobility services or due to travel times. If not considering HOA Viva, an above-average travel time by public transportation appears to correlate with a low estimated bicycle parking demand, as this complies with both the HOAs in Tuve as well as HOA Albertina, see Table 16.

Additionally, as it was discovered that theft had occurred at HOA Viva, the low estimated bicycle parking requirement could possibly be attributed to this. Andersson's (2017) study found that people prefer indoor bicycle storage as the perception of security is higher. If thefts do occur, it might cause residents to be hesitant to store their bicycles in the bicycle parking garage. However, HOA Akterspegeln has one of the highest estimated bicycle parking demand despite thefts have occurred there as well, see Table 15. As a result, determining the impact of thefts on the estimated bicycle parking demand is difficult.

5.2.1 Bikesharing's Impact on Bicycle Parking Demand

Property owners that provide bikesharing enables people to cycle without worrying about storage, parking or high purchase costs (Shaheen et al., 2010). Thus, making it interesting to examine if residents in HOAs that offer such measures prefers to use bikesharing vehicles rather than owning a bicycle, i.e. examine if these HOAs have a lower estimated bicycle demand. HOA Viva is the only of the associations examined that provides bikesharing to the residents, see Table 17. In addition, HOA Viva has the lowest estimated bicycle parking demand. This could imply that residents need for bicycle parking reduces as a result of access to bikesharing.

Table 17. Bicycle parking demand and available bikesharing.

Area	Homeowner Association	Estimated bicycle parking demand	Bikesharing	Number of apartments
Tuve	Ljuspunkten	0.8	-	72
	Ljusglimten (55+)	0.8	-	47
Sannegården	Akterspegeln	1.0	-	85
	Kajutan	1.3	-	22
Eriksberg	Salteriet	-	-	61
	Albertina	0.8	-	89
Munkebäck	Munkebäcksäng	-	-	79
	Munkebäckslund (55+)	-	-	66 (of which 15 are not sold)
Guldheden	Viva	0.7	5 electric bicycles 3 electric cargo bicycles Service room	132
Mölndal	Tigeröga	-	-	26
	Grandalia	-	-	69
	Rosenrot (55+)	-	-	50
Partille	Kronhöjden	-	-	74 (of which 1 is not sold)
Average	-	0.9	-	

Aside from the availability and accessibility to bikesharing, the actual usage and utilization rate, as well as factors that promotes usage, needs to be considered. Figures 13 and 14 below present the monthly bikesharing usage at HOA Viva.

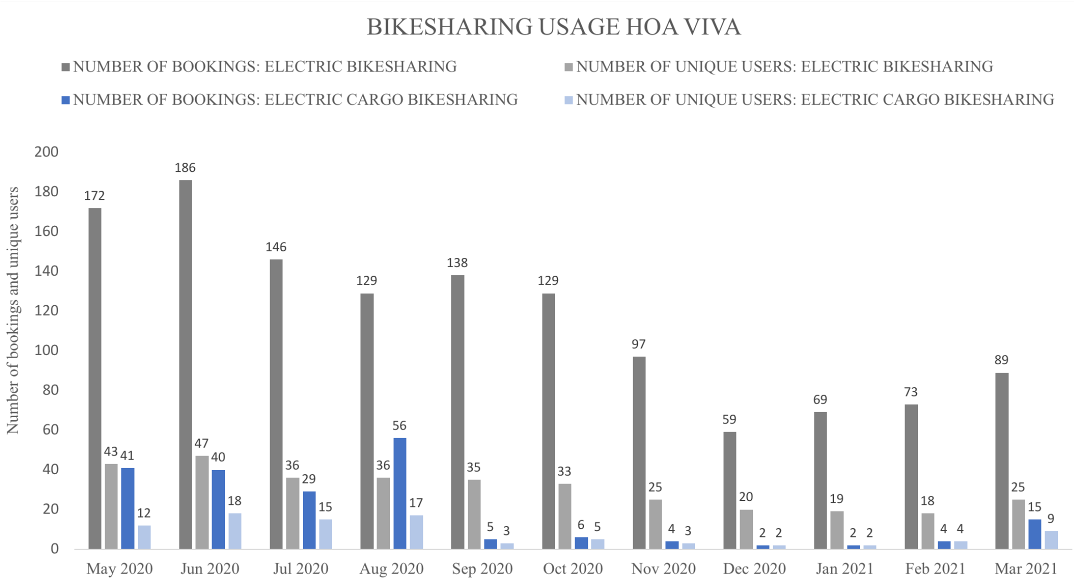

Figure 13. Bikesharing usage HOA Viva.

Figure 13 presents the monthly number of bookings and unique users of the electric bikesharing and electric cargo bikesharing vehicles at HOA Viva. What can be established is that the number of bookings and the number of unique users are higher for the electric bicycles compared to the electric cargo bicycles. The number of bookings for the electric cargo bicycles can be considered overall low, except during the summer months where the number of bookings is higher, yet substantially lower than the electric bikesharing usage. Based on Figure 13, it can be estimated that on average, 27% of the bookings for electric bikesharing are made by unique users. For the electric cargo bikesharing, this figure is 67 %. Implying that, although the usage of electric bikesharing is higher, the spread of unique users is low.

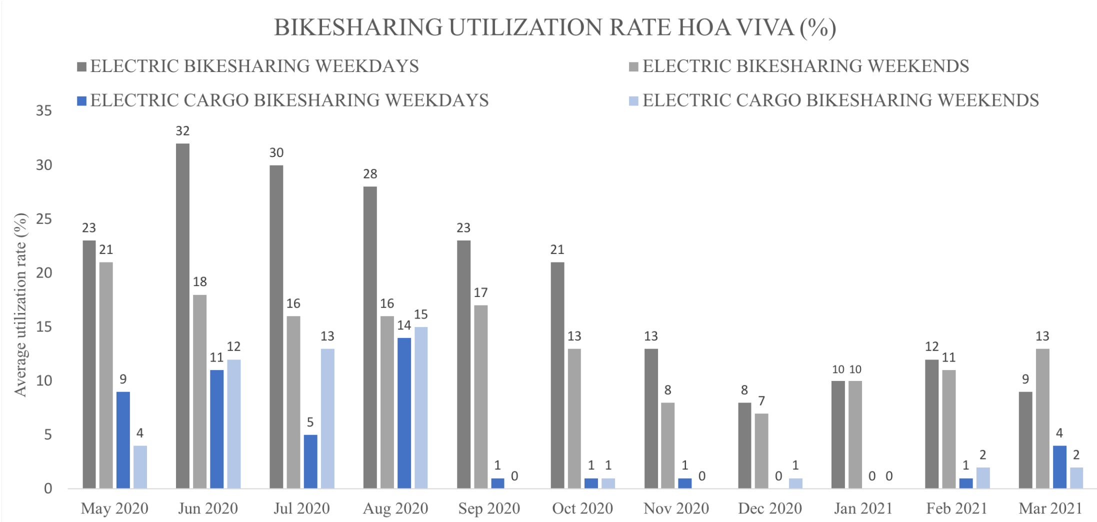

Figure 14. Bikesharing utilization rate HOA Viva.

Figure 14 depicts the average utilization rate for the bikesharing vehicles at HOA Viva, divided into weekdays and weekends. The average utilization rates for the electric bicycles are relatively low, particularly on weekends. The highest utilization rate is 32% during June 2020. The average utilization rate for the electric cargo bicycles are even lower, the highest rate is 15% in August 2020. The utilization of the electric cargo bicycles is higher on weekends than on weekdays during the summer months, opposite to the electric bike's utilization rate that in general is higher on weekdays than weekends. However, as the bikesharing vehicles are available between 7:00 am and 11:00 pm, it is naturally that the average utilization rates are low.

Since HOA Viva is the only of the HOAs examined that provides bikesharing, it is impossible to compare the bikesharing usage. If only considering availability, the access to bikesharing in combination with carsharing could possibly explain the low estimated bicycle parking demand at HOA Viva. However, the estimated bicycle parking demand does not differ much between HOA Viva and the HOAs Ljuspunkten, Ljusglimten, and HOA Albertina, as shown in Table 17, despite the fact that the three latter associations do not provide any mobility services. Thus, determining the effect of bikesharing on estimated bicycle demand as well as draw conclusion on what facilitates bikesharing usage is impractical. Likewise, Teixeira et al. (2020) argues that there is limit existing research on the benefits of bikesharing. Although, some studies claim that bikesharing can decrease the cars modal share (Teixeira et al., 2020). However, since HOA Viva has a zero car parking requirement, it is impossible for this study to investigates the effect of bikesharing on private car use and estimated car parking demand.

5.2.2 Bicycle Parking Demand in Relation to Gothenburg's Guidelines

As previously stated, the analysis of the figures in Table 15 indicates that the majority of the observed bicycle storage rooms are to some extant oversized. Parking garages that are not being used can be assumed to be an unnecessary cost for the property owner. It is therefore interesting to compare the estimated bicycle parking demand with the current guidelines for bicycle parking requirements. As mentioned in the theoretical framework, guidelines from the municipalities govern the parking requirements. The municipality of Gothenburg has set the starting value to 2.5 bicycle parking spaces per apartment (Göteborgs stad, 2019a). The starting value can be increased to a maximum of 3.0 or reduced to a minimum of 2.0 parking spaces per apartment. The HOAs included in this report were built before the current guidelines came into force which explains why the parking requirement figures are higher or lower. However, all HOAs examined have a demand below 2.0 bicycles per apartment, with an average of 0.9.

Note worthen is that the Gothenburg's guidelines parking requirement also consider bicycle parking outdoor and the observation solely consider parking indoor. Still, the observations showed that the bicycle rooms were far from fully utilized. Yet, from a sustainability standpoint, it is important to promote more environmentally friendly modes of transportation. As the bicycle can mitigate many of the negative environmental effects of car use (Martens, 2007), the perquisites for using bicycle should be attractive and accessible.

5.3 Car Parking in Relation to Bicycle Parking

The previous chapters have analyzed and discussed the car and bicycle parking situations separately. In Table 18 are the car parking situation related to the bicycle parking situation to evaluate possible correlations. The discussion below mainly addresses the HOAs where the estimated bicycle parking demand is known.

Table 18. Car parking in relation to bicycle parking.

Area	Homeowner Association	Estimated car parking demand	Car parking requirement	Car parking occupancy rate	Number of residents in queue to parking	Estimated bicycle parking demand	Bicycle parking requirement	Bicycle parking occupancy rate
Tuve	Ljuspunkten	1.0	0.8	100% to underground car park, 33% to ground parking	15 queuing to underground car park	0.8	3.2	26%
	Ljusglimten (55+)	0.7	0.6	100%	5	0.8	2.7	29%
Sannegården	Akterspegeln	0.7	0.6	100%	8	1.0	1.2	89%
	Kajutan	0.4	0.6	57%	0	1.3	1.7	68%
Eriksberg	Salteriet	1.2	0.8	100%	26	-	2.1	-
	Albertina	1.1	0.7	100%	38	0.8	1.2	65%
Munkebäck	Munkebäcksäng	0.6	0.5	100%	8	-	1.6	-
	Munkebäckslund (55+)	0.8	0.7	87%	0	-	1.9	-
Guldheden	Viva	0	0	-	-	0.7	2.0	35%
Mölndal	Tigeröga	0.2	0.2	100%	0	-	1.5	-
	Grandalia	0.3	0.7	67%	0	-	1.8	-
	Rosenrot (55+)	0.5	0.8	60%	0	-	2.0	-
Partille	Kronhöjden	0.6	0.8	100% to underground car park, 25% to parking deck	5 queuing to underground car park	-	NA	-
Average	-	0.7	0.7	-	-	0.9	1.9	52%

As illustrated in Table 18, HOA Ljuspunkten has an above-average estimated car parking demand while the estimated bicycle parking demand is below average. In addition, both the bicycle parking requirement and car parking requirement is above average, with the car parking being completely utilized and bicycle parking being underutilized. The low estimated bicycle parking demand in combination with a high estimated car parking demand may simply indicate that the residents at HOA Ljuspunkten prefer to travel by car rather than by bike. As previously indicated, the high estimated car parking demand may be due to longer than average travel time to city center by public transportation. Further, while the car parking demand at the nearby HOA Ljusglimten is lower than at HOA Ljuspunkten, the estimated bicycle parking demand is equal. This suggest that the bicycle parking has no effect on the estimated car parking demand at HOA Ljusglimten or at HOA Ljuspunkten.

Of the HOAs examined, HOA Kajutan has the highest estimated bicycle parking demand and the lowest estimated car parking demand, see Table 18. Given that residential car parking can potentially reduce private car use (see, e.g., Christiansen et al., 2016), a high estimated bicycle parking demand could have indicated that the residential car parking is completely utilized, resulting in directing the residents to higher bicycle usage. This is not the case at HOA Kajutan, since the car parking occupancy rate is relatively low. The car parking is underutilized, yet the residents use bicycles to a greater extent than at the other HOAs. The relatively low car parking occupancy rate is not due to high car parking requirements, as HOA Kajutan's requirements are below average. The reason for the low car parking occupancy rate might simply be due to the high bicycle parking demand, i.e. the residents choose to travel by bike instead of by car. As previously indicated, the high estimated bicycle parking demand can be ascribed to short travel time to the city center by car, bike and public transportation. Further, nearby HOA Akterspegel has the same prerequisite in terms of travel time to the city center, yet their estimated bicycle parking demand is slightly lower, see Table 13. It appears as the residents at HOA Akterspegeln prefers to travel by car rather than by bike, contrary to the residents at HOA Kajutan. An explanation for the difference in car parking demand between the two HOAs could be that they share an underground car parking located underneath Akterspegel, making the distance to the car parking longer for the residents at HOA Kajutan. This is supported by Christiansen et al. (2016) which states that longer distances between home and residential parking substantially lower the cars modal share.

Furthermore, HOA Salteriet has the highest estimated car parking demand of the HOAs examined, see Table 18. However, as no observations were made of their bicycle parking, this cannot be compared to the estimated bicycle parking demand. Yet, it is worth emphasizing that HOA Salteriet has one of the highest bicycle parking requirements of the HOAs examined. Despite good opportunities for bike ownership, the residents of HOA Salteriet appears to prefer travelling by car. Again, the high estimated car parking demand can be attributed to the above-average travel time by public transportation to the city center, as well as to absence of carsharing.

HOA Albertina has an average car parking requirement, 100% car parking occupancy and a relatively long queue to the car parking, see Table 18. Again, considering that residential car parking can be used as a tool to promote more sustainable travelling, the limited possibility for car parking could have steered the residents to higher bicycle usage. Yet, this is not the case at HOA Albertina since the estimated bicycle parking demand is below average. Once more, the high estimated car parking demand can be linked to above-average travel time by public transportation to city center and to absence of mobility services.

Overall, there appears to be no correlation between car parking and bicycle parking. Low car parking requirement or fully occupied car parking's seems not to encourage higher bicycle usage as it has no impact on bicycle parking demand. Additionally, generous bicycle parking requirements appears to have no effect on the car parking demand.

6 Applying the Results on the Development of Backaplan

The development of Backaplan aims to be a part of the transition to a more sustainable society where the car is no longer the primary mode of transportation (Sundberg and Mattsson, 2019). As Backaplan is an upcoming project, there is an opportunity to learn from established urban housing projects and their resident's parking demand. This chapter begins with a brief background to the development of Backaplan followed by the area's mobility prerequisites and ambitions. Then, mobility recommendations for the area are presented.

6.1 Background to the Development of Backaplan

Backaplan is located on Hisingen close to the river Göta Älv and is an important piece in the development of connecting Gothenburg city across the river (Göteborgs stad, n.d). Göteborgs stad aims to transform Backaplan from a trade and business area to an attractive mixed city, with a varied selection of residence, shops, parks and cafes. The area will undergo a densification within the next 20 years as a part of the large urban development project Vision Älvstaden, and around 7,000 residences will be developed, see Figure 15 (Göteborgs stad, 2019b). Riksbyggen is one of the property owners involved in transforming the area and plans to develop around 700 residences (Riksbyggen, 2019). With proximity to services, schools and recreational spaces, the development of Backaplan is hoped to make it easier to live and travel more sustainable (Göteborgs stad, n.d).

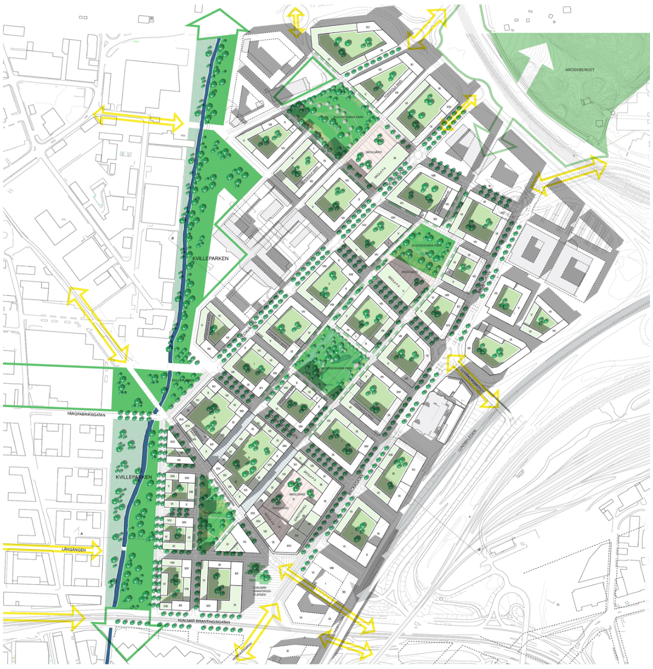

Figure 15. Planned design of the development of Backaplan. Adapted from White Arkitekter (n.d.)

The development of Backaplan is divided into several detailed development plans (Göteborgs stad, 2020). Riksbyggens interest and planned development belongs to DP3, see Figure 16, which is still under construction (Göteborgs stad, 2019b). DP3 predominantly includes residential buildings with premises on the ground floors (Göteborgs stad, 2019b).

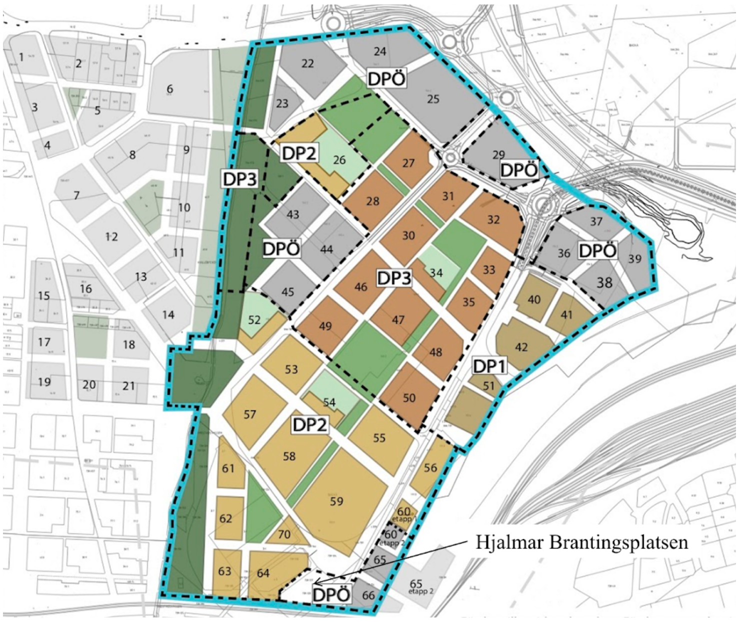

Figure 16. Map of the Backaplan area and the division of the detailed development plans. Adapted from Fastighetskontoret (2015).

6.2 Mobility Prerequisites and Ambitions

Backaplan is today a commercial center with large paved areas where people mainly travel by car (Sundberg and Mattsson, 2019). The area has a large pedestrian flow between the public transportation stops, shops and housing in the immediate area (Göteborgs stad, 2019b). Yet, Backaplan is poorly designed for pedestrians as it consists of large open parking spaces and streets mainly adapted for industrial purposes. The public transportation to Backaplan is considered relatively good as Hjalmar Brantingsplatsen is the strongest hub for public transportation on Hisingen (Göteborgs stad, 2019b). The hub is heavily trafficked with numerous bus and tram lines, and the journey from Hjalmar Brantingsplatsen to Brunnsparken takes only 7 minutes. Comparatively, traveling by car takes 6 minutes. Furthermore, Backaplan is connected to one of the city's larger bicycle paths which runs along Hjalmar Brantingsgatan and is connected to Frihamnen and Hisingsbron (Göteborgs stad, 2019b). It takes approximately 12 minutes to cycle from Hjalmar Brantingsplatsen to the city center.

Backaplan's future mobility is currently being investigated, but the objectives for the area are in line with the Gothenburg traffic strategy (Sundberg and Mattsson, 2019). By the year 2035, the traffic administration office aims that walking, cycling, and public transportation will be the preferred modes of transport in the area (Sundberg and Mattsson, 2019). The objective is that 15% of all travel will be made by car, 15% by bicycle, 40% by public transportation and 30% by pedestrians. An ambitious goal as statistics from 2020 shows that cars account for 48% of daily travel in Gothenburg, while bicycles account for 9%, public transportation accounts for 24%, and pedestrians account for 19% (Trafikkontoret, 2020). The area aims to provide a well-developed pedestrian infrastructure and bicycle infrastructure, as illustrated in Figure 17, (Göteborgs stad, 2019b). As well as an attractive public transport, see Figure 18. Hjalmar Brantingsplatsen is strategically important and will continue to be developed to a hub with a large mix of functions and high access to public transportation (Göteborgs stad, 2020). The term "bus rapid transit”, see Figure 18, refers to a vehicle that travels in designated bus lanes and has priority at traffic lights. The high capacity bus (Stombuss) is characterized by a high trip frequency and a larger passenger base than regular bus lines. A new station for commuter trains is planned in Brunnsbo that aims to strengthen the regional connections and conditions for urban development in the northern parts of Backaplan (Göteborgs stad, 2019b). Also, the new station will connect the national and regional public transport network. The aim is that the entire Backaplan would have access to public transportation within 300 meters.

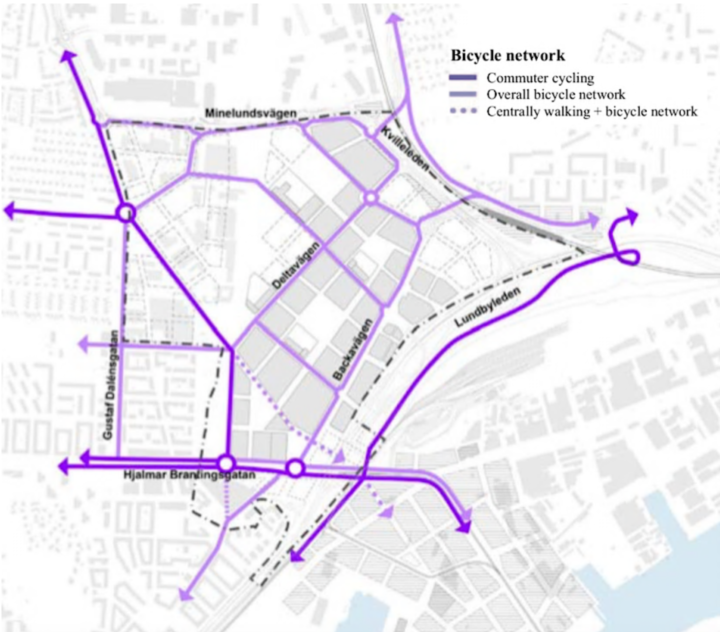

Figure 17. Map of the planned bicycle network in Backaplan. The author's own translation. Adapted from Göteborgs Stad (2019b)

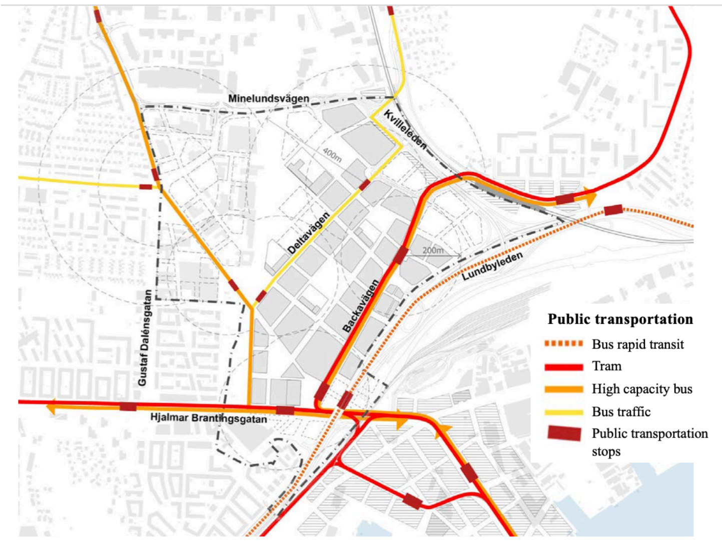

Figure 18. Map of the planned public transport in Backaplan. The author's own translation. Adapted from Göteborgs Stad (2019b).

The ambition is thus that there should be good prerequisites for other modes of transportation than the car and that proximity to businesses and services should reduce the need for car-ownership. According to Gothenburg's guidelines, Backaplan is located within zone A and should have a parking requirement for residential buildings of 0.2-0.5 per apartment (Göteborgs Stad, 2019a). Since Backaplan will be built gradually, the need for parking will need to be addressed within each respective detailed development plan. All property owners in the area thus have an opportunity to undertake mobility measures to reduce the need for car parking related to their specific development (Sundberg and Mattsson, 2019). In the whole area, a theoretical demand of 3,650-4,190 residential car parking spaces has been estimated (Sundberg and Mattsson, 2019). These parking spaces are planned to mainly be located in various parking facilities in the development area and will be shared by all residents in the area.

6.3 Mobility Recommendations

The densification of the Backaplan area will proceed during the next 20 years and the standard for designing residential parking might change during this time. There are proposed amendments (SOU 2021:23) to the Planning and Building act (PBL 2010:900) suggesting that car parking requirements should be disregarded, instead, future urban housing should merely focus on individual's and society's mobility needs. The subsequent chapter presents mobility recommendations for Riksbyggens development of Backaplan that looks beyond the City of Gothenburg’s guidelines for residential parking. The recommendations are based on the analysis and discussion from the multiple case study and are supplemented with findings from the theoretical framework that is not addressed in the multiple case study.

6.3.1 Recommendations for Car Parking

Residential underground car parks typically have a limited use area (Broere, 2016), necessitating research and planning for future residential mobility design. The findings from the multiple case study indicates that HOAs with high parking requirements often have a high estimated car parking demand. Since residential parking affects trip frequency, car ownership, and mode preference, it's vital to regulate parking and use it as a tool to encourage people to use more environmentally friendly modes of transportation (see, e.g., Christiansen et al., 2016). If considering Gothenburg's guidelines, as Backaplan is located in zone A, the lowest possible parking requirements to achieve is 0.2 (Göteborgs Stad, 2019a). Although this thesis aims to look beyond the guidelines, a parking requirement of 2.0 is recommended. This is due to the fact that Backaplan's development will include services and shops, and the area is expected to have a good location assessment. According to Weinberger (2012), if residential parking requirements are generous, people are more likely to use private cars for destinations that are well integrated to public transportation. Low parking requirements are once again motivated since Backaplan is designed to have a well-established public transportation system.

A parking requirement set to zero is not recommended as it can lead to the residents parking their cars in the immediate vicinity of the residence such as on the street. This assertion is supported by research conducted at HOA Viva, which offers no car parking spaces (Lund, 2020). Although surveys show that car ownership is lower in HOA Viva than the average in Gothenburg, some residents still keep their car. That is, although non-existent residential parking has reduced car ownership to some extent, there is a possibility that residents park their cars on the street.

As concluded in the analysis and discussion of the multiple case study, the distance between home and residential parking can influence the estimated car parking demand.

For example, the estimated car parking demand at HOA Kajutan is lower than the nearby HOA Akterspegeln, which has car parking in direct proximity to the residential building. Likewise, the underground car park at HOA Kronhöjden is completely occupied, while the parking deck located approximately 300 meters away is only 25% utilized. In addition, the residents parking on the deck are queuing to the underground car park, implying that it is less appealing to park with a distance from home. As a result, it is recommended that the residential car parking at Backaplan should be in parking facilities that are located farther away from the residence rather than directly adjacent to it. According to Christiansen et al. (2016) is a distance of approximately 150 meters between home and residence what residents are willing to accept, therefore, a distance longer than 150 meters is recommended in order to make private car ownership less attractive. Yet, since the ambition for the development for Backaplan is for everyone living in the area to have access to public transportation within 300 meters (Göteborgs Stad, 2019b), it is proposed that the car parking is located as far as 300 meters away from the residence. This will make the accessibility to public transportation equally good or even better.

The HOAs in Mölndal all have a below-average parking demand, where neither HOA Rosenrot nor HOA Grandalia have a full parking occupancy rate. This can be traced to the fact that residents were only allowed to rent one parking space per apartment when they moved in. Therefore, a similar car parking restriction at Backaplan should be considered, as a it seems to correlate with decreased car ownership.

Although findings from the multiple case study indicate that the cost for parking has no effect on estimated parking demand, previous research suggests that it can. According to Ostermeijer et al. (2019), parking costs will influence car ownership, making it a factor to consider. As presented in the theoretical framework, the construction cost for one car parking space in a parking facility is approximately 1200 SEK (Malmö Stad, 2020). As 1200 SEK is above the average price for car parking of the HOAs studied, the price is considered relatively high, a lower cost can contribute to more social equality. However, the parking construction expense is project-specific and the recommendations for Backaplan are that the parking fees should cover the construction cost for one parking space.

6.3.2 Recommendations for Bicycle Parking

The city of Gothenburg's ambition is that cycling should triple from 2011 to 2025 and that the city should be seen as bike-friendly by three out of four people (Trafikkontoret, 2017). The development of Backaplan follows this vision as the aim is to provide a well-developed bicycle infrastructure. Backaplan is located close to the river Göta Älv and the travel time by bike to the city center is only 12 minutes. The multiple case study indicated that a below-average travel time by bike to the city center results in high estimated bicycle parking demand. Prerequisites and ambitions for a high and widespread use of bicycles in the Backaplan area are good, which should be reflected in the design of bicycle parking. As a result, it is suggested that Riksbyggen continues to develop large and spacious bicycle storage rooms to promote cycling. As the bicycle is substantially more sustainable than the car (Martens, 2007). In addition, the bicycle parking should continue to be placed indoors, as the perception of security is higher (Andersson, 2017). In terms of recommendations for more precisely bicycle parking requirements, the result from the multiple case study indicates that approximately 2.0

bicycle parking per apartment is enough. The city of Gothenburg's recommended parking requirements ranges between 2.0-3.0, yet all HOAs examined had a demand below 2.0 bicycles per apartment, with an average of only 0.9. If also taking into account that various forms of mobility services will be available at Backaplan, a bicycle parking requirement around 2.0 is considered enough.

6.3.3 Recommendations for Mobility Services

It is recommended that Riksbyggen should provide various mobility services to the residents. The recommendation for providing mobility services is based on the findings from literature and the multiple case study and not necessarily on what the basic package and star package state in the Gothenburg's parking requirement guidelines.

6.3.3.1 Mobility Services Provided by Riksbyggen

The results from the multiple case study shows that a high estimated car parking demand can be due to the absence of carsharing. Therefore, Riksbyggen should provide carsharing since it can minimize household car ownership which correlates with a lower parking supply (Vaca and Kuzmyak, 2005). To encourage residents to use the shared vehicles, carsharing should comparatively be more available than private cars. Hence, it is recommended that the shared vehicles are parked as close to the HOAs as possible. If several HOAs are located close to each other, the vehicles and associated parking should be shared among the residents. Although it is desirable to have carsharing vehicles parked on city-owned public parking lots to promote usage (Kang et al., 2016), there is currently no legal support for parking for it in Sweden (SOU 2020: 22). HOA Viva has the most extensive carsharing usage of the examined HOAs, with zero car parking requirement. Hence, the number of carsharing vehicles provided is suggested to be around the same number of shared cars per number of apartments as it is at HOA Viva. HOA Viva has 3 carsharing vehicles and 132 apartments, i.e. 0.02 vehicles per apartment.

The implementation of various mobility services in combination with a MaaS concept can ideally meet residents' everyday travel needs with flexible and more sustainable alternatives to private cars. Liljamo et al. (2021) argues that MaaS potentially can reduce car ownership. Although there are those who disagree about its effect on private car ownership (Storme et al., 2020), MaaS are clearly emerging in the transportation field, and is expected to be commercialized and developed in Sweden (Boyer et al., 2020). Since it is recommended that Riksbyggen should aim for low car parking requirements at Backaplan, the MaaS concept can assist residents in accepting the limited residential car parking, as it did at HOA Viva (Olsson Jeffery, 2021). Personal counseling, resources, and campaigns should be included in the MaaS incorporation with the aim of finding the best mobility solutions for residents. This is particularly relevant when it comes to providing carsharing information to older people, as findings suggest that they do not use it as frequently as younger people. In addition, it is vital that the concept meet people's mobility requisites while generating economic benefits, to avoid making it a complement to the private car.

Furthermore, similar to why Riksbyggen should provide large and spacious bicycle parking and storage rooms to encourage sustainable traveling, it is recommended that they establish various forms of bikesharing. Even though there is limited research on the actual benefits of bikesharing, some studies argue that bikesharing can compete with the car (Teixeira et al., 2020). HOA Viva is used as a reference for the number of vehicles that are recommended to be included in the bikesharing fleet, as the travel time by bike from Backaplan and HOA Viva to the city center is the same. Also, since it is recommended that Riksbyggen should strive to achieve low parking requirements, the potential usage of bikesharing at Backaplan can be considered similar to the usage at HOA Viva. There are 5 electric bicycles and 3 electric cargo bicycles to share at HOA Viva. As established in the multiple case study, the usage for the electric bicycles are relatively widespread, particularly during summer. The usage of the electric cargo bicycles is overall low, with a maximum average utilization rate of 15%. Based on this, it is recommended that Riksbyggen provides the same number of electric bicycles at Backaplan but reduces the number of electric cargo bicycles. Hence, 0.04 electric bikesharing vehicles per apartment and 0.01 electric cargo bikesharing vehicles per apartment are recommended. Additionally, the shared bicycles should be placed indoors in direct connection to the resident, preferably on entrance level to increase accessibility, but without insight and with high security.

Loder and Axhausen (2018) states that private car ownership can be reduced if the provision of public transport is good and comparatively more accessible than the private car. Traveling by public transportation is a more sustainable option than the use of a private car and should according to Redman et al. (2012) be encouraged to be the primary mode of transportation together with walking and cycling. Sundberg and Mattsson (2019) presents that the objective is for public transportation to account for 40% of all travel in the Backaplan area. Hjalmar Brantingsplatsen is a strong hub for public transportation and is expected to remain so in the future (Göteborgs stad, 2019b). Additional public transportation stops, and stations will be developed in the Backaplan area, see Figure 15, and the aim is that all residents at Backaplan will have access to public transportation within 300 meters (Göteborgs Stad, 2019b). In addition, both findings from the literature and the multiple case study emphasizes on the importance of public transportation's travel time for the degree of usage. The multiple case study indicates that a travel time over 18 minutes with public transportation can result in a high estimated car parking demand. Traveling by public transportation from Hjalmar Brantingsplatsen to central Gothenburg takes 7 minutes, which is just one minute longer than driving, resulting in a higher market share for public transport (CE Delft, 2018). Emphasizing on both the accessibility of public transportation at Backaplan and the travel time, it is recommended that public transportation should be promoted as the main mode of transportation. In addition, future residents should be offered to buy a public transportation card with a significant discount, preferably one card per apartment valid for 365 days. According to Loder and Axhausen (2018), making a financial investment in a season ticket for public transit is a powerful incentive to actually use it. Hence, it is not recommended that public transportation cards be given away for free, as it was in the HOAs in Mölndal.

6.3.3.2 Mobility Services in Collaboration with other Stakeholders

As a complement to the mobility services that Riksbyggen provides, it is recommended that property owners together with other stakeholders involved in developing the Backaplan area coordinate mobility hubs. Mobility hubs that offer services make environmentally friendly modes easier, more convenient and more appealing to use (Schemel et al., 2020). These hubs can, for example, include bikesharing and shared electric scooters that everyone can use. Such mobility services are already established in Gothenburg, allowing people to leave their rented vehicle in a variety of locations throughout the city, or alternatively, making a seamless interchange at Hjalmar Brantingsplatsen and take public transportation from there. As presented in the theoretical framework, combining bikesharing with public transportation can compete with the car and potentially decrease its modal share (Teixeira et al., 2020). To encourage high usage of the mobility services, it is recommended that Riksbyggen together with the other stakeholders offers discounts for membership to their residents.

Smart placing of mobility hubs is a way to nudge people to change their mobility habits (Schemel et al., 2020). While Hjalmar Brantingsplatsen will remain a large and strategically significant hub, it is suggested that additional smaller mobility hubs should be built closer to the residents. Since DP3 is still under construction, the precise location of the mobility hubs is uncertain. It can be interpreted from Figures 15 and 16 that the residence in DP3 are to be designed as blocks. It is therefore suggested to especially perform mobility hubs investments in neighborhoods that are farther away from Hjalmar Brantingsplatsen, such as blocks 27-28 or at blocks 30-31.

6.3.4 Summary of Recommendations

Car parking

- Property owners should strive towards low parking requirements, yet, not as low as zero car parking requirement.
- Residential car parking should be in parking facilities located between 150 and 300 meters from the residence.
- Possibly restrict the residential car parking by only allowing the residents to rent maximum one car parking space per apartment.
- The monthly cost of renting a car parking space should cover the construction cost of building a car parking space in a parking facility.

Bicycle parking

- Residential bicycle parking should be large and spacious. A bicycle parking requirement of 2.0 is considered enough for the Backaplan area.
- The residential bicycle parking should be placed indoors.

Mobility services provided by Riksbyggen

- Provide a carsharing fleet of 0.02 carsharing vehicles per apartment at each HOA. To facilitate usage, it is vital to provide information on how to utilize them, especially for the elderly.
- Provide both electric bikesharing and electric cargo bikesharing. 0.04 electric bikesharing vehicles per apartment and 0.01 electric cargo bikesharing

vehicles per apartment are recommended.

- Subsidizes public transportation cards should be provided to the residents to promote public transport as the main mode of transportation, preferably one card per apartment valid for 365 days.

- The mobility services should be located as close to the HOAs as possible in order to comparatively be more accessible than the private car.

- If several HOAs are located adjacent to each other, the carsharing vehicles should be shared among the residents.

- The shared bicycles should be placed indoors, preferably on entrance level to increase accessibility, but without insight and with high security.

- Establish a MaaS concept.

Mobility services in collaboration with other stakeholders

- Establish smaller mobility hubs with services such as bikesharing and shared electric scooters. Particularly at blocks located farther away from Hjalmar Brantingsplatsen, for instance at block 27-28 or at block 30-31.

- Offer discounted membership for mobility hub services to the residents.

7 Conclusion

For individuals, the car is often the most prevalent form of transportation, but a significant barrier in the transition to sustainable mobility. The topic has received a lot of attention in research and a widely debated measure is to regulate residential parking as it is thought to have an effect on car ownership, trip frequency and mode choice. Yet, there has been limited studies concerning the correlation between residents' mobility prerequisites such as parking supply or travel time by public transport, and their parking demand. This correlation is relevant from the aspect that future legislation may disregard the car parking requirement and instead concentrate solely on residents' mobility needs (SOU 2021:23). This paper investigates various factors that are thought to influence residents' car and bicycle parking demand in 13 different HOAs in Gothenburg, Mölndal and Partille. Although the multiple case study may not be empirically representative of spot samples of populations of similar residential areas, the findings can give indications about similar residential areas. The cases studied can also be used as a training example of mobility design, promoting critical thinking and new planning perspectives in urban areas for property owners that desire to look beyond the parking requirements. In order to theoretically realize the implementation of the findings from the multiple case study for future urban housing, Riksbyggens planned development of residential buildings in Backaplan has been used.

This, along with previous research on the topic, is intended to address the study's aim of examining the role of residential parking in the work to promote sustainable mobility. In this chapter, the results of the study will be summarized in relation to the thesis research questions and suggestions for future studies will be presented.

7.1 Answering the Research Questions

RQ1: How does the car and bicycle parking supply at the examined homeowner associations correspond to the residents' car and bicycle parking demand?

The majority of the examined HOAs have higher estimated car parking demand than the parking supply. At a few HOAs the car parking demand is lower than the parking supply. At one HOA, the resident's car parking demand exactly corresponds to the car parking supply. However, both the average car parking requirement and the average estimated car parking demand is 0.7 car parking spaces per apartment, demonstrating that the overall car parking supply corresponds to the residents’ car parking demand.

The estimated bicycle demand was significantly lower than the parking supply in all of the HOAs where bicycle parking was observed, suggesting that the bicycle parking met the residents' needs. Yet, as the average estimated bicycle parking demand was 0.9 while the average parking requirement was 1.9, it indicates that the majority of the bicycle parking’s are oversized.

RQ2: How does the car and bicycle parking demand at the examined homeowner associations correspond to the municipality of Gothenburg's current guidelines regarding car and bicycle parking?

In general, the estimated car and bicycle parking demand does not correspond with the parking recommendations from the municipality of Gothenburg. The results from the multiple case study shows that the estimated car parking demand is overall higher than the municipality's car parking requirements. According to the guidelines, the majority of the HOAs examined is recommended to have a parking requirement of 0.3-0.6 parking spaces per apartment. Only HOA Kajutan with an estimated parking demand of 0.4 complies with this. On the contrary, the estimated bicycle parking demand is overall lower than the municipality's bicycle parking requirements. The municipality's recommendations for bicycle parking vary between 2.0-3.0 bicycle parking per apartment. All HOAs examined have an estimated bicycle parking demand below 2.0 bicycles per apartment.

RQ3: How does the carsharing and bikesharing usage differ between the examined homeowner associations, and what factors influence the usage?

The usage and utilization rate of the mobility services at the HOAs examined varied. Understanding what factors influencing usage is vital when implementing mobility services. The result from the multiple case study indicates that carsharing usage increases when the possibility of owning a private car is limited, for example by low parking requirements. Additionally, the carsharing usage is lower and not as widespread at 55+ housing. From this, it can be concluded that in future developing housing areas, such as Backaplan, carsharing should be made available in conjunction with low parking requirements. In terms of bikesharing, since only HOA Viva has been examined, it is impossible to determine differences in usage and hard to establish what facilitates usage. Only two conclusions can be drawn: electric bikesharing is more extensively used than electric cargo bikesharing, and the overall bikesharing usage and utilization rates are substantially higher during the summer months.

RQ4: How does the prerequisites for parking and mobility services in connection to residential buildings affect the residents' car and bicycle parking demand?

High parking requirements, absence of carsharing, and above-average travel time to city center by public transportation can contribute to higher estimated residential car parking demand. Hence, high car parking requirements are not recommended for housing developments with similar conditions as the cases studied, such as the development of Backaplan. The lower car parking requirement should be supplemented with mobility services such as carsharing and subsidized public transportation cards. In addition, implementation of a MaaS concept and development of mobility hubs are recommended, in order to promote usage of other modes of transportation than the private car.

Car parking farther away from the residence as well as restricted car parking that only allows residents to rent one parking space per apartment can reduce the estimated car parking demand. As a result, it is recommended to locate residential car parking in parking facilities farther away from the residence, with a possible restriction of maximum of one car parking space allowed per apartment. Additionally, findings from the multiple case study shows that low estimated car parking demand is related to few apartments and to below-average apartment sizes.

Findings from the multiple case study shows that below-average travel time to the city center by car, bike and public transportation can result in high estimated bicycle parking demand, while an above-average travel time by public transportation contributes to lower estimated bicycle parking demand. This indicates that residential buildings located relatively close to the city center have a higher bicycle usage. Thus, it is recommended for housing developments with similar conditions, such as the development of Backaplan, to develop large and spacious bicycle storage rooms that corresponds to and facilitates a relatively high estimated bicycle usage.

7.2 Future Studies

Although the authors are thankful for the opportunity to examine real data, such as parking occupancy and carsharing use, privacy rules prevent them from obtaining accurate details about the residents. If conducting a comprehensive survey among residents with personal detailed information, an analysis more linked to socio-economic factors can be carried out. Furthermore, future research will preferably examine a greater number of HOAs. If successfully completed, such a study would provide a better understanding of residents' travel behaviors in relation to their location and other surrounding factors. Future studies should also study a greater amount of housing that offers bikesharing to the residents, so that the benefits of bikesharing, what facilitates usage, and how bikesharing correlates with bicycle parking demand can be investigated. In addition, the analysis in this study is based on data taken during the covid-19 pandemic, therefore it would have been advisable to perform a similar study under normal circumstances and compare the results to obtain the pandemic's impact on residents' travel habits.

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