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Park-and-ride areas for the future of Botkyrka

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INTRODUCTION

BACKGROUND AND MOTIVATION

“Parking is an essential component of the transportation system. Vehicles must park at every destination. A typical car is parked 23 hours each day and uses several parking spots each week. Parking facilities are a major cost to society and parking conflicts are among the most common problems facing designers, operators, planners and other professionals. Such problems can be often defined either in terms of supply (too few spaces are available, somebody must build more) or in terms of management (available facilities are used inefficiently and should be better managed). Management solutions tend to be better than expanding supply because they support more strategic planning objectives as for instance:

- Reduced development costs and increased affordability;
- More compact, multi-modal community planning (smart growth);
- Encourage use of alternative modes and reduce motor vehicle use (thereby reducing traffic congestion, accidents and pollution);
- Improved user options and quality of service, particularly for non-drivers;
- Improved design flexibility, creating more functional and attractive communities;
- Ability to accommodate new uses and respond to new demands;
- Reduced impervious surface and related environmental and aesthetic benefits;”

(Litman T., 2016)

Park-and-ride facilities are often an important part of a regional transportation system because they can provide more travel alternatives by facilitating shifts from car to rail, bus, or carpool (especially for commuters), they can increase the effectiveness of transit systems and help to reduce the need for parking in the central business district (Nicholas, 2004). Usually park-and-ride facilities are oriented towards rail transit serving the central business district and are primarily used by commuters (ibid.). Most park-and-ride areas exist to support transit use by allowing it to draw more riders from a wider area than if riders relied on local bus service or walking and biking to get to a transit stop with

service to downtown. By allowing commuters who might otherwise drive downtown for work to park their cars further out and take transit in, there is less need for parking in the downtown. It is important to note that park-and-ride areas are primarily useful for commute trips and are generally not an effective substitute for nonwork trips (CMMPO, 2012).

The parking charges at park-and-ride areas are not meant to manage the parking supply but they may help to cover some operations and maintenance costs at the facility (Litman, 2006). If a fee is charged, it is preferable to have a system that charges the user for each time he or she uses it so that there is an incentive to supplement travel with other modes if possible.

With the increasing popularity of transit-oriented development (TOD), the place of the park-and-ride in a transit system is changing. In general, park-and-ride facilities are located with as much convenience as possible to the transit station to make using the facilities more attractive. The land close to a rail station is, however, the prime location for the higher density and mixed-use buildings that characterize TOD (Turnbull, Pratt, et al., 2004). If the land value around the train station is low due to the lack of mix of land use, then that area could not have a transit-oriented development and it may be more appropriate for park-and-ride.

A directly related and synergic parking “strategy” is park-and-pool facilities. Unlike park-and-ride areas, these are not necessarily directly served by transit but are instead meant to facilitate carpool and vanpool activities. Suburban employment centers are often difficult to serve with fixed-route transit (bus or rail) but are good candidates for carpooling. Park-and-pool areas are usually located near expressways and major highways in an urban area and are generally smaller than park-and-ride facilities (Turnbull, Pratt, et al., 2004). By increasing vehicle occupancy before drivers get on expressways or major highways, park-and-pool areas help reduce congestion on those roads. The areas also encourage carpool formation between commuters who otherwise live too far apart to consider carpooling (ibid.).

Park-and-ride areas don’t lead directly to an increased number of users for public transport. The primary effect is to re-distribute car flows and this means that the number of car users does not change.

Indeed, people will anyway take the car, also with park-and-ride areas; destinations are what change. Secondly, the increasing of the infrastructural supply for cars could lead to increase their use. This research does not want to calculate the entity of this effect, but anyway inducted demand theories must always be taken into account while managing car facilities. The same effects could be considered for bikes. Moreover, parking areas located on strategic places close to residential areas could lead to an increase of the number of bike users higher than car ones because car costs are higher than bicycle ones and if people must move for short distances to reach park-and-ride areas and then commute to the public transport, then it is reasonable to think that they will use bikes instead of cars (for routine trips and with fair weather conditions). Especially if, on longer distances, there are a few (or any) parking areas or if those are not convenient.

Finally, Johansson (2015) asserts that a large proportion of users of park-and-ride areas can imagine them at a more peripheral location. Prerequisites are high frequency of public transit and that they are safe locations. The design and availability of parking has the potential to shape the look and feeling of a city, the quality of life of its citizens and visitors, and the potential for new growth and development. The need to accommodate parking must be balanced with other competing goals for the built environment such as livability and economic development. It is important to acknowledge that it is impossible to accommodate the land consumption that would be required to park every vehicle since it would prevent any city from achieving its goal of being a livable community.

SCHEDULE

The thesis have been carried out in 20 weeks from October to February, collaborating with Botkyrka for data and with supervisors for theoretical contents. The research followed this time frame:

- First part of October: Analysis of several other Swedish cities' strategies about parking management;
- Second part of October: Literature review of Botkyrka's documents to get data;
- November: Continuing with the literature review about Botkyrka. Writing first paragraphs with the description of Botkyrka transport and parking systems and with the interpretation of

data. First draft;

- December: SWOT analysis. Spatial analysis. Ideas from literature and case studies. Identification and choosing of parking management strategies;
- January: Concluding the thesis and submitting second draft;
- February: Correcting the thesis and submitting it.

2 RESEARCH QUESTIONS AND METHODOLOGY

GOAL AND RESEARCH QUESTIONS

The overall goal is to achieve an efficient and innovative use of Tumba station's parking areas through a "Parking Management Proposal".

This thesis studies planning documents, academic articles and public/private analysis to find out how to manage park-and-ride areas around Tumba train station. The research applies parking management strategies to propose innovative solutions and smart space-uses to Botkyrka municipality which collaborates to this study.

Research questions are:

- How Tumba's park-and-ride areas can become more efficient?
- What parking fee should be applied?
- Which parking management strategies (PMS) should be applied? And how can they function together?

OBJECTIVES

Following planning objectives is useful to structure the proposal and so to achieve the goal. Research's objectives are selected according to Litman's study "Strategies, Evaluation and Planning" (2016) and then ordinated hierarchically considering thesis case study. Objectives are:

- Revenue generation. Some management strategies generate revenues that can fund parking facilities, transportation improvements, or other important projects;
- Supports Smart Growth. Parking management helps create more accessible and efficient land use patterns and support other land use planning objectives;

- Reduces land consumption. Parking management can reduce land requirements and so helps to preserve greenspace and other valuable ecological, historic and cultural resources;
- Supports transit. Parking management supports transit-oriented development and transit use;
- Improved quality of service. Many strategies improve user quality of service by providing better information, increasing consumer options, reducing congestion and creating more attractive facilities.

METHODOLOGY

The research have used data that associate name, address and car ownership in an aggregated manner due to possible ethical issues. Moreover, Botkyrka municipality asked to sign a document to extract data from the Botkyrka municipality's digital base map. This document has been called "license agreement". The municipality's copyright also includes the licensee's processing of the material.

The thesis has been conducted with a high difficulty due to the academical lack of studies about park-and-ride areas and due to the starting vague guidelines from the municipality which instead helped a lot during the research.

The scheme at the end of the paragraph shows the logical and creative process used to set the thesis.

First of all, there was the need of a period of study about local aspects and practices and about Parking Management Solutions (PMS). The knowledge learned has been organized in chapters 3 and 4. In chapter 3 there are literature reviews both of parking strategies in several cities in Sweden and both of academical knowledge about PMS.

Chapter	Technique	Objects	Purpose
3	Literature review	Examples analysis divided in: management policies, parking fees, solutions. Theory about PMS	To learn how other cities solved similar tasks and what are the PMS
4	Literature review	Area characteristics, modal share, accessibility, car ownership, travel time ratio between public transport and car, commuting flows, distribution of the demand, location of parking users	To learn about Botkyrka overall traffic system and
5	SWOT Analysis, multi-variable method to locate park-and-ride areas	Traffic data about Botkyrka	To plan how to act in Tumba and to write the Parking Management Proposal

Table 1 Thesis's methodology: techniques used, their objects and purpose.

In chapter 4 there is an other literature review for a deep description about the transport system in Botkyrka. Literature comparisons have been particularly difficult due to the multilinguistic references, different case studies and examples and due to the lack of information about park-and-ride areas in the transport planning subject.

Secondly the research continued with a SWOT analysis in order to classify and evaluate the most significant and important elements present on the territory. It is an important strategic planning tool, which will allow to identify objectives and strategies that will constitute the research proposal. Moreover, it is useful to summarize all data and considerations made until chapter 4. Depending on the role and effects of the elements identified through this analysis, they are cataloged as strengths, weaknesses, opportunities or threats.

First result of the thesis is the proposal which has been written considering the administrative perspective and so choosing what to do in the short and in the long period.

The core strategy in the long term is to move the current six car parking areas towards more efficient places.

This due to the following reasons:

1. In the Parking Guidelines (2017), Botkyrka municipality writes: "In the short term, parking spots should be provided in areas close to commuter train stations. In the longer term, the land must be used more efficiently"
2. The land has higher value when closer to infrastructures. So, it is not efficient to use the land close to the station for parking areas. That could be instead used for offices or houses. Indeed, the land close to a rail station is, however, the prime location for the higher density and mixed-use buildings
3. Relieving the inner city from cars that would otherwise go directly to the station (which is the center of the city)

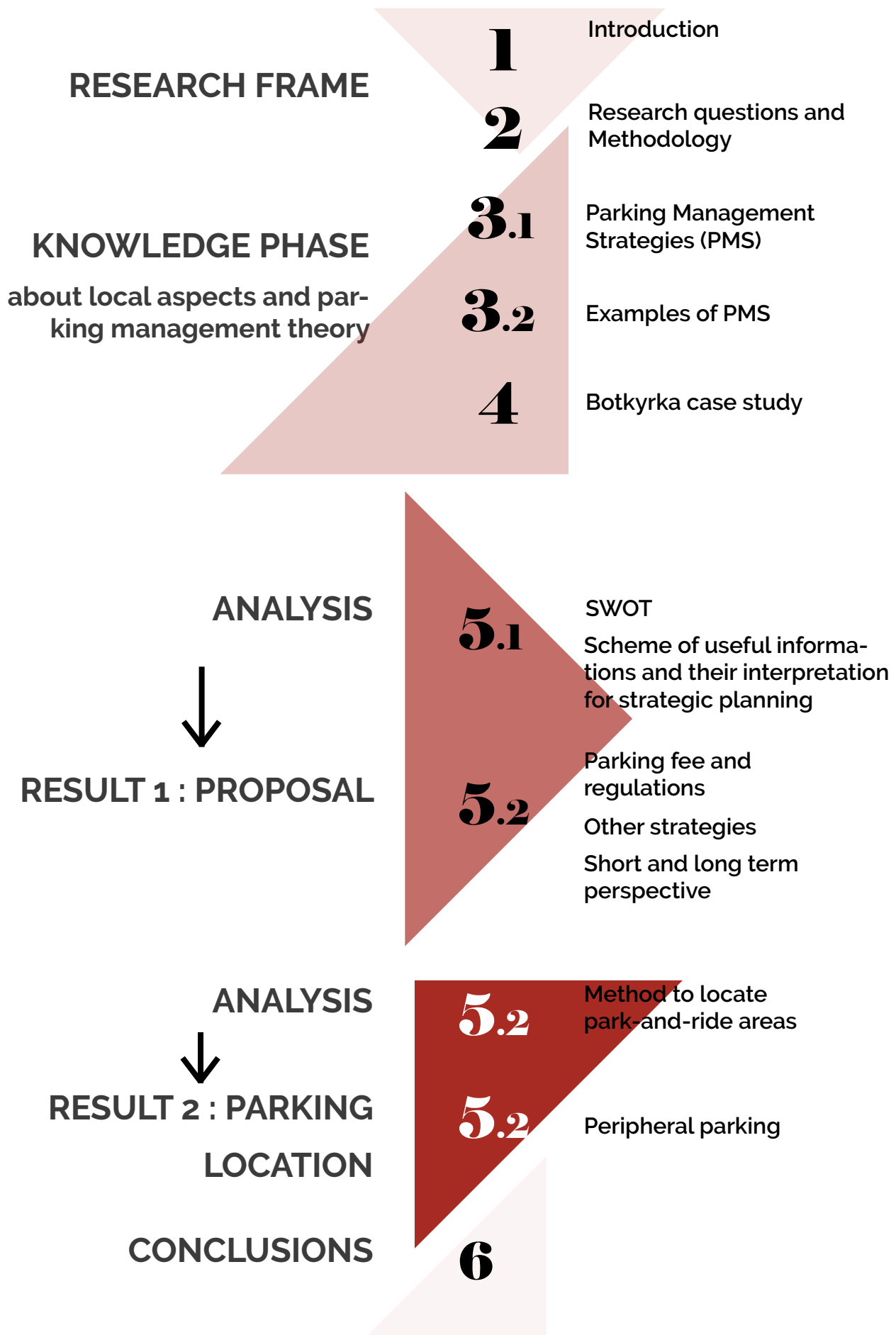
This research studied a method to choose where to (re)locate park-and-ride areas. It is composed of three steps:

1. To analyze the following variables:
 - The origin points of the demand for those parking areas (section 4.2), which refers to the transport demand;
 - Car flows (section 4.3), which refers to the

transport demand;

- Bus stops location and their nearby. For the nearby has been chosen a buffer ray of 400 meters. The same distance has already been used by Botkyrka and other municipalities as acceptable walking distance.
 - Preschool and school locations. Moreover, the presence of schools reminds to the Paquette's research (2018) which asserts the habit of the 63% of his statistic sample to bring children to school before going to the park-and-ride area. The study of these aspects brings to a location analysis map, which refers to the transport demand.
2. To choose the locations and sum them up in a map ("Proposed locations"). **This is the second main result of the study.**
 3. To check the land property. Indeed, changes are easier on public land and, due to SLL guidelines (SLL, 2018), just on public land it would be possible to create "neighborhood land" (kvartermark, look at section 5.1) needed to charge and regulate parking areas.

METHODOLOGY SCHEME



3 LITERATURE REVIEW OF PARKING STRATEGIES

3.1 PARKING MANAGEMENT STRATEGIES (PMS)

SUMMARY

Parking subject effects on other factors have called into question parking policy and management, new aspect of land-use planning which before was not considered. Specifically, concerns about air quality, traffic congestion, and financial feasibility have influenced this shift. Parking management embraces a variety of strategies that seek to either reduce parking spaces needed or to use parking spaces more efficiently. Indeed, the vast amounts of high-value land used as parking spots could be put to better use.

Parking management strategies are divided by Litman (2016) on if they act on spot supply or on user demand. The supply management strategies (S.M.S.) chosen for this research are shared parking, on-street parking and peripheral parking and shuttle service. According to Litman (2016), shared parking typically reduces of 10-30% the parking spots. Peripheral parking (also called remote or satellite parking) can be defined as the use of a parking facility far from the area under analysis (Litman 2016). While the parking area gather car users they can be transferred to commuter train station or to any other polarity by a shuttle bus. About demand strategies (D.M.S.), in this research will be considered: improve user information and marketing, parking regulations and fees.

PMSs can be classified in two categories:

1. Parking Supply Management Strategies:
 - Shared parking;
 - Employer / institutional parking;
 - On street residential parking;
 - On street commercial area parking;
 - Peripheral parking and shuttle service;
 - Park-and-ride;
 - Bicycle parking;
 - Reduce residential street width requirements.
2. Parking Demand Management Strategies:

- Improve User Information and Marketing;
- Parking pricing;
- Elimination of employer parking subsidy;
- Overflow Parking Plans;
- Parking regulations.

From a researcher perspective is important to list all the possible options to have clear what tools could be used. Anyway, this thesis will not go deeply on every one of them, but it explains, at the beginning of every section, which ones are discarded and why. From the list above park-and-ride areas are already considered as one of the possible strategies. This research will continue trying to find synergies between the park-and-ride solution already applied in Tumba and other measures and nevertheless it will try to adjust the use of the park-and-ride strategy itself.

PARKING SUPPLY MANAGEMENT STRATEGIES

Parking management embraces a variety of strategies that seek to either reduce parking spaces needed or to use parking spaces more efficiently. As explained in the section “4.4 Parking rules in Botkyrka” it is difficult to say what the minimum or maximum parking requirements in a region (or in a city) should be, even if specified by land use and standards. About standards Litman (2016) explains that it is possible to use efficiency-based standards. They consider geographic, demographic and economic factors that affect parking demand and “also reflect the relative costs and benefits of different options, so less parking is supplied where parking supply is relatively costly to provide or where management programs are easy to implement” (Litman, 2016).

In this thesis the following supply management strategies will not be considered:

- On street residential parking;
- On street commercial area parking;
- Bicycle parking;
- Reduce residential street width requirements.

The on street residential parking topic focuses on neighborhoods with high demand for parking and/or high parking fees which may push demand for parking into nearby residential neighborhoods.

Park-and-ride areas have as object routine trips and they don't really consider the usual on street parking.

Since the largest peak-period demand for parking comes from home-to-work trips, employer parking management strategies can be very successful at reducing overall vehicle journeys. The goal for an employer who uses parking strategies is to reward people who use carpooling services or who take alternative modes of transportation and discourage or penalize single-occupant drivers. Unfortunately, this research does not aim to speak directly to employers.

Bicycle parking is already considered and, as explained in the previous chapters, it exists already in the area considered.

Reducing the residential street width "allows developers to build new urbanist communities with narrower streets and less parking and rely more on efficient parking management" (Litman, 2016) but the topic of the research is not about nor new buildings nor street renovations.

SHARED PARKING

Shared parking is defined as "the use of a parking space to serve two or more individual land uses without conflict or encroachment" (Smith 2005). The key to shared parking is a mix of uses that require parking at different times of the day, or different days of the week. For example, an office building in the same area as a movie theater would be a good candidate for shared parking. Indeed, the peak hours for office buildings would be in morning and in the late afternoon while for the movie theater they are in the evening and night. Instead of building one parking lot for the office building and another one for the movie theater, the two uses can share a lot.

According to Litman (2016), this strategy typically reduces of 10-30% the parking spots. The San Francisco's Metropolitan Transportation Commission in 2007 prepared a document called "Parking Policies to Support Smart Growth" to evaluate various strategies and their effectiveness at reducing parking demand. In that document (San Francisco's Metropolitan Transportation Commission, 2007) shared parking is considered a strategy with medium/high impact and a typical reduction of 10-20%. Pretty close to the estimations made by Lit-

man.

To use properly this strategy there is the need to analyze the mix of land use and pick hours around Tumba commuter train station.

ON-STREET COMMERCIAL AREA PARKING

On-street parking, as close to a business as possible, is the most convenient type of parking for potential customers and keeping those spots available for short-term use should be a high priority.

Managing parking in commercial areas typically involves setting peak hour, daytime, or 24-hour parking restrictions and establishing parking time limits. The parking charge settled to favorite short-term user is also a measure that favorites on street commercial area parking.

PERIPHERAL PARKING AND SHUTTLE SERVICE

Peripheral parking (also called remote or satellite parking) can be defined as the use of a parking facility far from the area under analysis (Litman 2016). Peripheral parking can also be used as "facilities located at the periphery of a business district or other activity center and use of overflow parking during a special event that attracts large crowds" (ibid.). While the parking area gather car users they can be transferred to commuter train station or to any other polarity by a shuttle bus. If the parking area is placed close to very low-density zones, then users will reach it by car, commute to the bus and reach the inner city, a train station, etc. Indeed, this strategy works if the starting point of car trips is very uncomfortable and/or the density of the region is very low. Sometimes could be time-saving for the user to continue the trip buy car instead of to commute and wait for the shuttle.

PARKING DEMAND MANAGEMENT STRATEGIES

In this thesis the following demand management strategies will not be considered:

- Elimination of employer parking subsidy;
- Overflow parking plans.

The elimination of employer parking subsidy is one of those strategies which regards employers as the one called "on street commercial area parking". For the same reason it will not be considered in this research.

According to Litman (2016) overflow parking plans are the last resource that will be applied when parking facilities fill. Some examples could be “special events, peak shopping periods, or temporary reductions in parking supply” (ibid.). The goal of this research is not to provide a new plan for seldom peaks so this strategy will not be taken into account even if could be synergic and could be a good resource also for park-and-ride facilities.

IMPROVE USER INFORMATION AND MARKETING

The user information and marketing strategy includes all kind of info useful for the traveler such as: the availability of spots in the closest area, where is it located with signals to bring there the user, info about price and regulations and travel options that is not obvious the traveler knows. It can be provided by signs, apps and websites (that can be useful to share real time data), and brochures.

PARKING REGULATIONS

Regulations aim to control who, when and how long vehicles may park at a location, to prioritize parking facility use. The table number 3 describes common regulations and the type of parking activity they favor.

PARKING PRICING

Currently there aren't formal ways to calculate the parking fee for park-and-ride areas. Todd Litman (2008) offers a succinct version of many possibilities:

- Wherever possible, charge motorists directly for using parking facilities. If parking must be subsidized, offer comparable benefits for the use of other travel modes, such as cash out payments;

Name	Description	Favored Activity
User or vehicle type	Spaces dedicated to loading, service, taxis, customers, rideshare vehicles, disabled users, buses and trucks.	As specified.
Duration.	Limit parking duration (5-minute loading zones, 30-minutes adjacent to shop entrances, 1- or 2-hour limits).	Short-term users, such as deliveries, customers and errands.
Time period restrictions	Prohibit occupancy at certain times, such as before 10 am, to discourage employee use, or between 10 pm and 5 am to discourage resident use.	Depends on restrictions.
Employee restrictions.	Require or encourage employees to use less convenient parking spaces.	Customers, deliveries and errands.
Special events	Have special parking regulations during special events.	Depends on restrictions.
Accommodate short-term users.	Provide options for vehicles that make numerous short stops, such as special parking passes.	Delivery and service vehicles.
Residential parking permits	Use Residential Parking Permits (RPPs) to give area residents priority use of parking near their homes.	Residents.
Options for special users.	Establish a system that allows specific parking spaces to be reserved for service and construction vehicles.	Vehicles used for special activities.
Restrict overnight parking	Prohibit overnight parking to discourage use by residents and campers.	Shorter-term parkers
Street cleaning restrictions	Regulations that prohibit parking on a particular street one day of the week to allow street sweeping.	Street cleaning. Insures motorists move their vehicles occasionally.
Large vehicle restrictions	Limit on-street parking of large vehicles, such as freight trucks and trailers.	Normal-size vehicles
Arterial lanes	Prohibit on-street parking on arterials during peak periods, to increase traffic lanes.	Vehicle traffic over parking.
abandoned vehicles	Have a system to identify and remove abandoned vehicles from public parking facilities.	Operating vehicles.

Table 2 parking regulations. Reference: Litman, 2016

- Manage and price the most convenient parking spaces to favor priority users. Charge higher rates and use shorter pricing periods at more convenient parking spaces (such as on-street spaces, and parking near building entrances) to increase turnover and favor higher-priority uses. Prime spaces suitable for short-term use should generally be at least twice as expensive per unit of time as less convenient spaces suitable for longer-term uses. For example, in a central business district charge \$0,25 (2,5 SEK) for each 15-minute period with a two-hour limit, while at the fringe charge \$4 (40 SEK) per day. The ratio between short- and long-term spaces may need occasional adjustment to optimize use;
- Use variable rates that are higher for peak locations and times. Apply performance-based parking prices, which means that prices are set so that about 15% of parking spaces are unoccupied during peak periods (Shoup, 2005). For example, charge \$1 (10 SEK) per hour for parking downtown during weekdays, \$0.75 (7,5 SEK) per hour for parking downtown during evenings and weekends, and \$0.50 (5 SEK) per hour for parking in other locations (ibid.);
- Improve pricing methods to make parking pricing more cost effective, convenient and fair. For example, use electronic pricing systems that accommodate various payment methods and rates, and allow motorists to pay for just the amount of time they will be parked. For short-term parking change by the minute rather than by the hour, and for long-term parking charge by the hour rather than by the day or month;
- Avoid discounts for long-term parking leases (i.e., cheap monthly rates);
- Use a progressive price structure in more convenient spaces to favor short-term users. For example, charge \$1.00 (10 SEK) for the first hour, \$1.50 (15 SEK) for the second hour, and \$2 (20 SEK) for each subsequent hour;
- To increase revenues, expand when and where parking is priced rather than raising rates at existing priced facilities. This is more efficient and equitable, reduces spillover problems, and usually raises more total revenue;
- Set parking prices to equal or exceed transit fares. For example, set daily rates at least equal to two single transit fares, and monthly rates at least equal to a monthly transit pass;
- Minimize discounts for long-term parking passes. For example, set daily rates at least 6 times the hourly rates, and monthly rates at least 20 times daily rates. Even better, eliminate unlimited-use passes altogether. Instead, sell books of daily tickets, so commuters save money every day they avoid driving;
- Eliminate early-bird discounts;
- Unbundle parking, so people who rent or purchase building space can choose how much parking is included;
- Avoid excessive parking supply. Use parking management to encourage more efficient use of existing parking facilities and address any spillover problems that result from pricing;
- Encourage businesses to price, cash out and unbundle parking by providing rewards to those that do, legislating it, or by imposing special property taxes on un-priced parking;
- If parking must be subsidized, use targeted discounts and exemptions, rather than offering free parking to everybody. For example, to subsidize customer parking, allow businesses to validate parking tickets or provide free parking coupons to customers. To subsidize parking for people with low incomes or disabilities, provide discounts directly to those individuals;
- Tax parking spaces and encourage or require that this cost be passed on to users. Reform existing tax policies that favor free parking. For example, tax land devoted to parking at the same rate as land used for other development;
- Charge a tax on curb cuts comparable to potential revenue foregone had the same curb area been devoted to price on-street parking. This would encourage property owners to minimize the number and width of curb cuts, through access management and consolidation of driveways and parking facilities, which helps improve traffic flow and create more pedestrian friendly streetscapes;
- Price on-street parking in residential neighborhoods. Create parking benefit districts, with revenues used to benefit local communities;
- Allow motorists to lease on-street parking spaces;

ces. For example, let residents and businesses lease the parking spaces in front of their homes or shops, which they could use themselves, reserve for their visitors and customers, or rent to other motorists;

- Develop and utilize transportation management associations to provide parking management, user information and brokerage services in a particular area;
- Use parking pricing revenues to fund transportation programs;
- Provide free or discounted parking to rideshare vehicles.

3.2 EXAMPLES OF PMS

SUMMARY

Stockholm uses an interesting way to park bicycles called “bike boxes” which guarantees repair and prevents theft. This city has been chosen because Botkyrka is within Stockholm County’s edges and what the municipality of Stockholm does influences smaller municipalities of the County. Huddinge and Sollentuna are good examples of municipalities under the Stockholm influence because of the prices and regulations chosen for park-and-ride areas. They have been also innovative: Huddinge because of the method and the technology used after Atkins Sverige AB’s study and the collaboration with SL; Sollentuna due to the attention to the role of the mobility manager, to the Safe Traffic Environment project (just cited in this research) and due to the high involvement on biking development. Malmö has been chosen for its parking policies and agreements between the municipality and builder companies. Indeed, through the mobility manager, Malmö reached very interesting agreements to lower the number of parking spots, for instance the builders committed to pay residents’ pool membership in the first five years. Gothenburg, second bigger city in Sweden for number of inhabitants, published recently new guidelines for mobility and parking (2018) to summarize old initiatives and have a clear traffic strategy.

MANAGEMENT POLICIES

The main trend among municipalities is to reduce

the demand of car parking spots and not increase the supply. To reduce car parking demand, they bet especially on increasing bike parking (less spot-space for single person compared to car), on agreements between specialists and builders (as for Malmö and Sollentuna) and on the mutual synergy between strategic and action plans.

PARKING FEES AND REGULATIONS

The average ticket cost for using a spot in the analyzed park-and-ride areas is about 20 SEK / h (around 2 euros per hour) but actually, considering the whole Stockholm County, parking is free of charge almost everywhere. Stockholm has two charges: a regular and a discounted one. To get the discount fee users must start the parking in the morning between 05 and 09 AM.

SOLUTIONS

Measures that can be used to higher the flexibility both of car and of bicycle parking areas are well listed by Huddinge and Gothenburg. In particular Huddinge instituted the Green Travel Plan: a planning toolbox implemented by employers to encourage more sustainable trip-choices among employees. Interesting is also the choice of creating test areas for automatic vehicle parking. The most innovative solution about bike parking is the installation of bike boxes by Stockholm. These blue boxes offer a repaired place for the bike and can have many accessorize as an electric recharge station.

STOCKHOLM

In Stockholm there are 34 park-and-ride areas with 3681 parking spots in total (www.stockholmparking.se).

MANAGEMENT POLICIES

Thanks to park-and-ride areas, Stockholm aims to have less pollutant, especially through the installation of charging stations for electric cars (power outlets are of Typ2 Mode3, up to 3,7 kW), less crowded traffic in the queues and fewer parking on the streets. Main policies are:

1. Create more bicycle parking areas adjacent to garages as an integral part of a mobility solu-

tion;

2. Manage constructions and operations of the city's "bike boxes" in Åkeshov;
3. Introduce bicycle parking rights

(Atkins Sverige AB, 2011)

PARKING FEES AND REGULATIONS

Regulations are very low, indeed most of park-and-ride areas are accessible 24/7. Some of them are opened just on workdays (Monday – Friday) and a few are closed during the night typically between 00-05 AM or 10 PM - 06 AM. The fee is usually divided in two categories: regular and discount. To get the discount fee you must start the parking in the morning between 05-09 AM. The regular charge is between 5 - 20 SEK / hour or 15 – 50 SEK /



Figure 1 Bike box with its typical blue color. Reference: www.stockholmparkering.se

day. The discount fee is between 15-20 SEK / day (or until 18/24 PM).

For the Odenplan bicycle garage are applied the following rent rates from September 1st, 2017:

- Standard bike location: 100 SEK incl. VAT / month;
- Last bike seat: 100 SEK incl. VAT / month;
- Bicycle place with cabinet: 125 SEK incl. VAT / month;
- Bike box with charger: 200 SEK incl. VAT / month.

The garage has the same closing times as Odenplan ticket hall: Mon-To 01:30 to 04:00 AM, Fr 02:25 -

04:00 AM, Sat 02:25 - 05:00 AM, Sun 01:30 - 04:00 AM.

In all parking facilities users pay by card or via the mobile applications "Betala P", "EasyPark" and "Parkster". The same code applies to all mobile services. In particular "Betala P" is made by Stockholm City and it lets you use, as a customer, the application to pay on all parking facilities and on streets for which the city is responsible. "Betala P" is cost-neutral which means that no additional fees are added to the parking charge. Users can download "Betala P" from Appstore or Google Play and create an account before starting to park. "EasyPark" and "Parkster" are mobile applications owned by private companies and they don't require any payment to download the app.

SOLUTIONS

In Stockholm there are four different kinds of bicycle parking spot:

1. A bicycle garage, where there are only bicycle locations for rent. The garage is called "Odenplan bicycle garage" and it has about 300 rented bicycles spots on two-level stand (also called "structured spots"). There are also six bike boxes with electric bicycle storage and three bicycle storage bays. The unit is camera-controlled and there is a common air pump and sink to wash hands. The first 70 places in bicycle racks (number 1-70) also have access to a small cabinet where you can storage the helmet;
2. Bike boxes located in Odenplan garage and in Åkeshov. Bike boxes can be with a key lock or with electric door locks. There is also the opportunity to lock the bike inside the box with

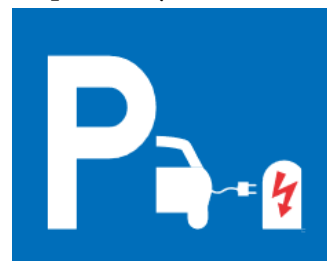


Figure 2 This sign indicates the possibility at the parking area to recharge your electric car.

Reference: www.stockholmparkering.se



Figure 3 "SL ACCESS CARD APPLIES". Free parking for those who own a public transport card with an active 30-days ticket. Reference: stockholmparkering.se

wires around the rail. The box is about 1.3 meters X 2 meters and the monthly rent is 100 SEK;

3. Free bicycle parking spots;
4. Bicycle parking right for customers who rent a car. Bicycle parking right means that you, as an existing car renter, can park your bike in specific facilities.

Between October 1, 2010 and August 31, 2011, an attempt was made at six Stockholm Park's park-and-ride areas where SL travelers who have a ticket loaded with 30 days or longer memberships can park free of charge. A reader on the car machine reads the SL access card, after which a ticket is solved. "Stockholm Parking" (Parkingare) is responsible for the operation and maintenance of the ticket selling machines and parking areas. For this attempt, Stockholm Parking has entered into an agreement with SL that a valid pass card provides free parking. Stockholm Parking and SL share the cost of subsidizing parking for SL users.

The following parking facilities are included in the attempt: Farsta strand, Hanviken (Skrubba), Hökarängen, Johannelund, Råcksta, Rågsved

GOTHENBURG

MANAGEMENT POLICIES

In the "Mobility Guidelines" published in 2018 Gothenburg municipality says that the number of bicycle parking facilities planned should be extended in central Gothenburg within easy walking distance to target points. Bicycle parking will also be arranged at park-and-ride areas, at shuttle parking and at all major public transport stops. It adds design directives as for instance that the parking spots should be safe, of good quality, have weather protection and there should be possibilities for locking or fixing the bike.

Extracts from the "Strategic action plan" (2014):

- Change today's car spots in downtown;
- Plan for unchanged availability to the Event Area;
- Prioritize car pooling;
- Use fees and time-limited parking to reach the

goals;

- Prioritize short-term and half-day parking;
- Available parking for accommodation at block land;
- Prioritize urban environment before car parking;
- Adjust the car parking to the cityscape;
- Replace land parking with joint facilities;
- Build safe and attractive.

The Gothenburg vision for car parking is that it will be easier in the inner city, but there will be less spots on streets and on squares and the price will reflect what it costs to build new parking spots on attractive land.

In the "Parking Policy for the City of Gothenburg" adopted by the City Council in 2009 there is a focus on redistributing space between different modes of traffic to create the conditions for attractive, lively and thus safer urban spaces. In the same document Gothenburg administration asserts that the handling of parking spots in urban environments is a key issue for the opportunity to create space for city life. The parking policy points to the need for more bicycle parking near to cyclists final destinations. Streets, which today are parking for cars, need to be released because parking spots are more and more placed in parking facilities. The city's ongoing work on bicycle programs and guidelines for parking in the inner city of Gothenburg concretizes solutions to these issues.

PARKING FEES AND REGULATIONS

In Gothenburg there are several fee levels for street parking in the inner city and near suburbs, which goes from 8 to 30 kr / hour, between 8 AM and 22 PM or 8-18. Accommodations with parking permit pays between 190 and 635 kronor per month.

SOLUTIONS

The following solutions are repeated and further developed both in the "Parking Policy for the City of Gothenburg" (2009) and in the Traffic Strategy (2013).

- Reserved parking spots for car pool area local squares, key points of interest and hubs;

- Redistribute the floor space and create more space where people want to stay and move (surface);
- Move car parking from street to parking facilities;
- Build more bicycle parking in the dense city environment. Offer bicycle services in the form of such as service;
- Provide more spots for car pool and loan bikes;
- Work with flexible use of the floor space, such as bicycle parking or seat furniture during spring, summer and autumn and car parking at other times;
- Create test areas for automatic vehicle parking;
- Reduce car speed within the city.

MALMÖ

MANAGEMENT POLICIES

Malmö city applied so-called flexible parking standards. Indeed, in addition to the area-specific conditions, the municipality entered into agreements with the builders. In the agreement builders committed to implementing the car pool and bicycle pool, providing attractive bicycle parking and a series of other management measures and behavioral measures. The builders also committed to pay the residents' pool memberships in the first five years to make it easy to establish a sustainable behavior. The agreement also included that the property owners redeemed 170 parking spots for the municipality, which was instead organized in an existing parking garage. In return, against the builders' commitment, Malmö lowered the parking rate by 30 percent, from 1.0 to 0.7 (plus 0.1 for visiting). The agreement also includes that property owners annually report the car ownership to the municipality for them to follow developments. In a survey conducted at the end of 2012 (Stjärnkvisst A., 2013), the car ownership was 0.6 cars per apartment, i.e. slightly lower than the lowered parking space and significantly lower than the original parking standard. The car ownership in Fullriggaren (one of the main neighborhoods) is also lower compared with other neighborhoods in the Western Harbor, which has not been treated with MM (mobility

management) measures in the same way: in Bo01 (the important neighborhood) the car ownership is 1.06 per apartment while Turning Torso is 0.9 cars per apartment.

PARKING FEES AND REGULATIONS

Malmö charges for street parking in the inner city, between 10 and 25 SEK per hour, either 24 hours, 09-18 or 09-20. Accommodation with a parking permit pays between 15 and 25 kr per day, that is, a little more than one hour's fee.

SOLUTIONS

- The builders committed to pay the residents' pool memberships;
- Great cost savings for builders who provides adaptations to the current demand for parking;
- Additional reduction of the p-standardized by car pool in more mobility measures combination;
- Minimal p-norm for offices / operations with mobility measures;
- Parking-house.

HUDDINGE

Within Huddinge municipality there are car park-and-ride areas located at the commuter train stations in Huddinge (2 park-and-ride areas), Stuvsta (2 parking lots), Trångsund (3 parking lots), Flemingsberg and Skogås. Park-and-ride areas for bicycles is varied at all stations. A total of 1135 parking spots are available for car parking and 1037 scheduled parking spots for bicycles (Atkins Sverige AB, 2011).

Parking spots are in most cases taxed, and the municipality of Huddinge is responsible for parking fees. The spots repartition is:

- Flemingsberg: 200 spots (parking fee for all);
- Huddinge station, west side: 112 places;
- Huddinge station, east side: 86 spots (parking ban at night 02-05);
- Skogås: 26 spots (parking fee, free of charge for those who have SL's ticket for 30 days or lon-

ger);

- Stuvsta station, east side: 94 spots (parking fee, free of charge for those who have SL's ticket for 30 days or longer);
- Trångsund: 65 spots (parking fee, free of charge for those who have SL's ticket for 30 days or longer).

MANAGEMENT POLICIES

Huddinge municipality offers the possibility of flexible parking spots for new development projects and rebuilding of homes and businesses. Flexible parking means that a reduction in parking rates is offered to the builder / property owner committing to implement measures that can reduce the demand for parking. For a reduction to take place, the land under construction must be located in an area with good access to public transport. Huddinge is divided into three areas: Zona A (the center), Zone B (the closer area to the center) and Zone C. Being offered a flexible parking space in Zone A or B is not a right the developer / property owner has but it is determined by the municipality. The structure generally provides a subsidy for the builder / property owner in the form of lower housing costs.

Atkins Sverige AB (2011) highlights that car parking facilities can eventually be transformed into more land, environment and cost-effective use in the form of offices or housing in accordance with the municipality's goals of sustainable development.

The infrastructures and parking areas in Huddinge are owned by SL, although they are formally located on the municipality's land, and there is a cooperation between operation and maintenance. For most of the facilities, the park-and-ride areas and all related accessories are SL's property including to the foundation, surface covering, fencing, water pipelines, lighting and electrical installations and signs. SL has been responsible for investments and maintenance costs for all park-and-ride in Huddinge (the parking facility at Murvägen i Trångsund excluded). Huddinge municipality is responsible for contracts, for operation, ongoing maintenance and supervision (Atkins Sverige AB, 2011).

Expected investment costs per facility including administrative costs and information are estimated at approximately SEK 230,000, including 20% surcharge for uncertainty (ibid.). Existing opera-

ting costs are expected to increase due to the operation of parking machines as well as possible cash. Operating costs are assessed increase by approximately SEK 9,200 per facility per month, of which approximately one third is the cost of expanded monitoring (ibid.).

PARKING FEES AND REGULATIONS

Park-and-ride areas permits 24 hours line-up. The percentage using the park-and-ride areas according to the intended purpose is less than 50% (Atkins Sverige AB, 2011). Applications include free parking for residents, workplace parking and visitor parking to nearby businesses and shops in connection to the stations (ibid.).

In 2018, Huddinge introduced parking fees on park-and-ride areas. Those who do not have a monthly SL pass, or longer fare, pay a fee of 10 SEK per hour up to 40 SEK per day. In Huddinge municipality it has been seen that almost half of the spots are used by park-and-ride areas users (Botkyrka municipality, 2018).

SOLUTIONS

Below there are suggestions that should be included in a future action plan about parking. In some cases, there are concrete measures that should be carried out while in other cases there is a need for further investigation (Huddinge municipality, 2016):

- Investigate how a system of parking fees should be designed and how this should be organized;
- Extend and permanently attempt the fees on park-and-ride areas;
- Determine where and to what extent parking and bicycle parking charges should be available;
- Provide procedures for how the municipality can apply flexible parking rates;
- Meet the need for additional bicycle parking at stations and center;
- Review the timing of existing car parking spots to steer correctly use and increase accessibility;
- Follow the inventory that has been completed to see where there is available parking which can be used for additional buildings or alternatively used to other purposes;

- Investigate demand for loading and car parking spots for the construction of the future parking facilities, as well as the possibility of supplementing existing facilities with charging stations and car parking spots;
- Further investigate possibilities for using cars charged with fuel cells or solar cells.

In the case of flexible parking spots, the percentage of parking spots for people with disabilities shall be calculated before reduction is made. No reduction is made in the number of disabled people. The measures are implemented and financed by the developer / property owner. In return, this discount is obtained in the form of lower requirements for number of car parking spots. Measures that can be used to higher the flexibility are for instance (Atkins Sverige AB, 2011):

- A bicycle pooling service set up for residents where they can borrow bicycles and electric bicycles;
- Membership in the car-pooling service is guaranteed for residents for at least five years and the annual fee for;
- The car pool is included in the rental rent / fee;
- Parking is possible in a larger facility;
- Real investment and operating costs for parking are distinguished from the rented housing /charge;
- Newly introduced starter package including bicycle renting card, SL card (at least one-month card in SL traffic included in occupancy) and information about public transport, bicycle room and others mobility measure;
- Continuous promotion of the various Mobility Management measures addressed to each household twice a year;
- Own mobility solutions (e.g. delivery / cold rooms);
- Annual follow-up of car ownership among the residents of the property in order to be able to follow up demand for parking.

In 2016 Huddinge municipality instituted the **Green Travel Plan** to accept a reduction in parking space in the case of new and / or rebuilding activities. The Green Travel Plan can be described as a

planning toolbox **implemented by employers** to encourage more sustainable travel choices among employees.

Below are listed actions that the Green Travel Plans may contain (Huddinge municipality, 2016):

- Introduction of parking fees at the workplace (desirable if the user of parking lot pay per time and not through monthly subscriptions);

Good shower and changing room to facilitate pedestrians and cyclists;

- Individual transport advice to employees;
- Service car pool that minimizes the need to go with your own car to work;
- Service bikes for the employees;
- Perform annual "try on" campaigns, such as test travel campaigns for public transport and test stamp campaigns for cycling;
- Subsidized public transport cards to employees.

The more actions the builder / property owner takes on and the longer is the long-term commitment then the more the parking space can be lowered. Usually an agreement is signed between the municipality and the developer and / or the property owner where the latter pays and guarantees that a Green Travel Plan is made and that behavioral actions will be implemented in connection with the use of property. In return, the municipality decreases the parking space for the development (Huddinge municipality, 2016).

SOLLENTUNA

MANAGEMENT POLICIES

Sollentuna focused its management parking policy especially on flexible parking and mobility management (Trivector, 2014). In particular, in Sollentuna the planning negotiation practice is developed and mature at the point that if the municipality owns the land, mobility management requirements may be already written in the permission to build, otherwise there will be a negotiation in connection with the retail or construction law (ibid.). To create an economic incentive for the developer, it receives a discount on the cost of mobility management measures. For residential real estate, the municipi-

ality usually asks to the developer to ensure that the car pool is established and its membership is included for the first five years. Other measures imposed by municipalities are that the developer will provide attractive bicycle parking within the property, indoors and outdoors, providing to new tenants with a welcome package consisting of public transport tickets, discounted bicycle prices, etc. that will make it easier for residents to try and continue traveling other than with own car. In new buildings or new entrants, the municipality can also offer personal travel advice to inform the new entrant about the conditions for a more sustainable traveler.

To encourage electric vehicle, use, charging stations for electric cars should be introduced at several parking spots in strategic locations both on street spots and parking facilities. No matter where, charging stations should be in the most attractive parking areas, near entrances or elevators, etc. to further stimulate their use (Trivector, 2014).

PARKING FEES AND REGULATIONS

Sollentuna municipality has a total of 599 spots on its park-and-ride areas. The fee to park is 20 SEK for 12 hours (www.sollentuna.se). It is possible to pay via SMS, the app SMS Park and via payment card. It is also possible to extend the parking period via SMS and app. There is a parking ban for several hours once a week, at night, in all the parking spaces in question. The prohibition times vary between parking areas to make it possible to park at park-and-ride areas even at night.

SOLUTIONS

- Provide guidelines about mobility management actions that developers can carry out in newbuildings to, for example, motivate a discount in the form of lower parking rates;
- Trivector (2014) analyzing Sollentuna explains that physical measures can be for example shower and change possibilities in the workplace, safe and accessible bicycle parking, car pool, telephone and video conferencing equipment, flexible working hours or the opportunity to work from home. In addition, incentives and instruments can be applied to encourage and control travel in the desired direction, such as parking fees can be introduced to subsidize public transport tickets to those who choose to travel collectively;

- Develop existing travel policies for the municipality with guidelines about how employees should travel as well as suggestions for other measures that encourage sustainable travel;
- Developing Green Travel Plans to promote a more sustainable journey. A green travel plan may include actions such as: meeting and travel policy, introduction of a car pool and bicycle pool, etc. ;
- Continue and develop the Safe Traffic Environment project (promoted from Sollentuna's municipality) around schools to get more students (as well as parents and employees) to go and ride a bike to school. In addition to physical infrastructure measures for increased road safety, it is also important to work with students and their parents to establish healthy travel.

Trivector (2014) highlights how important is to develop bike infrastructure both at home and at the destination points. Indeed, bicycle parking facilities should be available at all important points of interest in Sollentuna such as public transport, workplaces, schools, leisure facilities, centers and services. To give priority to cyclists, bicycle parking places should be closer to the corresponding car parking areas and be provided with good lighting and frame locking. Bicycle parking is particularly important at Sollentuna's commuter train stations to facilitate the change between bicycle and commuter train. The bicycle parking at the commuter train stations should be equipped with ceilings, lighting, frame locking and bicycle pump. Exactly what standard that applies to homes, businesses and public transports, etc. is proposed to be included in a future parking policy.

Below there are examples of guidelines useful for a parking policy (Trivector, 2014):

- Standards need to be developed and, for example, divided into three areas: center areas, out-center areas with lower exploitation and access to service, as well as other municipalities (currently there are not parking standards in Sollentuna);
- Flexible parking space, i.e. what conditions / measures can lead to departures from the parking standard (e.g. localization location in the municipality, public transport standard in the area, introduction of car pool and other types of MM actions);
- Acceptable walking distance from parking for

- visitors, residents, active, commuter carriers;
- Guidelines for parking charges and timing.

OTHER FEES

For a better understanding of parking fees within the Stockholm County, it has been made an analysis between fees of several different cities of which the park-and-ride areas were managed by SL, the regional traffic agency.

Municipality	Fee	Other regulations
Danderyd	Free	07–16 with permission. After 16 without
Ekerö	Free	-
Haninge	Free except in the parking lot in the parking garage	Ban between 02–04. Garage free for SL card with 30 days on
Järfälla	Free, except in the parking lot in the parking garage	Garage free for SL card with 30 days on
Nacka	Free	
Norrtälje	Free	
Nykvarn	Free	
Nynäshamn	Free	
Salem	Free	
Sigtuna	Free	
Södertälje	Free	
Tyresö	Free	
Täby	Free	
Upplands-Bro	Free	
Upplands Väsby	20 kr for 12 hours on weekdays	Free on Saturdays, Sundays, holidays and day before holiday. No limit to how long you may be parked
Vallentuna	Free	
Vaxholm	Free	
Värmdö	Free	
Österåker	Free	

Table 3. Analysis of the regulations of park-and-ride areas under SL management.

Municipality	Policies	Fee and regulations	Solutions
Stockholm	Create more bicycle parking places adjacent to garages as an integral part of a mobility solution; Manage construction and operation of the city's "bike boxes".	Regular fee: 5 -20 kr / hour or 15 – 50 kr/ day; Discount fee: 15-20 kr / day (or until 18/24 o'clock). Discount if parking between 5.00-9.00 AM.	SL card charged with 30 days or more provides free fee; Odenplan's bicycle garage; Bike boxes; Bicycle parking right for car renters.
Gothenburg	Parking spots placed in parking facilities; Prioritize urban environment before car parking; Redistributing space between different modes of traffic.	Fee: 8 to 30 kr / hour, between 8 AM and 22 PM or 8-18. Accommodations with parking permit pays between 190 and 635 kronor per month.	Car pooling; Use fees and time-limited parking to reach the goals; Prioritize short-term and half-day parking.
Malmö	Flexible parking; Mobility management.	Fee: 10 and 25 SEK per hour, either 24 hours, 09-18 or 09-20. Accommodation with a parking permit pays between 15 and 25 kr per day	The builders committed to pay the residents' pool membership; Great cost savings for builders who provides adaptations to the current demand for parking; Additional reduction of the p-standard by car pool in more mobility measures combination;
Huddinge	Flexible parking; Mobility management.	Fee : 10 SEK / hour up to 40 SEK / day.	Determine where and to what extent parking and bicycle parking charges should be available; Green Travel Plans; Meet the need for additional bicycle parking at stations and center;
Sollentuna	Flexible parking; Mobility management.	Fee: 20 kr for 12 hours.	Offer developers Mobility Management advice for major exploitations; Green Travel Plans; Parking standards.

Table 4 City comparison about parking management policies, fees and solutions.

4 BOTKYRKA CASE STUDY

In Sweden, the major level of traffic plan for local administrations is made by the Traffic Strategy which is voluntary and which is already the result of a multilevel process. The Traffic Strategy is made of several topics (car traffic, walking strategies, bicycle mobility aspects, etc...), different levels (from national to local) and shall be specified in the Traffic Plan. The Traffic Plan consists of several sub-plans as, for instance, the Parking Plan. In theory, before the Parking Plan is developed, its tasks and long-term goals are clarified in the Traffic Plan because the Parking Plan is hierarchically under the Traffic Plan. All traffic plans shall contribute to the overall objectives of the Traffic Strategy. The purpose of a Parking Plan is to develop effective and useful tools to take well-balanced decisions that realize the comprehensive plan's goals and the Traffic Strategy's objectives and vision.

4.1 GEOGRAPHICAL DESCRIPTION OF BOTKYRKA

Botkyrka is a municipality within the Stockholm County in the south-west from Stockholm which borders with Ekerö Salem, Södertälje, Nynäshamn, Haninge and Huddinge. It has about 92145 inhabitants and a total area of 197 km². The municipality consists of five districts: Alby, Fittja, Halunda-Norsborg, Tullinge and Tumba-Grödinge.

This section uses mainly data from "Statistics Sweden", a government agency that brings official statistics to the public. The last check of all data here used was on January Friday 18th 2019. If not spe-

Botkyrka in 1970, approximately 25,000 people lived in the municipality. Only ten years later, nearly 65,000 people lived in the municipality. After that, Botkyrka has had a population increase of about 1.5 percent annually, in line with the County. In the regional plan (RUFs, 2010), the municipality's population is estimated to be between 117000 and 137000 in 2040. According to Botkyrka's Overview Plan (2014) the strategic local plan, the largest part of the exploitation will occur in northern municipalities. There, more than 40 percent of all new homes in the municipality will be built. The rest will be built in Tumba and Tullinge. In Grödinge, about three percent of all new homes will be built. Botkyrka has had a population with a low middle age. By 2017 the average age was 37.5 years. In

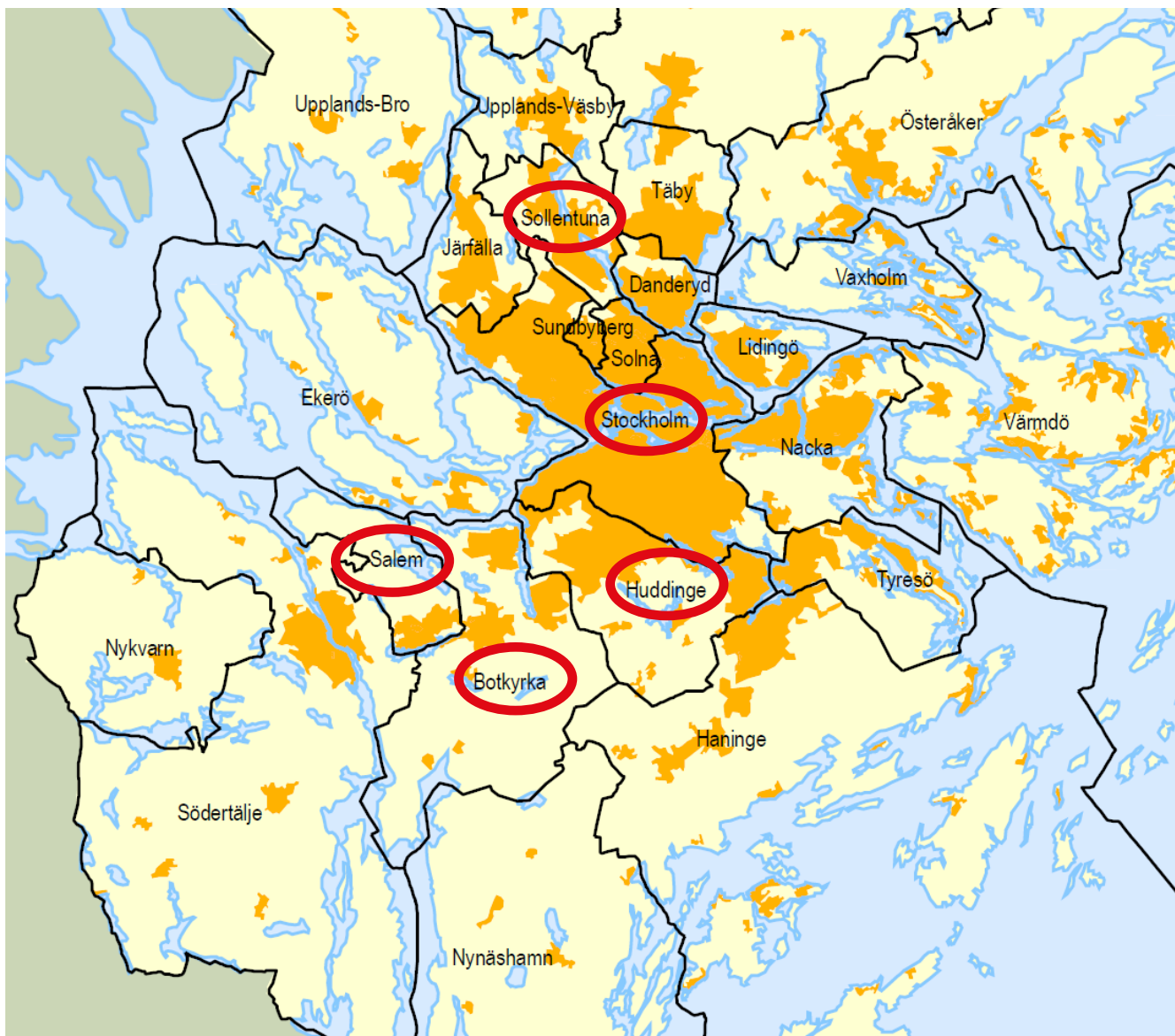


Figure 4 Stockholm County. In red the main municipalities for this research. Reference: WWW.LANSSTYRELSEN.SE

cified, data are from www.scb.se, otherwise there will be the relative reference.

Before the large-scale occupation of northern

the County the average age was 39 years. The proportion of those under the age of 20 in Botkyrka is about 25 percent.



Figure 5 Botkyrka municipality divided in its main districts. Uttran has been added for research purposes. Reference: WWW.BOTKYRKA.COM

There are approximately 25600 jobs and 6000 companies in Botkyrka. Botkyrka municipality is the largest employer with approximately 6000 employees. Other major employers are Alfa Laval Nordic AB and De Laval International AB. Approximately 90 percent of all other employers have fewer than 5 employees. Most jobs are in Tumba, approximately 10,200. In northern Botkyrka there are 9,400 jobs of which in Tullinge around 3,700. This means that there are 37 workplaces of 100 inhabitants aged 20 and 64 in northern Botkyrka. They are next as many as in Tullinge, where they are 34 every 100 inhabitants who are between 20 and 64 years old. In Tumba there are 59 workplaces each 100 people who are between 20 and 64 years old. In Tumba live around 17700 people (www.botkyrka.se, 2017-02-

10). Grödinge has a population of about 4344 and has seen this a greater proportion of residents using the shuttle parking than the Tumba municipality.

Main transport nodes are Tumba and Tullinge, where there are the only train stations, and Nor-sborg, where it is present the red metro line number 13. There is a rich net of bike lines that connects main parts of the municipality and the countryside as well.

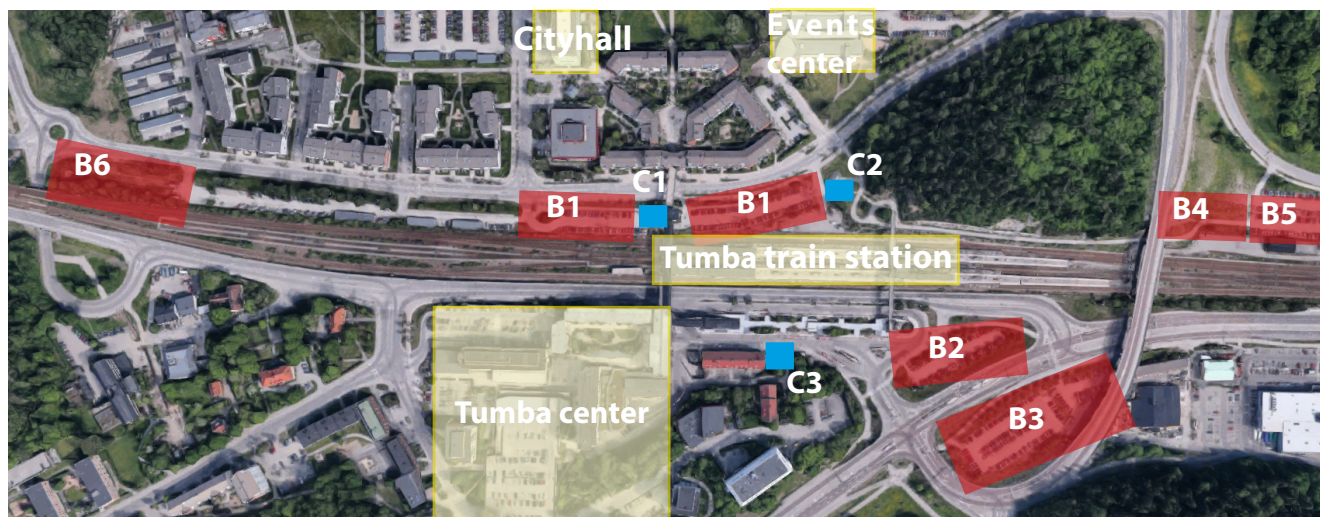


Figure 6 Park-and-ride areas location. B (bil) for car parking and C (cykel) for bicycle.

4.2 THE PUBLIC TRANSPORT IN BOTKYRKA

All data of sections “Transport modes and flows”, “Bicycle”, Public transport” and “Commuting” are from the source: Botkyrka Municipality, 2018. *Nulägesanalys av Botkyrkas transportsystem år 2018* (Current state analysis of the Botkyrka transport system by 2018). This source is not published yet but it is an internal document of Botkyrka municipality. In this paragraph the Botkyrka transport system will be described. More specifically will be analyzed strategies on official documents, modal share and flows, the use of bicycle, the public transport and the relations with close municipalities.

SUMMARY

The following chapter is full of data. To have an easier and lighter reading and to make order among

data, the most significant for this research are summed up in the table number 4.

TRANSPORT SUBJECT ON OFFICIAL DOCUMENTS

In the Botkyrka Overall Plan published in 2014 there are strategic visions about how the transport system will look in the future and how it will be developed. There are also five planning strategies and two of the strategies have a strong link to transport:

- Climate-smart life. The municipality wants to make it easy to use public transport, walk and cycle. It must be possible to live without a car;
- Place to grow. Build in already built areas, close to public transport.

In Botkyrka Municipality's Bicycle Plan published in 2010, the goal is to carry out several investments to improve the cycle infrastructure by 2020.

Botkyrka modal share					%	
Car					52	
PT					30 (up to 80% considering commuters from Botkyrka to Stockholm)	
Bicycle					3	
Pedestrian					9	
Other					6	
Main daily car flows						
			north - northeast		south-southwest	
from Botkyrka			25000		3000	
to Botkyrka			8000		3500	
Botkyrka modal share for specific purposes						
	To work (%)	2013-2017	To shop (%)	2013-2017	To recreational activities (%)	2013-2017
Car	41		60	-2%	50	-6%
PT	42	-7%	16	3%	20	
Bike	5		19		22	2%
Walk	9		3		6	4%
Other data						
Daily journeys/person:			2,1			
Car	% (within all car users)			Bike (within 2.5 km it is faster than a car)		
within 5km	30			average speed		16 km/h
within 2km	15			2 km		6 minutes
				5 km		18 minutes

Table 5 summary of the section “the public transport in Botkyrka”

Other goals are:

- Botkyrka municipality should be a municipality with good conditions for cyclists with bicycle paths that are attractive, accessible, traffic-safe and coherent;
- Promoting to municipality's residents the bicycle opportunities.

The program for a fossil-free Botkyrka by 2030 published in 2016 contains action paths and proposals for activities to be carried out. Here there are listed its priority actions:

- Reduced travel and transportation needs;
- More efficient travel and transportation;
- Public transport instead of car;
- Walking or cycling for short trips instead of cars;
- Renewable fuels vehicles.

Botkyrka aims to accommodate 20.000 new ho-

mes by the year 2040. One of the aims of the comprehensive plan is to densify and build near to public transport modes, to increase the conditions for walking, cycling and using the public transport. To build close to attractive public transport nodes, the land needs to be used more efficiently. A dense city creates proximity and it benefits from walking and cycling traffic as well as providing better support for service and public transport.

The Stockholm County's traffic office (Trafikförvaltningen) “is responsible for ensuring that Stockholm County residents and visitors travel safely and in an accessible and sustainable way by public transport in the county” (www.sll.se). Based on the traffic office's data from the county's travel survey from year 2015, the municipality of Botkyrka conducted an analysis within the municipality. The survey shows that 56 percent of all trips to, from and within Botkyrka are by car. Public transport journeys are 30 percent and bicycle trips are 3 percent.

Car is the most common travel mode betwe-

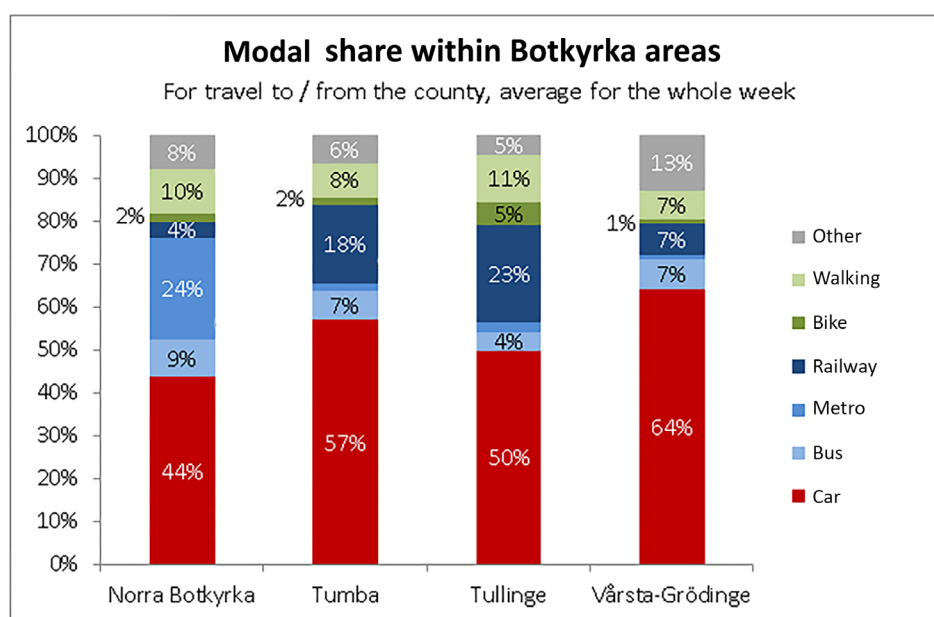


Figure 7 Modal share within Botkyrka areas. Reference; Botkyrka municipality 2018.

en Botkyrka and the other municipalities in the southern part of the county, indeed during weekdays car trips are about 66 percent of all trips. Car is the most common mode of traveling also for trips between districts, 72 percent, and within the same district, 52 percent. For trips to other municipalities in southern part of the County, about 70 percent travel by car.

The survey published in 2015 by the Stockholm County's traffic office shows that Botkyrka's inhabitants make 2.1 journeys per person daily, which is the lowest in the County. In the northern part of Botkyrka, journeys are more traveled by public transport than in the other districts, 37 percent. Indeed, in Tumba and Tullinge, the proportion of public transport is respectively 27 and 29 per cent; 15 per cent in Vårsta Grödinge.

More than 30 percent of all car trips in Botkyrka are shorter than five kilometers and 15 percent of all trips are shorter than two kilometers. At an average speed of 16 km / h it takes six minutes to cycle two kilometers and 18 minutes to cycle 5 kilometers. It is usually faster to ride a bike for 2.5 kilometers, because you do not have to look for parking and go to and from the car.

The vehicle distribution over the period 2005 - 2015 has changed both according to a survey published in 2005 by the National Travel Agency and according to the survey by the Stockholm County's traffic office published in 2015. In these researches, the questions were about journeys made during a designated day. Proportion of public transport

journeys with destination in the Stockholm region increased by 17 percentage points, excluding trips within Botkyrka. Car journeys decreased by 4 percentage points and walking and cycling trips were halved.

Once every two years, the municipality of Botkyrka does a survey, which includes questions about how they usually travel. The investigation published in 2017 shows that 41 percent of inhabitants go to work by car, 42 percent by public transport, 9 percent walk and 5 percent bikes. Between the period 2013-2017 travels by car increased by three percentage points, the cycling by four percentage points, and walking by one percentage point. The proportion of travels who used the public transport to the work place decreased by 7 percentage points.

The citizens survey from 2017 shows also that 60 percent choose the car when shopping, 16 percent public transport, 19 percent go shopping by walk and 3 percent by bike. For this purpose, between 2013-2017, car travels decreased by 2 percentage points, public transport increased by 3 percentage points while walking and cycling remained at the same level.

In the same survey, 77 percent of Botkyrka's inhabitants answered that it is easy to move by car. This share is equal to the county average and in the neighboring municipalities of Huddinge and Salem the value is respectively 76 percent and 86 percent.

In 2017, 50 percent traveled by car to and from recreational activities, 20 percent by public transport,

Modal share toward the workplace

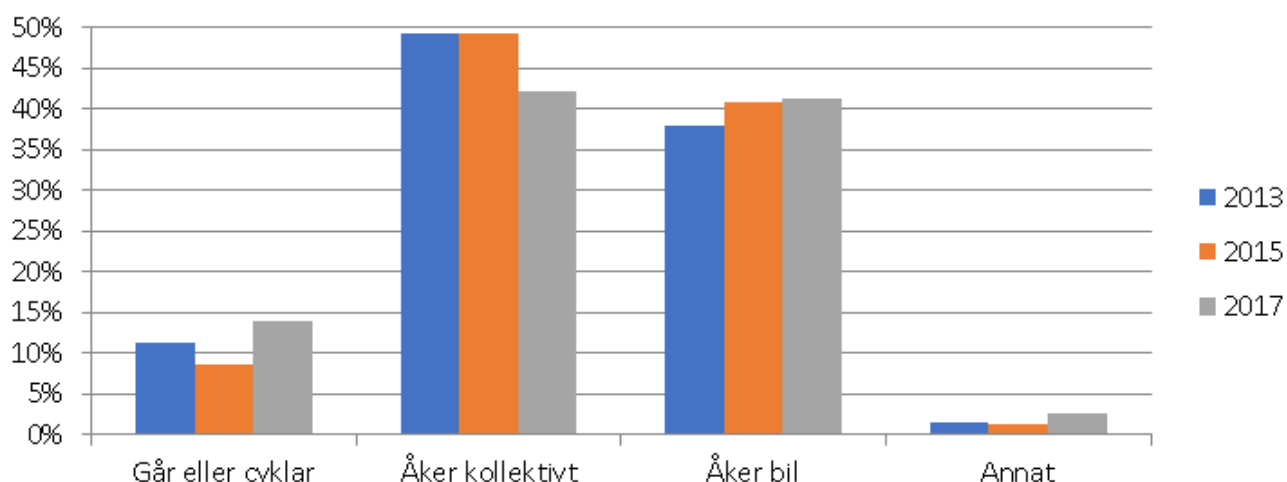


Figure 8 modal share toward the workplace. From the left: walking and cycling, public transport, car, other. Reference: Botkyrka municipality, 2018

22 percent by foot and 6 percent cycled. For journeys to and from recreational activities, car racing decreased by 6 percentage points between 2013-2017. Walking increased by 4 percentage points, cycling increased by 2 percentage points and public transport was at the same level.

BICYCLE

Stockholm County's traffic office published in 2015 shows also differences between women and men about cycling habits, indeed women tend to go less by car and more by public transport. The biggest difference between men and women is in northern municipalities. In Botkyrka, 36 percent of women

and 52 percent of men travel. The difference is 16 percentage points. In Tumba the difference is 10 percentage points.

Botkyrka municipality measures yearly how residents assess different aspects of living in the municipality. The measurement is done through a citizen survey. The survey contains several questions about traffic and outdoor environments.

In the citizens survey from 2017, Botkyrka's inhabitants graded walking and cycling routes with 6.8 on a scale from 1 to 10. The average for Stockholm County is 6.5, and for neighboring municipalities of Huddinge and Salem the value is 6.8 and 7.3, respectively. Around 20 percent of Botkyrka's inhabi-

How are bicycle roads in the municipality

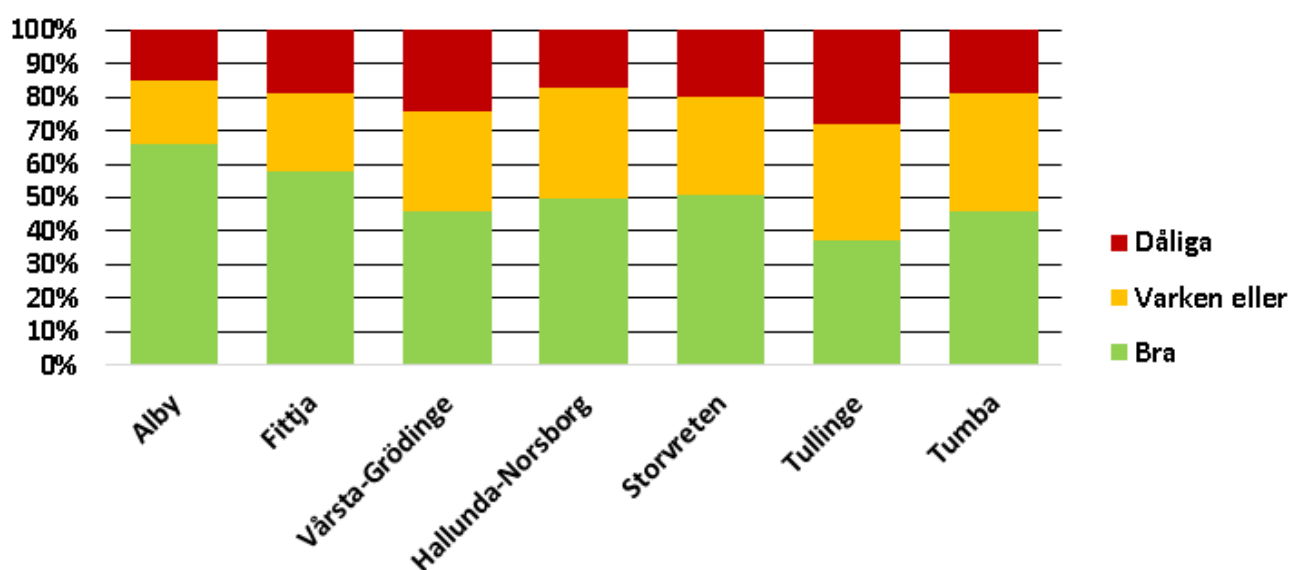


Figure 9 citizen survey about how bicycle roads in Botkyrka are. Red is bad, yellow is "so and so" and green is good. Reference: Botkyrka municipality, 2018

tants find that cycling roads in Botkyrka are poor and almost 50 per cent find that cycling roads in the municipality are good.

In the coming years, several Mobility Management projects for bikes will be made. In autumn 2018 and 2019, the company "Pedalista" will carry out activities to promote cycling in Hallunda / Norsborg and by 2019, research institutes and universities will conduct several research projects in cooperation with the municipality. Botkyrka municipality makes recurring Mobility Management activities each year during the European Road Traffic Week, such as offering free bicycle service.

PUBLIC TRANSPORT

In Botkyrka there are one subway line (in Norsborg, line number 13, color red, toward Ropsten), two commuter train stops (one in Tumba and one in Tullinge) and fifteen bus lines, but public transport is experienced by many residents in the municipality as not sufficiently attractive. Botkyrka's inhabitants assesses the possibilities of using public transport to daily trips 7.0 on a scale of 1-10. The average in Stockholm County is 6.7 and in the neighboring municipalities of Huddinge and Salem, Botkyrka is 7.0 and 7.3, respectively.

Approximately 50 percent of Botkyrka's inhabitants lives at less than 400 meters of aerial distance to a bus stop trafficked by a line with at least 10 minutes of headway during peak hours and / or less than 1000 meters in real distance to a train station. Almost half of all bus lines in Botkyrka have 15 minutes of headway during peak hours. About 25 percent of Botkyrka's inhabitants has both a bus line with 15 minutes of headway within 400 meters from where they live and a train station farther than 1000 meters from their homes. On one hand there are who have only access to bus lines that have low headway, 6 percent of the total population, and on the other who have a bus stop within 400 meters and a train station within 1000 meters, 7 percent.

Concerning the district of Tumba, bus lines with at least 10 minutes of headway during peak hours are present both in Skäcklinge and between Tumba city center and Rönninge station. Bus lines in Tullinge and Vårsta have a headway of 15 minutes or less. In Grödinge bus lines run by 60 minutes or less. In general, public transport in Uttran is lacking, as well as in parts of Vårsta and Vretarna. During the nights, buses replace commuter and subway. Night

buses also run between Northern Botkyrka and Tumba and between Tumba and Skäcklinge via Storvreten.

Bus traffic is an important part of Botkyrka's public transport network. The occupancy rate is a measure of how many travelers are on the buses and it varies on different lines and at different times of the day. During weekdays, the occupancy rate is highest on the lines that go from northern Botkyrka (where is present Norsborg, head-station of the metro red line) and which operate between Tumba and Northern Botkyrka. The highest occupancy rate is in the morning when it exceeds 50 percent on most lines. At that time, the highest load is line number 172 where several trips are basically full. Several lines have a high occupancy rate already at the first morning hours and then decrease slightly during the following departures before 7 am.

The municipality's comprehensive plan states that it should be possible to live without a car. It is therefore important that there are good conditions for living without a car. It should be easy to go, cycle and go collectively for most daily activities. There should also be good access to a dense public transport to various target points and access to both good cycle paths and a bicycle. It is not enough for example to have a bike if there are no bicycle paths or that bike paths are in perfect condition, but nobody can ride a bike or have a bike.

One transport system's goal is to create good accessibility. The level of accessibility depends, among other things, on people's goals, the location of operations, the density of the city, the and structure of the transport system. Most of public transport in Botkyrka, except in rural areas, is accessible. Most stops in the town center have marked walkways and have an elevated sidewalk. All buses have so-called low entrance and ramp at the middle door. On some bus stops there are electronic signs indicating departure information and by pressing a button, the traveler can get the information read.

Botkyrka municipality offers travel services in Stockholm County for those who have difficulty to use public transport due to a disability. Nevertheless, studies and analyzes show that there are shortcomings in public transport. Here there are some examples:

- From Northern Botkyrka, 12 percent of men and 5 percent of women travel to Södertälje (at least 3,000 people daily) but only a bus with a

headway of 15-minute travels the route, and it only a bus with a headway of 15-minute travels the route, and it only stops at Fittja station;

- In the internal travel survey (2017), several of the municipality's employees express shortcomings in the relations between northern municipalities and Tumba;

- Both a survey conducted by the municipality and published in 2017 within Riksten (a small part of Tullinge) inhabitants and the internal travel survey from 2018 stated shortcomings in public transport accessibility in Riksten.

The travel time ratio between public transport and car (PT (minuts) / car (minuts)) is equal to 2 for trips that begin or end in Botkyrka. This means

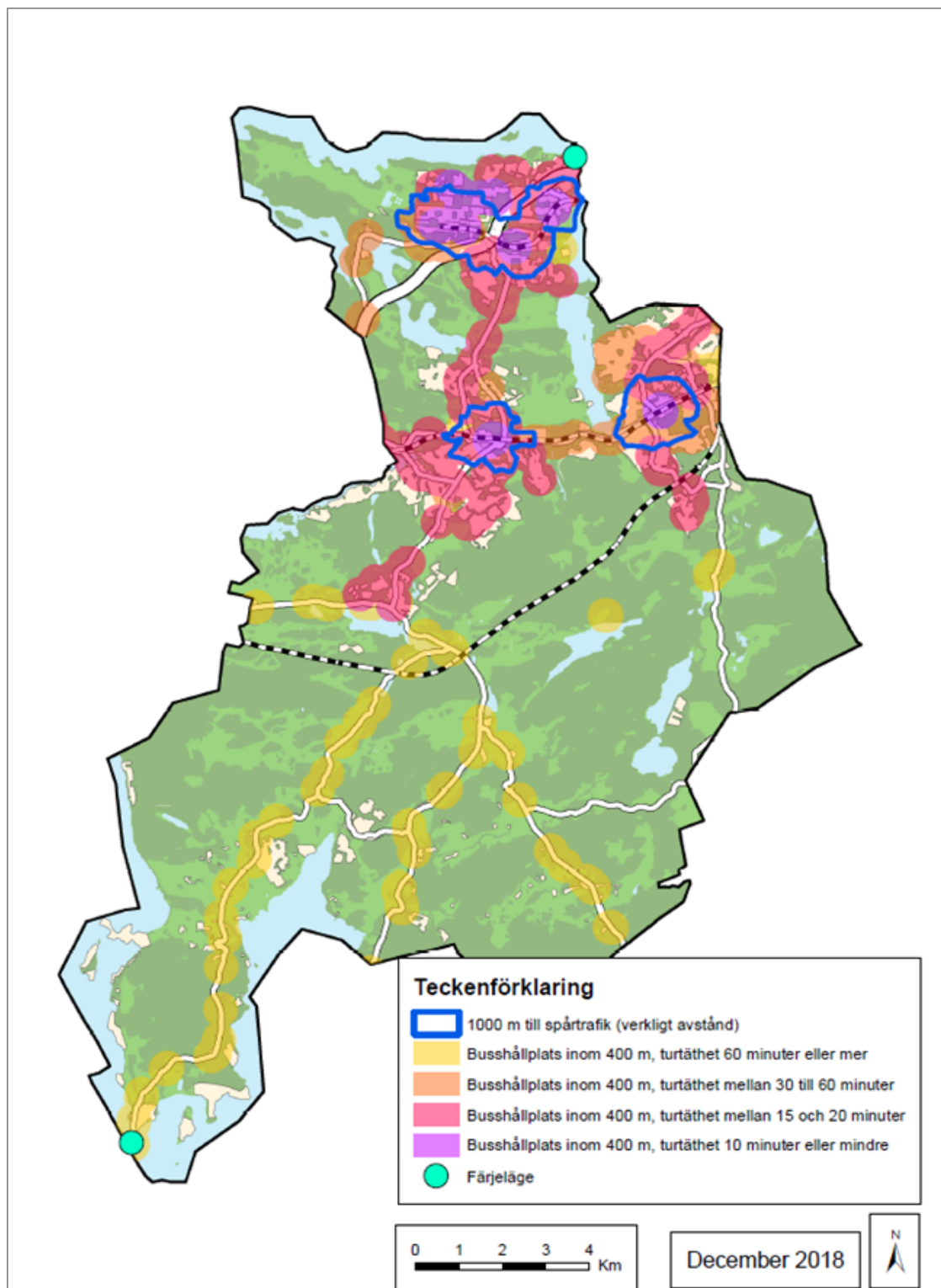


Figure 10 frequency of buses in areas within 400 m from a bus stop. In blue the areas within 1 km from a train station, from yellow (60 minutes or more) to purple (10 minutes or less). The cyan circle indicates a ferry stop. Reference: Botkyrka municipality, 2018

that it takes twice as long to travel by public transport than by car when traveling to, from or within Botkyrka. However, the travel rate is close to 1.0 to travel to certain destinations. For example, the commuter train and subway have a travel time ratio respectively of about 1.0 and a little less than 1.5 to travel between Botkyrka and Stockholm's inner city. The travel time ratio between Tumba and northern municipalities of the county varies greatly. For the path between Hallunda and Norsborg

metro stations it is approximately 2.0. For Alby and Fittja metro stations, the travel time ratio is often greater than 2.0.

For this research is useful to check and have an idea about the car ownership to know how many cars and inhabitants the study interests, directly or indirectly. It is also a good indicator to consider when thinking about mobility management strategies. In Sweden, there is a link between income levels



Figure 11 public transport network of Botkyrka.

and car ownership. The higher is the income, the higher the car ownership. There are also other factors that affect the car ownership, for example, the position of your living place. In major cities, the car ownership is lower than the average of the nation, especially in the central districts. In Stockholm there were 198 cars per 1,000 inhabitants in 2017, instead in Botkyrka it was 284 cars per 1,000 people in 2017, the fifth lowest in Sweden. In Botkyrka, the car ownership is lowest in northern distri-

cts and highest in Tumba excluding Storvreten. In Fittja and Alby, the car is the lowest. There were 159 per 1,000 inhabitants in Fittja and 190 cars per 1,000 inhabitants in Alby in 2017. In Storvreten and Eriksberg / Hallunda / Norsborg, car ownership per 1000 people was higher, 224 and 239 cars respectively. In Tullinge, average income is higher than in Tumba (excluding Storvreten area), but car ownership in 2017 was lower than in Tumba. Indeed, in Tullinge the car ownership was 345 cars per

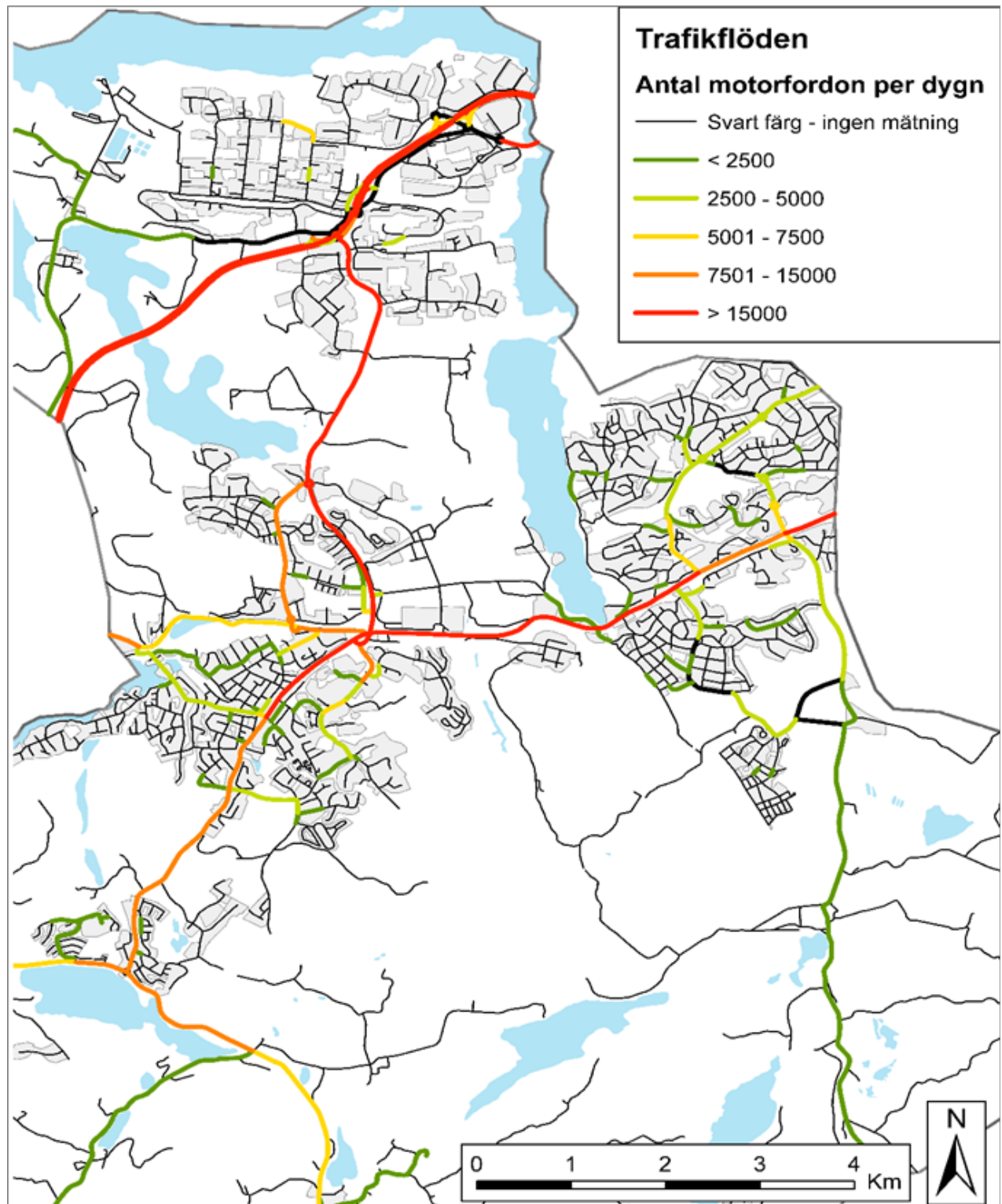


Figure 12 traffic flows on a typical yearly day. In black streets without data. Reference: Botkyrka municipality, 2018.

1,000 inhabitants compared to 352 cars per 1,000 inhabitants in Tumba. In Vårsta Grödinge, car ownership is the largest, 446 cars per 1,000 inhabitants in 2017. There is a low level of passenger transport and therefore the need for a car is larger than in the rest of the municipality.

The subject of parking management interacts with many aspects of daily life. Here I just want to give some data about the relation between transport and schools. The reasons will be clearer after the chapter about case studies. In Botkyrka there are about 75 preschools and about 90 percent of Botkyrka's inhabitants live within an aerial distance of 500 meters to a preschool. Besides in Botkyrka there are 29 schools and about 65 percent of Botkyrka's inhabitants has less than 500 meters to a school. Botkyrka municipality offers a school shuttle to those living in Uttran, Fiskarhagen and Grödinge. The proportion of Botkyrka's inhabitants who lives closer to 500m to a school or can use the school shooting is just over 85 percent. Some villa areas in northern Botkyrka are more than 500 meters distant to a school. About 30 percent of those living in Tumba and 30 percent of those living in Tullinge have more than 500 meters to the nearest school as well.

COMMUTING

Most of the Botkyrka's inhabitants travel daily to other municipalities in the county to study or work. Among Botkyrka's workers, 70 percent commute from the municipality, of which 37 percent commute to Stockholm. Among those working in Botkyrka, about 50 percent live in the municipality and 50 percent are inbound from another municipality. Largest commuting takes place towards / from north - northeast. To there about 25000 Botkyrka's inhabitants commute, and from nor-

th - northeast more than 8000 people commute to Botkyrka. Regarding commuting to / from south-southwest, the number of commuters and lorries is more even. About 3000 Botkyrka's inhabitants commute there and approximately 3,500 people commute from south-southwest. For trips to and from Stockholm's inner city, public transport is the most used transport mode, 80 percent.

The Stockholm County's traffic office measures traffic flows by state roads, while municipalities measure traffic flows by the most used municipal roads. Most of the measuring points in Botkyrka are located in Tumba, Vårsta and Tullinge. This is because these committees are included in Stage 1 and 2 (out of 4) of the Botkyrka Municipality's Traffic Measurement Agreement from 2016. Stage 3 (Alby / Fittja / Hallunda / Norsborg) is expected to be completed by 2018. There are currently no measurements for walking or cycling traffic flows but walking and cycling measurement points are included in Stage 4 and comprise 18 measuring points.

Besides the highway E4 / E20 the roads in Botkyrka with more than 15,000 vehicles per day are Hågelbyleden, Hågelbyvägen and Huddingevägen between Tumba and Tullinge. The road between Vattravägen and Tumba station reaches almost this number of vehicles. The size of traffic flows is one of the factors contributing to the barrier effect, which reduces the accessibility for pedestrians and cyclists. Those who walk, or cycle often have difficulty crossing a road with over 15,000 vehicles per day unless special measures have been taken as for example a traffic light. Already at 5,000 vehicles per day, the barrier effect starts to become noticeable, especially for children and the elderly. Several main roads in Botkyrka exceed this value.

Område	2011	2014	2017	Förändring 2011–2017
Fittja	154	154	159	3%
Alby	179	187	190	6%
Storvreten	217	215	224	3%
Eriksberg/Hallunda/Norsborg	238	238	239	0%
Tullinge	337	340	345	2%
Tumba (exkl Storvreten)	335	341	352	5%
Vårsta-Grödinge	464	453	446	-4%
Hela Botkyrka	272	277	279	3%

Table 6 car ownership every 1000 inhabitants. On the left Botkyrka districts, on the right the percentual difference between 2011 and 2017 and at the bottom the whole Botkyrka. Reference: Botkyrka municipality, 2018

4.3 THE PARKING SYSTEM IN BOTKYRKA

SUMMARY

To manage easier parking policies the Parking Program (2017c) divided Botkyrka in three zones based on the distance from each train station (there are two train stations, one in Tumba and one in Tullinge): Zone A, Zone B and Zone C. The zone division will be helpful to choose parking fees and regulations.

Based on COWI's research (2017) and a further investigation by Botkyrka municipality (2018), the about 500 car spots that are present in the six park-and-ride areas in Tumba are full (occupancy rate close to 100 percent) every morning on weekdays. According to the Botkyrka's analysis (2018), considering Tumba, Norsborg, Uttran and Grödinge, the municipality reaches 74 percent, a data very close to the 78 percent calculated by COWI in 2017. After Botkyrka, the most common municipalities where car owners live are Rönninge and Södertälje (about 5 percent each).

In the Botkyrka municipality's analysis made in 2018 they divided car user who parked on those six areas and live in Tumba by the distance between their homes and the commuter train station. About 38 percent of them lives at more of 2,500 meters of distance from a commuter train station. 9 percent have less than 1,200 meters to the station and nearly 50 percent have between 1,200 and 2,500 meters. So, within the 37 percent who lives in Tumba and use those parking areas for their cars (the data discussed previously), about 93 percent of people lives within 5 km of distance from the train station. This means that the 34 percent of who parks the car in the Tumba's park and ride areas lives at a distance that COWI considers acceptable to use bikes.

According to COWI (2017), the bicycle parking areas' occupancy rate is significantly lower than the cars' one, on average 38 percent.

THE PARKING SUBJECT IN OFFICIAL DOCUMENTS

The parking subject in Botkyrka consists of three main official documents all published in 2017: Strategy (2017b), Program (2017c) and Guidelines

(2017d) The Strategy for parking in Botkyrka municipality is adopted by the City Council. Based on the Strategy, targeting goals have been developed, which are presented in the Program for Parking in Botkyrka Municipality. How to work to achieve the goals is stated in the Guidelines for parking in Botkyrka municipality. Both the Program and the Guidelines are adopted by the Municipal Building Board (samhällsbyggnadsnämnden). Here there are briefly presented those contents from the Strategy and the Program which matters for the research. The Guidelines are presented deeply in the following chapter.

BOTKYRKA PARKING STRATEGY (2017b)

In order to build more in attractive public transport modes, the land needs to be used more efficiently. A dense city creates proximity and car transport needs to be reduced. The city benefits from walking and cycling traffic as well as providing better support for service and public transport. The municipal council has therefore decided to take a holistic approach to the development of parking for cars and bicycles, focusing on more efficient land use in central locations, attractive urban environments and increased sustainable travels. An important starting point is that planning and regulation of parking should be adapted depending on the proximity of rail public transport (commuter train and subway) (Botkyrka Municipality, 2017b).

BOTKYRKA PARKING PROGRAM (2017c)

The municipality's Parking Program published in 2017 with target year 2022 contains the following program points:

- Support development towards an attractive urban environment;
- Contribute to more efficient land use;
- Contribute to meeting the municipality's climate and environmental goals;
- Promote sustainable transport and reduce the proportion of traffic;
- Facilitate planning and cooperation for good accessibility;
- Provide information on how parking matters on the municipality's land should be treated;
- Facilitate planning and construction work ma-

nagement.

Conditions for sustainable travels vary in different parts of the municipality. The factors that affect parking needs the most are the nature of the building, the proximity to public transport and the practical possibilities for walking or cycling. This often coincides with denser housing, good accessibility to service and thus more people in the street, which increases safety. All of these factors point to how strategically important is the closeness to a rail station to encourage a sustainable traveler. Therefore, the municipality has been divided into three different zones, depending on the distance to good track-bound public transport (commuter train and subway): A, B and C, depending on the proximity to good public transport. Zone A is very close to the station (<600 meters from the railway station), Zone B is at about 600-1200 meters from the station and Zone C is the rest of the municipality. The density of buildings and the actual walking and cycling distances affect the zone division.

Based on the goals in the Comprehensive Plan and other governing documents, four orientation targets for parking have been formulated. The focus areas for parking in Botkyrka Municipality are:

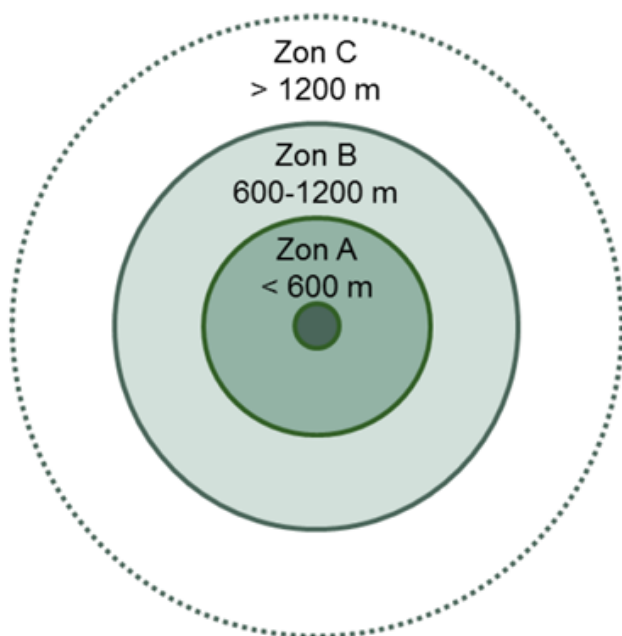


Figure 13 division of Botkyrka in zones (zon). Reference: Botkyrka municipality, 2018

- Objective 1: Extensive land-based parking should be reduced to favorite attractive public transport modes;
- Objective 2: The municipality's planning and

management of bicycle and car parking will help to increase the proportion of sustainable travels;

- Objective 3: The proportion of car trips to workplaces in Botkyrka will decrease. The municipality's properties and operations will be role models in implementing the proposed program for increased sustainable travels;
- Objective 4: Planning and control of bicycle and car parking should provide a good and balanced accessibility.

THE PARKING-HOUSE (PARKERINGSBUS)

The area nearby the current house is not enough and the municipal administration is divided in several different addresses today. Moreover, more space is required for the municipality's future needs and in recent years has been done much work to investigate possible future working methods. Indeed, a variety of activities have been carried out: surveys, workshops, study visits, deep interviews with some of the special activities and a "civil dialogue" (Norconsult, Botkyrka kommun, 2017).

In the long term, the municipality wants to build a new city hall. The new municipal building is planned to be a workplace for about 800 employees and will cover approximately 16 500 square meters. Next to the municipal house, closer to the railway, a parking garage will be built of about 12000 square meters on 2 floors. Here there are about 250 spots. In the Parkeringshus (it is so called the new parking building), both the municipality's carpooling and operating vehicles must be in place. Xenter's guests (the conference building nearby the city hall), students and staff are also referred here. Visitors to municipalities and the public in general are also able to use the parking garage.

The number of electric car spots in the project is 10 percent of the total. The number of parking spaces adapted for disabled people is assumed to be 5 percent of the total number (Norconsult, Botkyrka kommun, 2017). These should be placed in ground floor due to accessibility reasons. Several parking spaces will be needed directly connected with the municipal house. So, it will be a location with different uses and with the goal of concentrate several parking users.

Bicycles can be parked outdoors and in a separate building next to the municipal house. According to

Botkyrka municipality's cycle plan, it is estimated that office buildings need 10-20 bikes / 1000 m² of offices. The storage must be done safely and suit different types of bikes, including bicycle spots outside the house. There should also be a service station, electric bicycle charging station and bicycle pumps (Norconsult, Botkyrka kommun, 2017).

TUMBA CENTRUM

Close to the Tumba Station there is the Tumba Center which is a local mall. Its parking system requires no parking disk and, instead, a camera reads the vehicle's registration number on entry and exit. It is called "Autopay System" and "it is a simple parking system with no bars and parking tickets. It works much like congestion tax, when you enter the parking lot, your registration number is registered by a camera and your parking starts. Another camera registers when you leave the garage and then your parking will be terminated. It knows how long the Tumba Centrum

Close to the Tumba Station there is the Tumba Center which is a local mall. Its parking system requires no parking disk and, instead, a camera reads the vehicle's registration number on entry and exit. It is called "Autopay System" and "it is a simple parking system with no bars and parking tickets. It works much like congestion tax, when you enter the parking lot, your registration number is registered by a camera and your parking starts. Another camera

registers when you leave the garage and then your parking will be terminated. It knows how long the car was parked. The user no longer needs to consider checking fees, but pays only for the time the car is parked, if longer than 3 hours. When you leave the garage, you have four different payment options to choose from. In Tumba Center you park 3 hours freely a day. You can pay in one of the following ways" (www.tumbacentrum.se):

- Cash machine in the garage;
- Automatic payment connecting a debit card at www.parkman.nu;
- Pay within 48 hours at www.parkman.nu;
- Invoice: The invoice will be sent to the owner of the vehicle, an invoice fee of 30 SEK will be added.

The costs are:

15 SEK / h after 3 hours of free parking;

100 SEK is the max tax per 12 hours, which means that regardless of when you enter, the tax will be max 100 kr;

After 22:00 until 07:00, night tax is 40 SEK.

PARK AND RIDE IN TUMBA - CARS

Adjacent to Tumba station there were six car parking spaces and three for bicycles, both kinds lo-



Figure 14 project for the new municipality building and the new parking garage. On the left the location of the municipality building today and at the center where it will be. Reference: Norconsult, Botkyrka kommun, 2017.

Park and ride area	Spots available	Walking distance to the station (m)	Occupancy rate
B1	118	0-100	90/99
B2	55	200-225	78/85
B3	153	250-300	100/100
B4	44	280-300	100/100
B5	76	300-350	100/100
B6	42	450-500	Newer than COWI's research and so out of it
Total	488		

Table 7 data on park-and-ride areas in Tumba. Reference: COWI, 2017; Botkyrka municipality, 2018

cated on either side of the train track. The total number of car parking spots amounts to 488, the corresponding number of bicycles was 136. Surface B1, B2, B3 and B6 have a parking ban between 02-05 AM. Only areas B4 and B5 have 24-hour parking.

Distribution of the demand

COWI, a Danish company, wrote a report in 2017 about the situation of park and ride areas in Tumba when there were just five (from B1 to B5) out of the six current areas. COWI inventory was conducted on two occasions to reduce the risk that the collected material was non-representative. In the inventory, occupancy rate and registration number were checked. It was conducted on Thursday, October 20th and Wednesday, October 26th 2016 between 9am and 1pm. The analysis showed that the degree of occupancy of cars in Tumba is close to 100 percent.

In that investigation a total of 369 car registration numbers were noted. Part of the B1 area's spots (48) are missing in this compilation because they were not noticed until after the inventory was completed. Four cars are registered abroad and 21 listed as companies. Nearly half of the cars listed as owned by companies are registered in Stockholm. Corresponding to 37 percent of the cars registered, 136 are from Tumba. Considering Tumba, Norsborg, Uttran and Grödinge (all Botkyrka's districts), Botkyrka municipality as a whole reaches 291 registration numbers, 78 percent.

In mid-June 2018, a further investigation was car-

ried out by Botkyrka municipality itself on all six parking areas with similar results. Indeed, according to the Botkyrka's analysis, considering Tumba, Norsborg, Uttran and Grödinge, the municipality reaches 74 percent, a data very close to the 78 percent calculated by COWI. Moreover, it revealed that about 26 percent of those who park in Tumba do not live in Botkyrka municipality. After Botkyrka, the most common municipalities where car owners live are Rönninge and Södertälje (about 5 percent each). It is almost 15 and 10 percent who use the park and ride areas in Tumba but come from a municipality located respectively at north or at east of Botkyrka. The two park and ride areas located in Hans Stahle road in Tumba have the highest number of parked vehicles whose car owners do not live in Botkyrka, almost a half. According to the analysis by Botkyrka municipality, about 7 percent of the cars come from other parts of the region of Stockholm. This data was lower in the report published one year before by COWI where it reached 3 percent.

OTHER DATA ABOUT TUMBA

Since Tumba is for both the researches the main origin of cars that fill park and ride areas it is important to analyze it further. By COWI, five of the cars are registered at an address which is distant less than 1 km from Tumba station. The majority, about 70 percent of the parked cars, have an address within 5 km from the station area, which is usually considered to be the limit of acceptable bicycle distance. The prerequisites for increasing the

proportion that choose the cycle should therefore be good.

The six park and ride areas are attractive also for people who do not want to commute by train or bus because the spots are free of charge and opened 24/7. It is possible that some places are used as residential parking, indeed a few cars are listed within 1 km from the station. Another possible explanation is that those sites are used as short-term parking or by those working near the station. However, a check of the nearest addresses shows that none of them was parked on surface B4 / B5, on which night parking is also allowed.

In the analysis published in 2015 by the Stockholm County's traffic office, 41 percent of who lives in Botkyrka responded that they already use the public transport even if parking spots are free at the workplace. If parking at the workplace is charged than the percentage raises to 46 percent. Considering that in the survey the use of both car and public transport counted just as a public transport trip, the data means that when the parking is charged the amount of public transport users raises of 5 percent. It does not mean that the car users are -5 percent after the charge. About 80 percent choose to use the public transport system when the car parking spots are missing at the workplace.

PARK AND RIDE IN TUMBA - BIKES

The survey published in 2015 by the Stockholm County's traffic office showed that there is a lack of bicycle parking near homes. In northern Botkyrka, more than half of the inhabitants do not have access to a functioning bike and more than 20 per-

cent do not have the opportunity to park the bike safely near their homes. Mostly of Tumba inhabitants are within 2.5 kilometers from a station of the rail public transport system.

In the Botkyrka municipality's analysis made in 2018 they divided car user who parked on those six areas and live in Tumba by the distance between their homes and the commuter train station. About 38 percent of them lives at more of 2,500 meters of distance from a commuter train station. 9 percent have less than 1,200 meters to the station and nearly 50 percent have between 1,200 and 2,500 meters. So, within the 37 percent who lives in Tumba and use those parking areas for their cars (the data discussed previously), about 93 percent of people lives within 5 km of distance from the train station. This means that the 34 percent of who parking the car in the Tumba's park and ride areas lives at a distance that COWI considers acceptable to use bikes.

Botkyrka municipality conducted an analysis of bicycle park and ride areas in June 2017. The occupancy rate in bicycle locations is just over 40 percent at Tumba. On other bicycle parking facilities, the occupancy rate is lower than 10 percent except on Standage / Vattravägen, in Uttran, where the occupancy rate was 25 percent. In connection with Tumba station there are three bicycle parking spaces with a total of 146 spots. The parking spaces in Tumba have weather protection, it is possible to lock the bike at the door lock and it is present just one bicycle pump for all three areas. Today, an increasing number of electric bikes and other expensive bikes are being purchased. In the municipality's investigations and interviews, several participants have pointed out that bicycle theft is one problem that interests bicycle parking in connection with public transport. Several municipalities in the Stockholm region have built, or plan to build, a bicycle garage in connection with commuter train stations where you can park your bike for free or paying a fee. No bicycle garage is planned in Botkyrka. For bicycle parking at other destinations in the municipality, such as schools, sports facilities and shopping malls there is no knowledge of the situation.

According to COWI (2017), the bicycle parking areas' occupancy rate is significantly lower than the cars' one, on average 38 percent. In Tumba, the area C3 has the highest number of parked bikes and maximum occupancy, despite poor maintenance

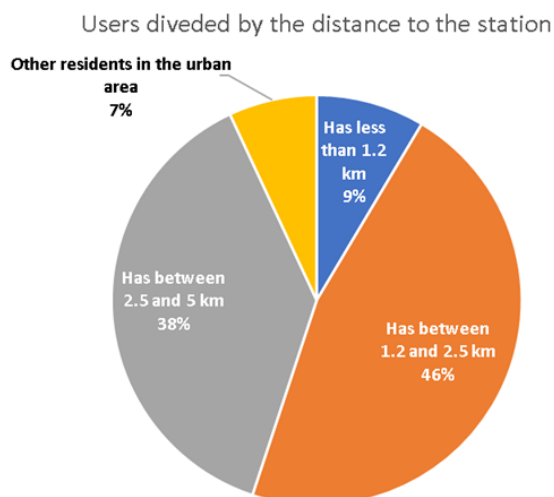


Figure 17 users divided by the distance to the station.
Reference: Botkyrka municipality, 2018

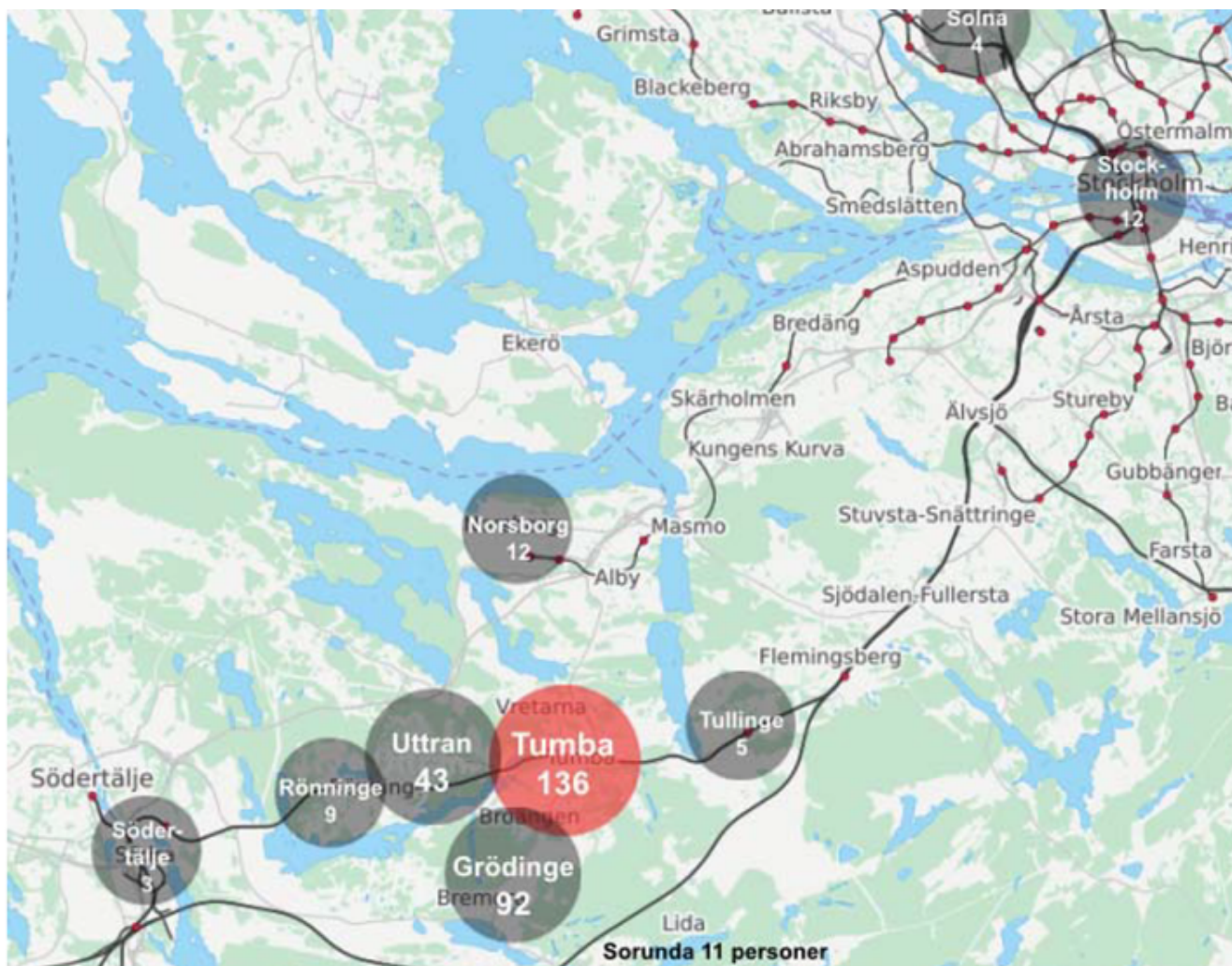


Figure 15 demand distribution. Reference: COWI, 2017

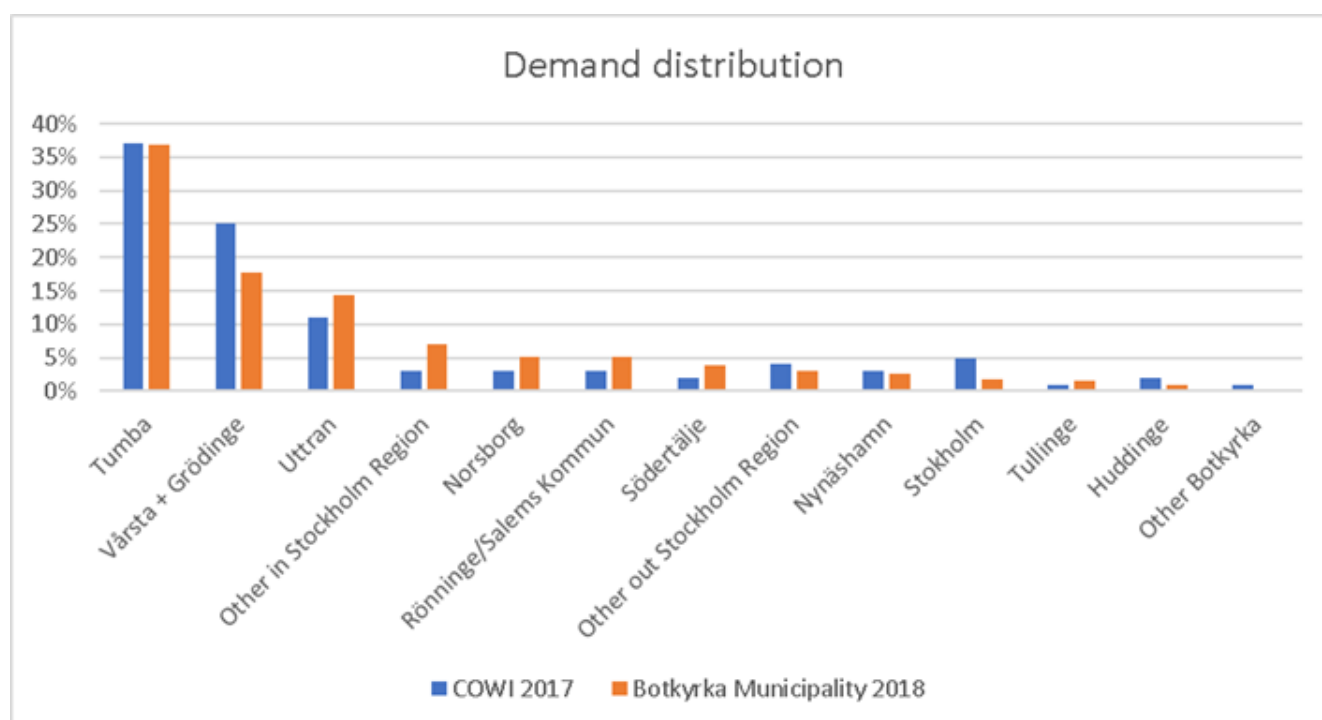


Figure 16 comparison between COWI's data (2017) and Botkyrka municipality's (2018)

and broken weather protections. One explanation may be that it is the only bike parking on the south side station. Area C1 has a very low level of quality and this could be a reason for some to do not choose this mode. Another reason could be its position under the bridge. C2 has the lowest occupancy of all bicycle parking, despite a strategic location near the commuter train. However, both C1 and C2 are farther from the bus stops than C3.

Park and ride area	Spots available	Walking distance to the station (m)	Occupancy rate 10-oct/26-oct (%)
C1	30	10	30/30
C2	58	100	15/17

Table 8 data about park-and-ride areas for bikes in Tumba station

C3	58	75	66/69
Total	146		

4.4 PARKING RULES IN BOTKYRKA

In the following chapter there is a summary of the official “Guidelines” document (2017d) by Botkyrka which regulate parking standards and planning tools to decrease parking need. It has been resumed considering the importance for the research. As always for these three documents (Strategy, Program and Guidelines) it begins with a summary of the previous documents and an introduction which is helpful to briefly understand the following contents.

PARKING GUIDELINES (2017d)

“To achieve the goals listed in the Strategy and in the Program, guidelines have been developed to create the framework for planning and managing parking in the municipality. The guidelines should be followed both in all new and rebuilding projects and should be applied to the existing environment and activities.

Parking should primarily take place in the neighborhood. Botkyrka municipality intends to avoid, as far as possible, the expansion of street parking

and instead to concentrate in parking sites apart from the street space. Botkyrka’s parking standards must be followed both in all new and in rebuilding projects. The municipality will offer the possibility of flexible parking standards for the renovation or rebuilding of homes and businesses. This means that the minimum standard can be reduced if the developer undertakes implementing measures that reduce car ownership / car travel, so-called mobility management measures. Botkyrka municipality can offer the opportunity to reserve land for future expansion of parking.

Botkyrka’s guidelines admit that sharing parking spots between land-uses is an effective way to decrease parking needs. Mainly, it is about activities which need parking spots at different times of the day. Botkyrka municipality shall, with the help of parking charges, control the demand for car parking spaces moving it from intensive parking areas in the most central locations (Zone A) to Zone B and Zone C. It should also be ensured that parking fees cover the actual cost of providing car parking.

In the short term, parking spots should be provided in areas close to commuter train stations. In the longer term, the land must be used more efficiently. Parking charges should be introduced on park and ride areas to better manage their use, while discounts are given to public transport passengers. In the long term, parking machines with check-in systems can be used for park and ride areas, where only commuter- travelers with SL access cards can park” (Botkyrka Guidelines, 2017).

In the municipality’s parking Program (2017), it was decided to introduce parking charges in the central and public transport modes in the long term.

Botkyrka municipality intends to avoid, as far as possible, the expansion of street parking, and instead concentrate parking spots in areas apart from the street space. In some cases, street parking may be relevant if it benefits the city life. In such cases, street parking on municipal land is prioritized for parking for disabled and short-term visitors.

PARKING STANDARDS

The car parking standard applied in Botkyrka municipality differs depending by the zone (A, B or C) and the characteristics of buildings. The standard for car and bicycle indicates always a minimum le-

Figure 18 C1, PARK-AND-RIDE AREA FOR BICYCLES, 30 spots. The part that lies under the footbridge (to the left in picture) has a slightly obscured position. The parking lots closer to the street and The bike lane (to the right in the picture) re much more used.

Reference: Cowi, 2017



Figure 19 C2, PARK-AND-RIDE AREA FOR BICYCLES, 58 SPOTS. Weather protection, lighting and possibility to lock fixed bike in frame. Open location next to walking paths where many PEOPLE pass.

Reference: Cowi, 2017



Figure 20 C3, PARK-AND-RIDE AREA FOR BICYCLES, 58 seats. Open location near bus stops and station, However, very neglected maintenance with broken weather protection.

Reference: Cowi, 2017

vel and they are counted as spots / apartment. The abbreviation “cpl” indicates always bicycle spots (cykelplats).

APARTMENT BUILDINGS AND SINGLE-FAMILY HOUSES

A starting point to calculate the need for bicycle parking is 1 spot (cpl) / person. In a single-family house, bicycle parking is to be organized on your own premises. There aren't laws strictly about parking standards, but the municipality suggests to arrange bicycle parking to about 3.5 cpl for one-family house and to 2 cpl / apartment for multi-family house. The area reserved for a bicycle spot is approximately 2 sqm considering that the spot could be used also by cargo-bikes and bikes with trolleys. In addition, the parking lot should be equipped with electrical outlets so that it is possible to charge electric bicycles overnight. On average there are 2 cpl / apartment including visitor parking. Adaptation should be done by apartment size. For student housing, 1.5 cpl / apartment. Half of the spots are arranged outdoors in connection with the entrance and half inside the ground floor.

The Guidelines document (2017) explicitly said that the introduction of mobility management measures can change car parking standards.

SINGLE-FAMILY HOMES AND APARTMENT BUILDINGS

In single-family homes, car parking should normally be done on their own premises, or as combined parking with the neighborhood. For visitors are added 0.1 spots per apartment (shown in brackets in the table number 8). The parking standard for apartment buildings is in the range of 0.3-0.9 depending on location and apartment size. For visitors are added 0.05 spots per apartment in Zone A and B, 0.1 in Zone C.

For apartment buildings the standard grows following the growing of the size of the apartment but it never reaches the number of single-family houses. One reason could be that applying the villa standard to entire buildings would create too many parking spots.

SPECIAL APARTMENTS

For certain types of apartments, for example student housing, it is good to not use the above stan-

	Zone A	Zone B	Zone C
One-family house (villa)	1,2 (+0,1)	1,4 (+0,1)	1,5 (+0,1)
Little apartment (45 m2)	0,3 (+ 0,05)	0,4 (+ 0,05)	0,55 (+0,1)
Medium apartment (75 m2)	0,45 (+ 0,05)	0,6 (+ 0,05)	0,75 (+0,1)
Big apartment (>75 m2)	0,6 (+ 0,05)	0,75 (+ 0,05)	0,9 (+0,1)

Table 9 parking standards for homes and apartments, spots / apartment. References: Botkyrka guidelines, 2017

dard because car ownership can be expected to be lower for students than for other groups. This may also be applied to housing for the elderly. A special assessment should be made in these cases. Anyway, for student housing, the parking standard is 0.1-0.3 spots / apartment depending on the type of student housing it is. For instance, corridor room buildings can receive lower parking rates than apartments and studios. A student housing in Zone C needs a special assessment. For visitor parking will be added 0.025 spots / apartment.

PARKING AT WORKPLACES AND BUSINESSES

The demand for parking at workplaces and busi-

	Zone A-B	Zone C
Student apartment	0,1-0,3 (+0,025)	Special investigation required

Table 10 student apartment's parking standards, spots / apartment. References: Botkyrka guidelines, 2017

nesses varies greatly depending on location and type of business. Anyway, it represents a great opportunity to influence how people choose to move, especially for everyday journeys as work trips.

The table below shows the appropriate number of parking spaces per employee. If the demand is judged to be greater than a dialogue with the developer / employer should be made about the ability to take measures to reduce demand through mobility management measures.

	Zone A	Zone B	Zone C
Employee	0,2-0,3	0,3-0,4	Special investigation required

Table 11 workplace's parking standards, spots / apartment. References: Botkyrka guidelines, 2017

PARK-AND-RIDE

The land in public transport is very attractive and using this for parking is neither effective nor auspicious for the cityscape. The document explicitly says that if more parking spaces must be provided, they need to be included in multi-plan solutions. Localization of park and ride areas should also be reviewed regarding land use in the central areas. The Stockholm County's traffic office is responsible for the construction of park and ride areas on municipal land. The municipality is responsible for land management, operation and maintenance. The agreement is usually valid for 25 years.

PARKING CHARGE

Botkyrka municipality shall, with the help of parking charges, control the demand for car parking spaces moving it from space-intensive land parks in the most central locations (zone A) to zone B and zone C. It is a goal in the Comprehensive plan (Översiktsplan) and in the Parking Program to streamline the land use, which includes the possibility of using the land for purposes other than car parking. Charges will also be used to control the demand from space-intensive land parking to the parking garage. It is intended that parking fees cover the actual cost of providing car parking at new or rebuilding.

FLEXIBLE PARKING STANDARDS

To reduce the demand for parking at homes there are several measures that can facilitate a sustainable journey and that can reduce the need to travel. Measures can take many different forms, ranging from behavioral to physical investments. Below there are several actions listed as if they are carried out by the builder as reasons to decrease the parking standards. The Guidelines document proposes the implementation of a "Green Mobility Plan" which can be a way for the builder to influence the need for parking. Green Mobility Plans are a package of measures implemented by employers to encourage a changing in the travel pattern of employees and

visitors traveling to the company. Green Mobility Plans are primarily focused on employee journeys, although most also include measures for deliveries, business trips and trips made by visitors to the company. If the municipality does not own the land, the Green Mobility Plan may instead be a negotiating argument in connection with the Comprehensive Plan, the detailed planning and the construction license application. For instance, the municipality may allow higher density buildings or lower parking standards in exchange for the developer to take different mobility management measures according to a pre-agreed action plan.

A Green Mobility Plans can be made for a single workplace or for a larger work area, for new construction or for existing activities.

Examples of content in the Green Mobility Plan:

- The introduction of parking fees at the workplace (it is desirable that the cost to the user would be calculated for each time parking and no discount would be given to those who park often through, for example, monthly subscriptions). The introduction of parking fees for employees is often a prerequisite for the reduction of the parking standard;
- The fees from parking return to a mobility fund. This can be used for various types of measures that promote walking, cycling and public transport, such as air pump for bicycle, mooring tools or subsidized public transport;
- Developing or reviewing the travel policy to support sustainable travel;

For business trips, different options are offered to your own car:

- Good quality service bikes (such as electric bikes) for the employees;
- Service car pool that minimizes the need to commute with your own car to the job;
- Annual competitions, such as cycling to work;
- Carry out annual "try-on" campaigns, for example, test travel campaigns for public transport and test-driving campaigns for cycling;
- Good shower and changing room to facilitate cyclists;
- Individual transport advice to employees;

- Marketing campaigns of alternative ways to get to the company;
- The employer pays for or subsidizes public transport cards to employees;
- Installation of telephone and video conferencing equipment as well as policies that encourage their use;
- To allow employees to work from home.

This research is not gone so far to understand how standards in Botkyrka are chosen but still it is due to highlight that the use of standards could overestimate the overall amount of parking spots.

CONSIDERATIONS ABOUT PARKING STANDARDS

Litman considers “optimal parking supply” to be “the amount that motorists would purchase if they paid all costs directly and had good parking and transport options” (Litman, 2016).

Now, this research clarified the municipal strategy and rules about parking areas in Botkyrka highlighting the presence of standards: tool which aims to provide the “optimal parking supply”. Litman (2016) argues that usually standards used from municipalities “are unconstrained and unadjusted values, which generally reflect the maximum supply that could be needed. These standards are often excessive and can usually be adjusted significantly downward.” Indeed, the municipality of Botkyrka itself propose the instrument of the Green Mobility Plan to lower them. Litman explains that usually standards “are derived from parking demand studies that were mostly performed in automobile-dependent locations. They are generally based on 85th percentile demand curves (which means that 85 out of 100 sites will have unoccupied parking spaces even during peak periods), an 85th occupancy rate (a parking facility is considered full if 85% of spaces are occupied) and a 10th design hour (parking facilities are sized to fill only ten hours per year) (ibid.). Applying these standards results in far more parking supply than is usually needed at most destinations, particularly where land use is mixed, there are good travel options, parking is managed for efficiency or priced”.

Trafikverket, the center for transport studies of Stockholm, studied in 2015 how parking norms affect the size of the housing stock. The main result is that “prices and profits are affected when constructors are forced through parking norms to build more parking spaces than the customers demand. This decreases the housing stock with 1.2 % and increases rents with 2.4 % in our example suburb Hagerstown.”

5 ANALYSIS AND RESULTS

5.1 SWOT ANALYSIS

As approach to the study of the parking asset of Botkyrka municipality, an initial analysis was carried out, in order to classify and evaluate the most significant and important elements present on the territory. This analysis (called “SWOT Analysis”) is an important strategic planning tool, which will allow to identify objectives and strategies that will constitute the research proposal. Moreover, it is useful to summarize all data and considerations made until now. Depending on the role and effects of the elements identified through this analysis, they are cataloged as strengths, weaknesses, opportunities or threats.

The juridical nature of the land where the park-and-ride area is located can change the management possibilities and strategies. Indeed, because of the official guidelines published in April 2018 by the Stockholm County (SLL), before every regulation, the municipality must demonstrate that the park-and-ride area land is considered “neighborhood land” (kvartersmark, usually financed by funds from the County Plan and SLL.). If not the municipality is allowed to use a detailed plan (detaljplan) to change the nature of the parking area to “neighborhood land” (kvartersmark). Indeed, the possibilities to regulate the use and charges are different depending on whether the location for parking is granted as a “public land” (allmän platsmark, which is considerable as any other public land) or “neighborhood land” (kvartersmark). On a “public land” (allmän platsmark) a municipality may not reserve parking spaces for an individual, natural or legal person (SLL, 2018) to avoid any possibility of discrimination. So, fees and regulations that commend commuters, for instance, can thus only be introduced on a “neighborhood land” (kvartersmark). Park-and-ride areas in sparsely populated areas usually does not have the same need for regulation as in urban areas and therefore requires no plan change to be approved as park-and-ride areas financed by funds from the County Plan and SLL.

The six park-and-ride areas analyzed in this research are already on “neighborhood land” (kvartersmark) in the detailed plan.

COWI’s research (2017) and a further investigation by Botkyrka municipality (2018), assert that the about 500 car spots are full (occupancy rate close to

100 percent) every morning on weekdays. This is a strength point because it lets hope higher incomes for the municipality through fees. Around 76 percent of parking users lives in Botkyrka. About 70 percent of the parked cars, have an address within 5 km from the station area (chapter 4).

The public transport system in Botkyrka is well organized and properly covers Tumba (chapter 4) and this is a great opportunity for park-and-ride because let it be free from shuttle services and, instead, let it use the current transport network.

Car is the most common travel mode between Botkyrka and the other municipalities in the southern part of the county, indeed during weekdays car trips are about 66 percent of all trips. Car is the most common mode of traveling also for trips between districts, 72 percent, and within the same district, 52 percent. For trips to other municipalities in southern part of the County, about 70 percent travel by car.

As said in chapter 3, many municipalities don’t have a parking fee or regulations on park-and-ride areas and this can be dangerous. Indeed, if a few areas will increase their regulations they will push out demand towards other cheaper or, in general, more convenient areas. So, the context is very important and Botkyrka municipality should work toward a coordination with the other municipalities while regulating its own parking areas.

Schools are the main reason to stop while going to a park and ride area (Paquette, 2018). All respondents to Paquette’s survey (ibid.) started their journey from the residence before leaving the car in the parking lot. Of those who did some stops between the home and the car park in the morning (63%), it was for all to leave children to school / preschool. Leaving children is the only matter done by respondents on their way to the parking lot.

Nowadays those six parking areas are free of charge and without regulations and this brings to no incomes for the municipality and a possible wrong use by the residents. Indeed, by COWI (2017), five of the cars have a registration address less than 1 km from Tumba station and so possible that some places are used as residential parking.

Largest commuting takes place towards / from north - northeast. To there about 25000 Botkyrka’s inhabitants commute, and from north - northeast more than 8000 people commute to Botkyrka. Re-

garding commuting to / from south-southwest, the number of commuters and lorries is more even. About 3000 Botkyrka's inhabitants commute there and approximately 3,500 people commute from south-southwest. For trips to and from Stockholm's inner city, public transport is the most used transport mode, 80 percent.

Juridical nature of "neighborhood land" of all park-and-ride areas in Tumba;

High car demand for parking areas (section 4.2);

Around 76% of parking users lives in Botkyrka. About 70 % of the parked cars, have an address within 5 km from the station area (section 4.3).

Strengths

Park-and-ride areas occupy land close to the train station (section 4.1);

Park-and-ride areas are free of charge and without regulations (section 4.3);

Low quality of bicycle parking areas (section 4.3);

The missed turn over of park-and-ride users (section 4.3);

Tumba's park-and-ride areas are used also by not train/buses users (section 4.3).

Weaknesses

The presence of the railway station increases the value of the land (paragraph 4.1);

Public transport system is well distributed (section 4.2);

The municipality's wish to have a more efficient use of the areas (sections 4.3 e 4.4);

Possibility to increase the bike's share through investments in safety and efficiency (section 4.3);

Schools are the main reason to stop while going to a park-and-ride area (Paquette, 2018);

Assign a more profitable land-use to the areas near the station.

Opportunities

Parking usually free toward the Stockholm County (section 3.2);

Negative attitude towards public transport and bicycle and very positive attitude towards car (section 4.2);

Botkyrka modal share: high use of cars (section 4.2).

Threats

Table 12 SWOT analysis of park-and-ride areas

5.2 RESULT 1: PARKING MANAGEMENT PROPOSAL

The study’s main result is the location where to move the current car spots of Tumba’s park-and-ride areas. This proposal is reached considering first the SWOT analysis and then applying a multivariable spatial analysis.

VISION

In the Botkyrka’s official parking Guidelines (2017d), described previously in the chapter “Parking Rules in Botkyrka”, the municipality explains that, in the long term, the land close to the train stations will be used more efficiently. Indeed, if in the short term it is useful to provide parking spots in that area, the municipality considers that the land value is higher the closer it is from the station and so it is not efficient to use that land for parking.

Other land uses, as residence or offices, would be more appropriate. According to this point of view, it would be good if in the long-term park-and-ride areas will be moved away from the station.

The following proposal will act as a structured strategy of actions which considers transformations to integrate and fit as much as possible with the municipality’s vision. Moreover, the proposal is integrated with innovative solutions that can be applied to the parking areas and sustainable actions that will contribute to create a high-quality environment, especially in the long term. Arbitrarily, long term has been defined as more than 10 years while short-term within 10 years from 2019. The figure below summarizes short term strategies that will be used in the proposal.

The scheme on the right shows the peripheral parking strategy as core of the proposal. It considers also regulations, the application of parking fees and other parking management strategies as measures to reach a more efficient use of the areas. The strate-

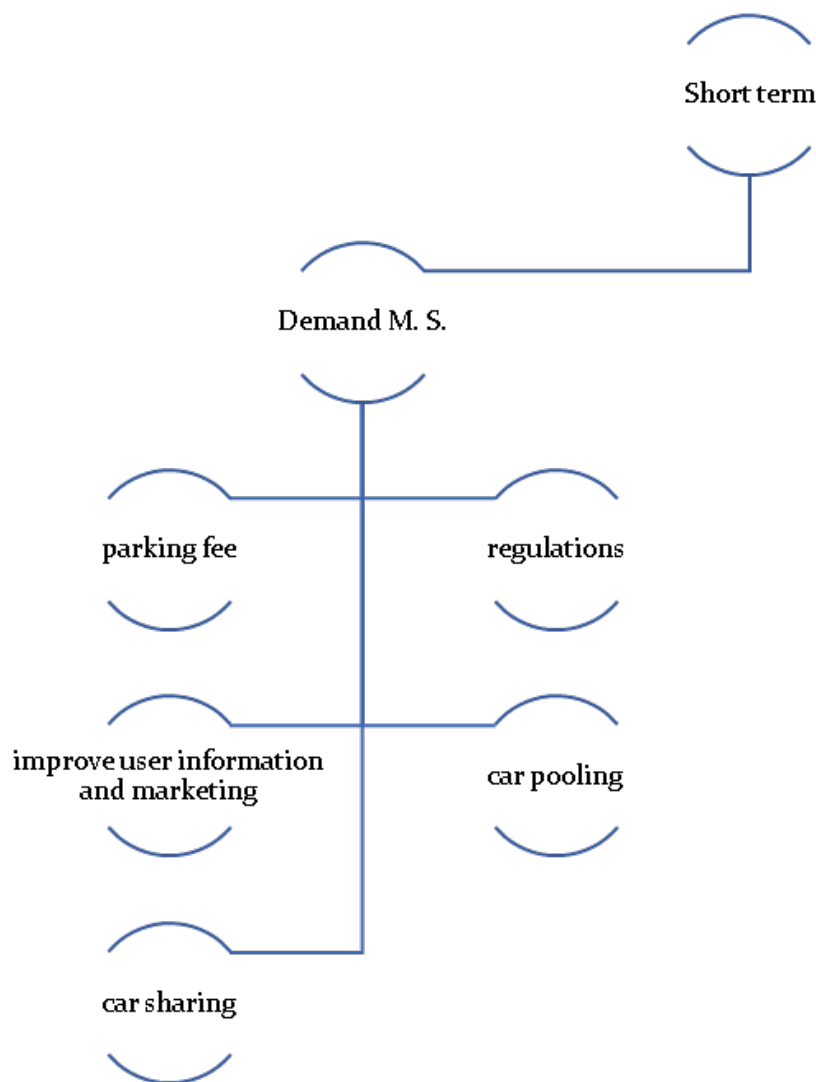
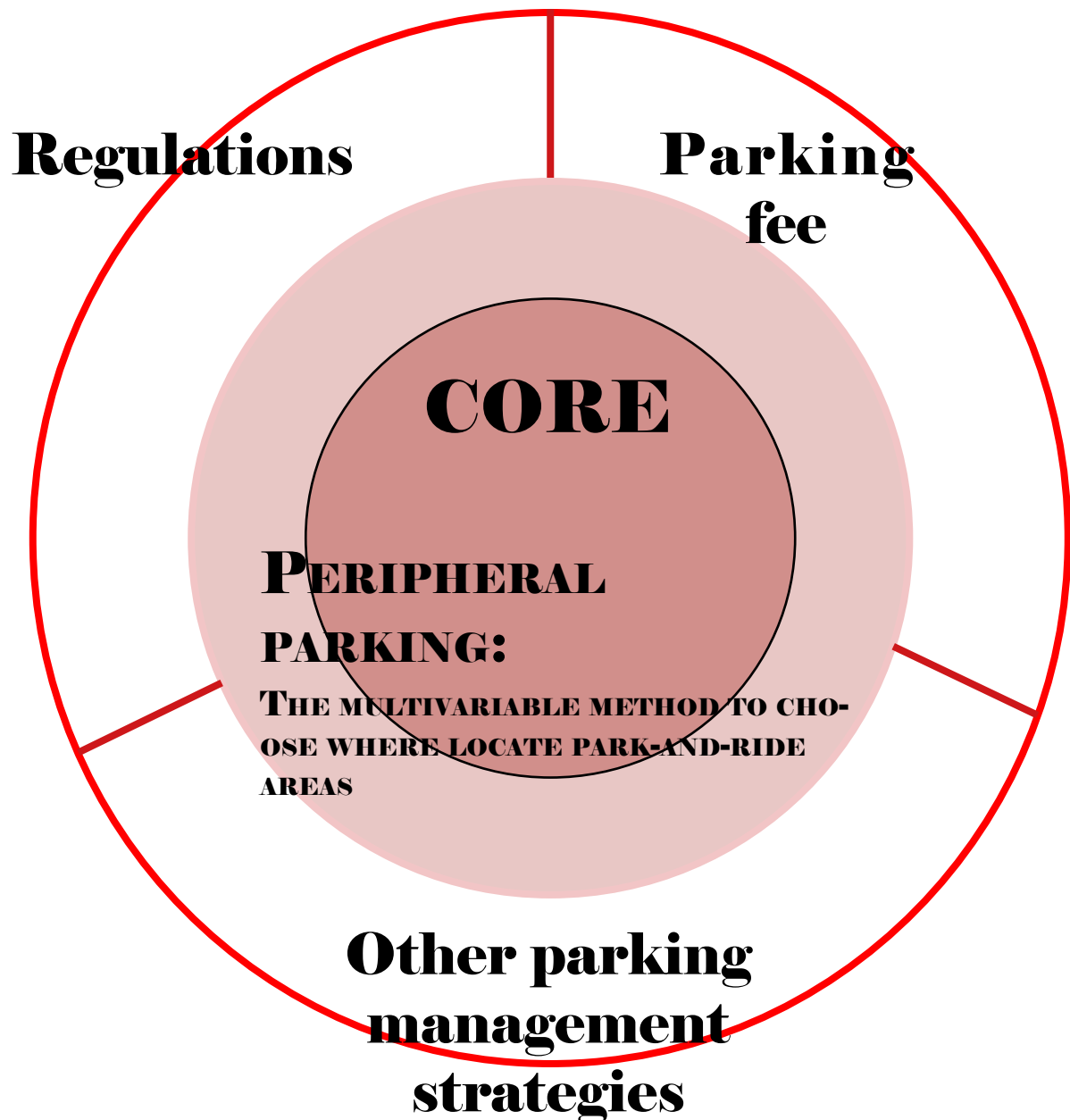


Figure 21 parking management strategies planned for the short term

Proposal structure



gies applied into the proposal have been chosed and motivated in chapter 3 section 1. Finally, the proposal will include a method to find out the best location where to place park-and-ride areas. In this way the thesis will propose scientifically to Botkyrka municipality where re-locate them and not just

that they should be moved. Long term strategies that will be used in the proposal are summarized in the figure 22.

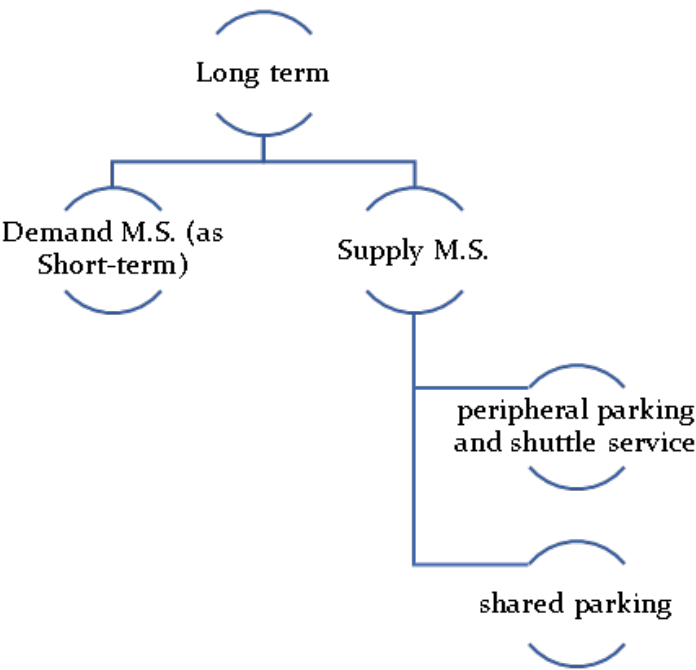


Figure 22 parking management strategies planned for the long term

REGULATIONS

USER AND VEHICLE TYPE

The typical user of a park-and-ride area arrives during the peak hour, leaves the car for all the day and come back in the late afternoon to take the car and go back home. This means that there is not any turnover within the parking area and that spots should be enough to absorb the peak hour flow which will mainly fill them. To rise the turnover rate, and so the efficiency of the parking area, would be useful that some parking spots were reserved for taxis and shared vehicles, both from private and public companies. Shared-vehicles companies can be divided in free-floating and stationary. Briefly, free-floating services allow the user to use any parking spot where (s)he could legally park, stationary services allow the user to park just on pre-selected parking spots that the public authority dedicated for that company. With parking spots reserved for shared vehicles, the user can leave the car and, during the day, someone else can take it and move it away from the parking area, leaving a spot free. Reserving spots for taxis it is useful to let them have more trips bringing people to the train station.

As said previously, Tumba’s park-and-ride areas are used also by not train/buses users even if their purpose is to let user to change transport mode from private car to public transport. In this sense it is useful to reserve the entire areas just to public transport users and ban the others. To do that users should be checked at the entrance and just those with an SL card should be able to access. This does not mean that the user will commute for sure, but at least we are sure that the parking area is used by its effective target of users. As showed during the literature review, other municipalities afforded the goal of restricting the access. The proposal as been inspired by Huddinge that chose to not exclude who does not have an SL card but to charge them more instead. This solution is less critical then the ban and so it decreases the level of social pressure of the regulation. Thereafter, it provides a greater income for the municipality because more people will be able to use the park-and-ride areas.

DURATION AND PERIOD RESTRICTIONS

Right now, the areas B1, B2, B3 and B6 have a parking ban from 2 to 5 AM while B4 and B5 are opened 24/7. The images below summarize the flows in Tumba’s train station during typical days.

From Monday to Friday there is a morning peak hour from 7 to 8 AM with a noticeable rise already at 6 AM. In the afternoon the peak is from 5 to 6 PM on Monday, Tuesday and Thursday while it is from 3 to 4 PM on Wednesday and Friday. The weekend is much different from the rest of the week. Saturday's flow is quite distributed during all day with a slight increase between 3 and 4 PM while Sunday's one increase during all the morning to touch peaks between 2 and 4 PM. In absolute values, morning week days peaks are the highest and weekend peaks are lower than the afternoon week-days ones. Finally, lower peaks are often between 10 and 11 AM.

In Tumba residents use park-and-ride areas so a parking ban during the night would be useful to avoid it. To allow the use by residents of this type of areas is not recommended because in the morning there could be their car inside excluding commuter

users and getting harder to the supply to reach the morning peak hour demand.

Because of these evidences the proposal is a night entrance ban from 8 PM to 5 AM to avoid residents parking but letting commuters to go out.

PARKING FEE

First of all, the parking fee cannot be too distant from the fees of the other parking areas around because otherwise users would move to the cheaper parking area, in terms of time/money relation. This relation is subjective because everyone of us gives a different value to the time, but the money assessment is clear and it must be objectively advantageous to let to the park-and-ride areas to have still attractive power. Taking into account the considerations exposed in chapter 2 about the situation of parking fees in the Stockholm County I propose, in

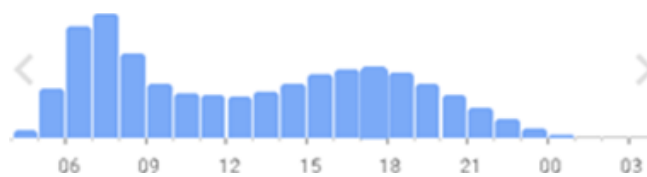


Figure 23 visitors at Tumba station on Monday. References: google maps [last visualization 20-01-2019]

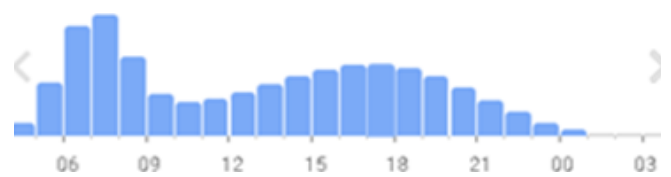


Figure 24 visitors at Tumba station on Tuesday. References: google maps [last visualization 20-01-2019]

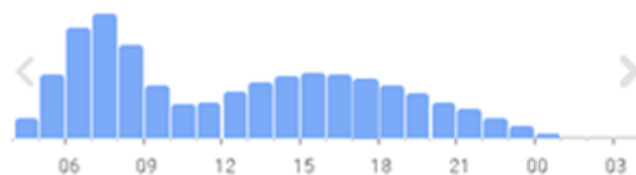


Figure 25 visitors at Tumba station on Wednesday. References: google maps [last visualization 20-01-2019]

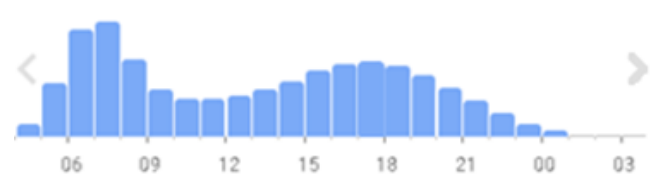


Figure 26 visitors at Tumba station on Thursday. References: google maps [last visualization 20-01-2019]

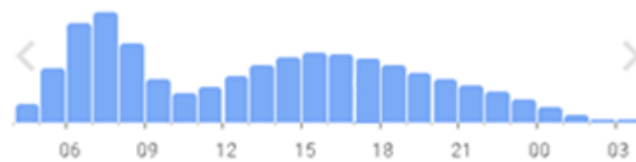


Figure 27 visitors at Tumba station on Friday. References: google maps [last visualization 20-01-2019]

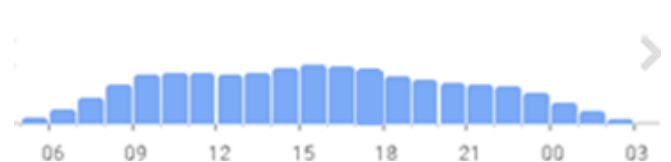


Figure 28 visitors at Tumba station on Saturday. References: google maps [last visualization 20-01-2019]

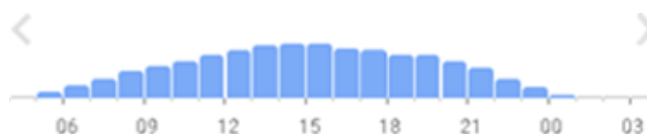


Figure 29 visitors at Tumba station on Sunday. References: google maps [last visualization 20-01-2019]

the short term, a parking fee of 10 SEK / h to max 40 SEK / day for who does not have an SL card. Free for who has a card charged with 30 days or more. This is inspired by Huddinge parking fee.

When, in the long term, the first new parking area will be ready then the prize for parking spots around Tumba station should rise to discourage parking there. It will be 15 SEK / h max 60 SEK / day for who does not have any SL card and still free for who does have 30-day SL card or more.

Then the second park-and-ride will be ready. Then the goal should be pushing out car users from Tumba station even more since in that moment the supply of parking spots will be very high. So, the parking fee will be payed also by who has a 30-days SL card at 10 SEK / h to max 40 SEK / day (the base). At new parking areas the fee should be the less possible to incentive people to park there. So it will be **free for 30-day SL card owners and 10 SEK / h to max 30 SEK / day** (a half of what they would

pay around the station). It is slightly less than Huddinge charge because Tumba is farer to Stockholm which is the main destination (section 4.2).

The fee might be too much if it rises at the opening of the new two. If the first two parking areas would be ready together, or in a very short term from one each other, then fees can be directly moved to the third step and so to 15 SEK / h max 60 SEK / day for who does not have any SL card and 10 SEK / h to max 40 SEK / day for 30-days SL card owners.

It would be useful to have a monthly fee as well. So, payments can be easier and the user is encouraged to use the parking area. If the maximum monthly payment would be 1200 SEK (60 SEK / day per 20 days), a monthly fee of 1000 SEK per month is still fair. For the starting phase we can avoid the monthly fee since the payment is not so high to discourage much potential demand.

The table 13 sums up phases and fees.

Phases	Fee: users without SL card	Fee: users with 30-day SL card or more	Monthly fee:
Starting (Huddinge fee)	10 kr / h to max 40 kr / day	Free	-
First new parking area ready	15 kr / h max 60 kr / day	Free	1000 kr
Second new parking area ready	15 kr / h max 60 kr / day	30-days SL card at 10 kr / h to max /40 kr	1000 kr
Third and Fourth new p. areas ready	Closed	Closed	Closed

Table 13 Phases and fees for the six park-and-ride areas near Tumba station until their dismissal.

**PERIPHERAL PARKING AND SHUTTLE SERVICE:
THE MULTIVARIABLE METHOD TO CHOOSE WHERE
TO LOCATE PARK-AND-RIDE AREAS**

The core strategy in the long term is to move the current six car parking areas towards more efficient places.

This due to the following reasons:

1. In the Parking Guidelines (2017d), Botkyrka municipality writes:” In the short term, parking spots should be provided in areas close to commuter train stations. In the longer term, the land must be used more efficiently”
2. The land has higher value when closer to infrastructures. So, it is not efficient to use the land close to the station for parking areas. That could be instead used for offices or houses. In-

deed, the land close to a rail station is, however, the prime location for the higher density and mixed-use buildings

3. Relieving the inner city from cars that would otherwise go directly to the station (which is the center of the city)

This research studied a method to choose where to (re)locate park-and-ride areas. It is composed of three steps:

1. To analyze the following variables:
 - The origin points of the demand for those parking areas (section 4.2), which refers to the transport demand;
 - Car flows (section 4.3), which refers to the transport demand;
 - Bus stops location and their nearby. For the

nearby has been chosen a buffer ray of 400 meters. The same distance has already been used by Botkyrka and other municipalities as acceptable walking distance.

- Preschool and school locations. Moreover, the presence of schools reminds to the Paquette's research (2018) which asserts the habit of the 63% of his statistic sample to bring children to school before going to the park-and-ride area. The study of these aspects brings to a location analysis map, which refers to the transport demand.
2. To choose the locations and sum them up in a map ("Proposed locations").
 3. To check the land property. Indeed, changes are easier on public land and, due to SL guidelines, just on public land it would be possible to create "neighborhood land" (kvartersmark, look at section 5.1) needed to charge and regulate parking areas.

It has already been said that: "by COWI five of the cars have a registration address less than 1 km from Tumba station. The majority, about 70 percent of the parked cars, have an address within 5 km from the station area, which is usually considered to be the limit of acceptable bicycle distance. The prerequisites for increasing the proportion that choose the bike should therefore be good" (in section 4.3). So, we can assume that, at least from April to September for the better weather, those people could choose to bike, especially if they will not find a parking spot for their car around Tumba station. Indeed, "if park-and-ride areas did not exist, then 82% would not use the car" as Paquette's research (2018) pointed out (look at chapter 2).

Biking will be even more attractive if the municipality chooses to invest on safety and efficiency and so if the quality of bike parking areas rises (as said in chapter 3.3 they are in a bad status). The research will continue assuming the worst point of view possible for users. For instance, considering that during winter there are less people that choose to move by bike and that we still have to find a solution for the remaining 30 percent of the "summer users". We will proceed now based on the demand distribution to choose where to locate park-and-ride areas. Basically, the demand distribution is interpreted as a hierarchy scale of priority. Finally, the North connection with Norsborg has the following bus lines 707, 708, 737, 738 which go from

Norsborg to Tumba station. So, a park-and-ride area in the north part of Tumba to commute car users would be useless because if someone would like to commute to the bus they would find it close to their homes in Norsborg.

RESULT 2: PROPOSED LOCATIONS

TUMBA

About the six park-and-ride areas analyzed, Tumba is the main car demand producer (about 74-76 % of the total demand) but it is also quite small and it has a public transport system that covers well resident areas (look at chapter 3.2 for further information). The area proposed is in the South-East part of the city. More precisely is at the crossing between Storvretsvägen and Skäcklingevägen on the green area in front of the preschool "Lövholmen". The area is still quite densely populated but there are two preschools and two bus stops. The bus line that stops here and go to Tumba station are 716 and 719 while 743 go directly to Fridemsplan (one of the biggest mobility nodes of Stockholm). The con is that the area has currently a nice built environment that a parking area could degrade (it depends by what is the project of the area).

This parking area can be avoided. Indeed, the area around has a high number of bus stops that, with a buffer zone of 400 m of ray, cover all the homes. Secondly, buses have a frequency of 6 minutes which high enough (Botkyrka municipality confirm this aspect).



Figure 30 The area proposed in Tumba is highlighted in red.

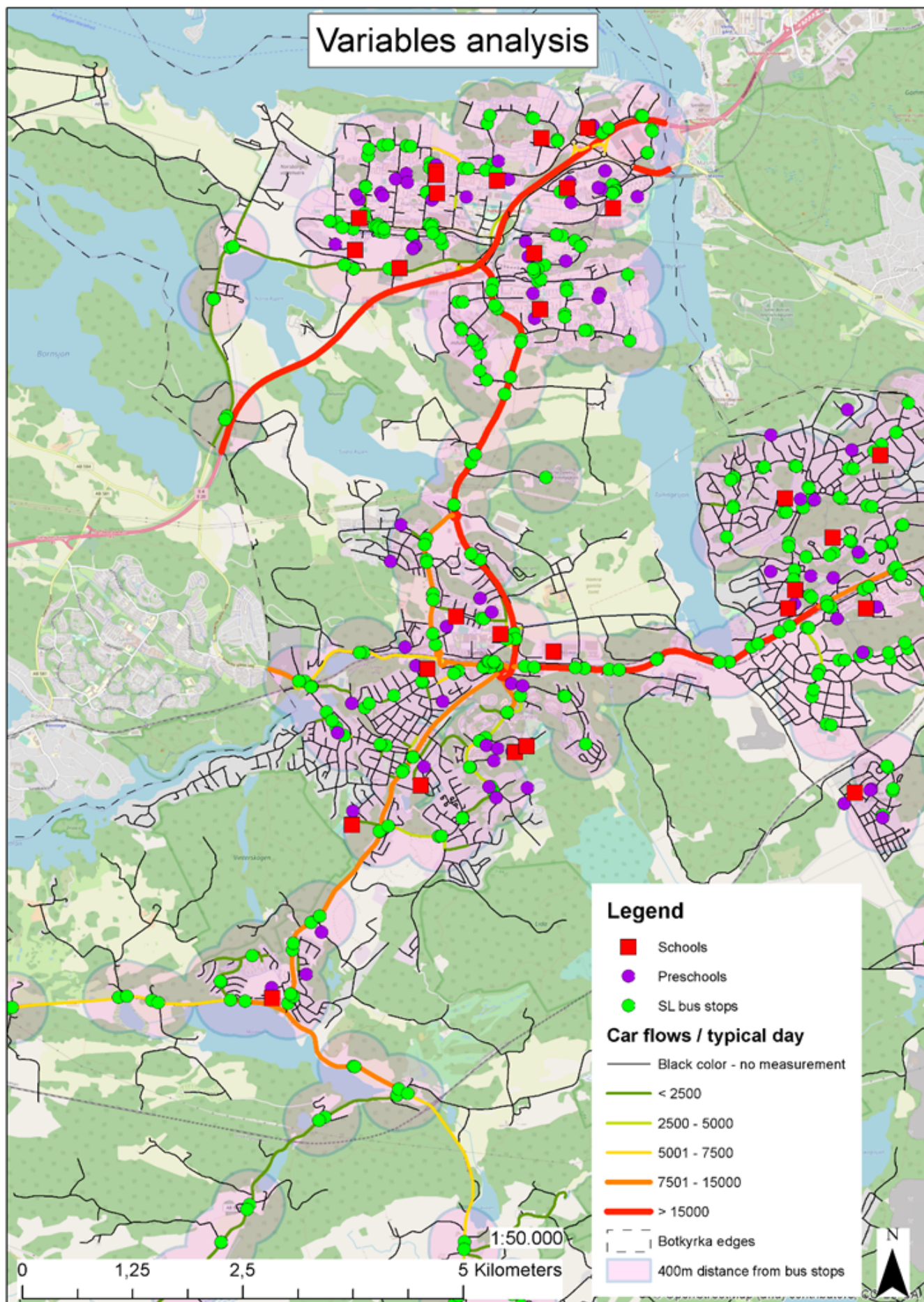


Figure 31 variables analysis. There are summarized the elements useful for the location of new park-and-ride areas

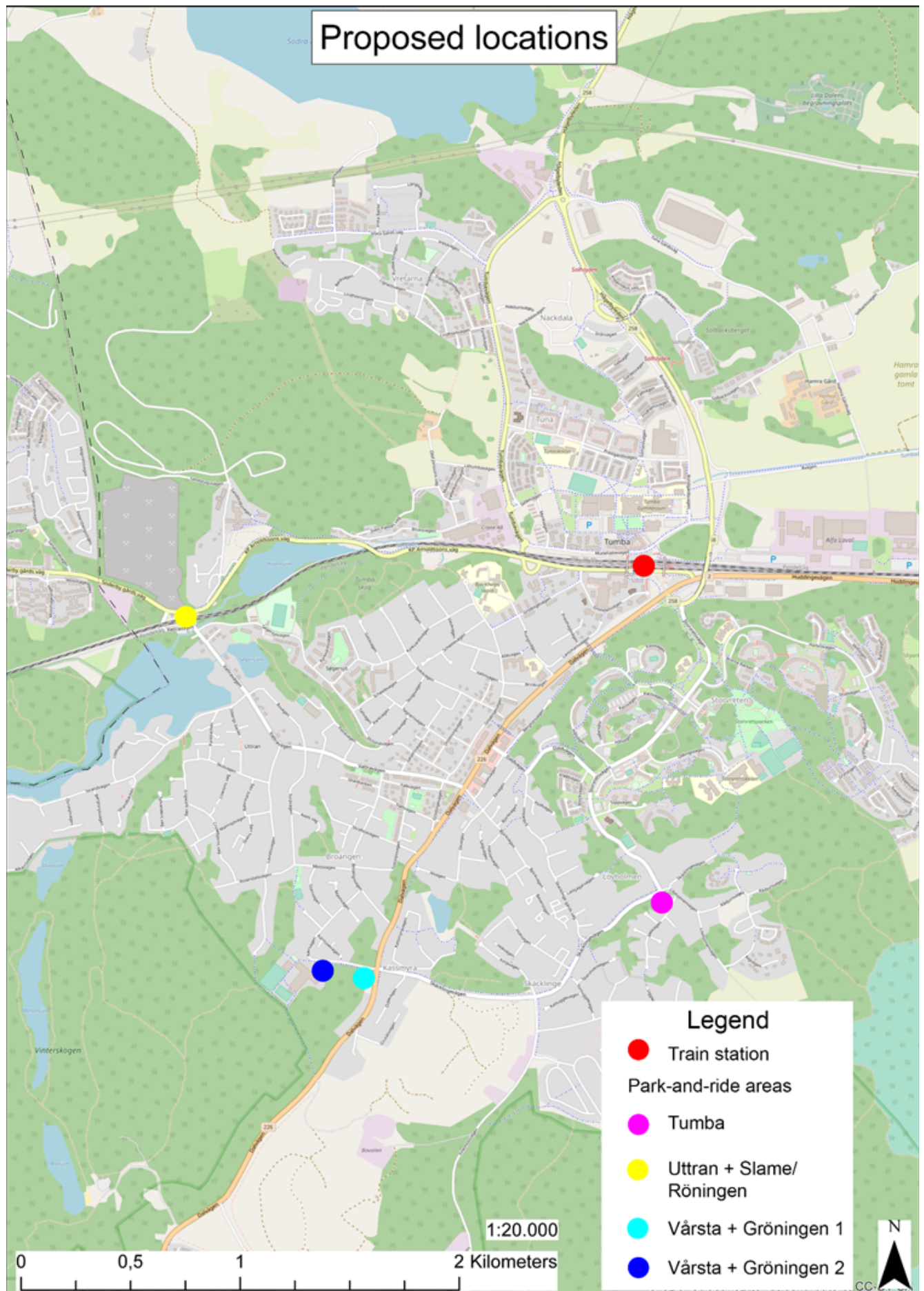


Figure 32 proposed locations for new park-and-ride areas.

VÅRSTA + GRÖDINGE

For the South connection to Vårsta and Grödinge there are two alternatives:

1. A proper location would be on Kärrvägen between the school (on the map below marked with a red square) and Dalvägen. Indeed, Dalvägen is a road with quite high traffic flow and with a bus stop. The bus lines that stops there are 716, 717, 727, 729 which all go to Tumba Station so there would not be the need of a shuttle service. The preschool and the school on Kärrvägen are at 350 meters from the stop. Finally, there is a lot of free space to use.
2. Another good option is to use the current school parking. Indeed, it is used just from the staff who as a schedule and so it could leave spots free. A further investigation should analyze if this would be possible contacting the school and knowing the actual number of parking areas and the juridical nature of the parking area. To the purpose of this research it is good to highlight that the use of shared parking would be a strategical option.

UTTRAN + RÖNNINGE / SALEM

Located on South-West of Tumba's station, it is a small part of the municipality much spreaded out due to the high presence of small lakes and due to its rough topography. K P Arnoldssonsväg is a road that connects Tumba's station with Uttran and then it continues changing its name in Söderby Gårdsväg to connect with Salem and further with Rönninge. Because of this, a parking area on this road would be useful both for Uttran and for Salem/Rönninge. In particular the best spot would be the current parking area in front of the bus stop where K P Arnoldssonsväg changes name in Söderby Gårds väg. In this way it is possible to reuse the space and, if it not enough, there is more space that could be used. By the way, here nearby there is a pizzeria (the building with a black rooftop on the left of the parking area) and so also in this case there could be a good synergy using the shared parking strategy.



Figure 33 Zoom from the variables analysis map. the parking area close to the school. It would be efficient to use it instead of building a new parking area.



Figure 34 Zoom from the variables analysis map. In orange K P Arnoldssonsväg. The area proposed is in a strategic location due to the presence of bus stops, due of the main road toward salem and due of the presence of a previous parking area.

LAND PROPERTY

To actually realize the parking areas the easiest way is to build on public land. The table below will describe the property of chosen areas. Data are from the public Botkyrka's geoportal reachable this link <https://karta.botkyrka.se> (in Swedish). The considered areas are all in red which means that they are all owned by Botkyrka municipality except for the one chosen for Uttran and Rönninge / Salem which is private.





Tumba

Vårsta + Grödinge

Uttran + Rönninge / Salem

Table 14 Land property check. Uttran parking area is the only one that could have problems because not all in red. REFERENCE: KARTA.BOTKYRKA.SE

The other management solutions

About the 70 % of who uses the current six park-and-ride areas lives within 5 km and people who move to Stockholm already use the public transport (80% of the total amount of people moving) (Botkyrka, 2018). From an user perspective, the increasing of parking fees and new regulations will push out demand that in the short time will find answer mostly on public transport. Moreover, two out of the three areas proposed could share parking spots with land uses nearby, in detailed the parking areas of Vårsta/Grödinge with the nearby schools and Uttran + Rönninge/Salem with the pizzeria. This means that new car park-and-ride areas will have less parking spots then the current ones. Thereafter, with spots reserved to car-sharing and car-pooling services there would be even less necessity of space.

Finally, without car spots nearby the station, car users will use park-and-ride areas out from the center of Tumba. The main synergy with these new parking areas is the total dismissal of the old ones. Both will create just more supply that will bring more demand (induction demand principle). That area free of commuter cars will rise the quality of life of the residents and the free space can be use, for instance, for other residential buildings or offices (as said previously).

Current parking areas are just indicated on roads with common signs. For a better communication with the users this research proposes to improve information and marketing. A parking guidance system will be used to direct users to areas with free spots. An example is the “Mercury Parking Guidance System” by Aesys and which “is a network of directional LED parking signs installed at varying points of a city that direct drivers to the nearest open parking area. Each sign is composed of the name and direction of the parking area with an LED component showing the number of open spaces” (www.aesys.com).

Communication problems affect disabled people the most for instance when the only spots wide enough for a wheelchair are used by people who are not supposed to use them or just because there are a few spots left and they must look around to find them. Telia, a telecommunication company, found a solution for this problem using parking sensors with a technology called NB-IoT (Internet of things). “Telia partnered up with three very different compa-



Figure 35 A directional LED parking sign showing the name of the parking area and number of available spaces. Reference: www.aesys.com/LED-signs-and-LED-display

nies to make this happen: APX Systems, who provides a parking app for end-users, the Norwegian Association of Disabled an advocacy organisation of people with disabilities and Huawei, providing the newest generation of NB-IoT enabled magnetic car sensors” (www.teliacompany.com) These are sensors you can drill into the ground, and the network enables 10+ years of battery life, and 7x better coverage than 4G, which means the sensors can stay underground for a long time.

The magnetic car sensors understand the presence of a car and turn on a led located on the parking edge closest to the road. In this way the led is visible from the road and if the parking spot is free it turns green. It is useful to understand from distant where parking spots are located.

According to the Telia web-site (ibid.) looking for a spot consumes about one million barrels of oil a day globally. This innovative solution is able to decrease driving time and so emissions to finally reduce the global environmental footprint. The “NB-IoT Smart Parking Solution” (which is the whole name of Huawei’s system) “collects parking data, such as occupancy and duration, and relays this information to service providers. This improves fee collection and reduces economic losses. Drivers can obtain the real-time parking space information. For example, when only few parking spots are available, drivers can be directed to the next vacant spot. This eases traffic congestion caused by frustrated drivers searching for potential spots” (www.huawei.com/minisite/iot).

The proposal of charging the parking brings to regulate the access to areas.

A technical solution with a parking bar effectively closes those who do not have the right to park at the facility. The disadvantage of a physical barrier is that the solution results in higher plant costs and normal even higher operating costs. Another significant disadvantage of a barrier solution is that it is demanding and generates queues at the entrance of the parking lot.

A ticket machine is significantly less demanding and does not involve the same risk of vehicle driving. Operating costs for repair and maintenance are also available for ticket vending machines but are experience less than for systems with barriers. Disadvantages of ticket vending machines are that they do not physically shut out those who do not have permission in the parking lot. They also require a driver to pick up a ticket in the vending machine and return to the vehicle, which means a greater effort for the traveler.

“Q-Park Access” is a solution from the Q-Park company that merges bar and machine systems letting you pay in three modes:

“The first alternative is to pay in the Pay & Display machine located in the garage, you then pay before exiting the garage. The second alternative is to pay via our website. The third options is to pay via invoice. The invoice will be sent automatically to the owner of the vehicle if no payment is detected within 48 hours” (www.q-park.se). Briefly, Q-Park Access is linked to a system that reads the vehicle’s registration plates, which gives to the user more freedom and makes parking easier.

The system proposed is based on the use of bars and machines to pay and to read SL cards.

The use of an app service would be interesting to register user’s car, credit card and intersect this data with the SL database. This would let know if the car owner has a public transport membership. In this way the user can pay through the app just starting it when parked and turning off the counter when goes away. Currently, app services for parking payment such as Betala-P, ParkOnOff, Easypark and Parkster don’t check SL database so the user must

use machines to register the SL card through NFC connection every time (s)he parks.

Recommendation for Botkyrka municipality

In case of new constructions, the municipality should allow the builders to submit Green Travel Plans (as in Huddinge, chapter 2) which departs from existing parking standard (so-called flexible



Figure 36 Ticket machine with reader for SL access card.
Reference: Atkins Sverige AB, 2011

parking spaces). The Green Travel Plans shall include proposals for measures that lead to reduced demand on accommodation parking. A reduced demand for housing parking means also reduced demand for park-and-ride areas. Mobility management measures should be combined with physical measures in the form of improved infrastructure for walking or cycling. When executed in combination, they increase the quality of parking areas. Improving bus traffic would reduce the need for spots on park-and-ride areas, especially toward Salem and Vårsta.

6 CONCLUSIONS

6 Conclusions

In the chapter Introduction has been identified the goal, the research questions and the objectives. First of all they will be check to demonstrate the coherence of the research and the proposal. Quotes to chapter 1 are made in *italics*.

GOAL AND RESEARCH QUESTIONS

The overall goal is to achieve an efficient and innovative use of Tumba station's parking areas through a "Parking Management Proposal".

Research questions are:

- *How Tumba's park-and-ride areas can become more efficient?*

The efficiency has been achieved by the regulations and parking charge which can be applied both in the short term and in the long term. They ave been thought to be developed through all the process of relocation of parking areas.

AM to avoid residents parking but letting commuters to go out.

- *What parking fee should be applied?*

About the parking charge the proposal is divided in four steps and is summed in the table number 13.

- *Which parking management strategies (PMS) should be applied? And how can they function together?*

During the process that brought to choose where to relocate parking areas has been considered the option **to share parking spots** with other land uses. **Car sharing** and **car pooling** are considered to decrease the need of car spots and used by reserving spots to those services. Further researches are needed to estimate their use. **To improve user informations and marketing**, a parking guidance system will be used to direct users to areas with free spots. The system proposed to pay and to give informations about charges is based on the use of bars and

Phases	Fee: users without SL card	Fee: users with 30-day SL card or more	Monthly fee:
Starting (Huddinge fee)	10 kr / h to max 40 kr / day	Free	-
First new parking area ready	15 kr / h max 60 kr / day	Free	1600 kr
Second new parking area ready	15 kr / h max 60 kr / day	30-days SL card at 10 kr / h to max /40 kr	1600 kr
Third and Fourth new p. areas ready	Closed	Closed	Closed

Table 13 Phases and fees for the six park and ride areas near Tumba station until their dismissal

About users regulations the proposal is to have reserved spots for shared vehicles, car pooling and for taxis which is useful to let them have more trips bringing people to the train station. Moreover, the proposal as been inspired by Huddinge that chose to not exclude who does not have an SL card but to charge them more instead. This solution is less critical then the ban and so it decreases the level of social pressure of the regulation. Thereafter, it provides a greater income for the municipality because more people will be able to use the park-and-ride areas.

Indeed, currently those six park-and-ride areas are free of charge and just B1, B2 and B3 have a parking ban between 02-05 AM. The proposal about regulations is a night entrance ban from 8 PM to 5

machines and on SL card readers.

OBJECTIVES

- *Revenue generation*

Current parking facilities are free. The proposal is to set a parking fee which increases until they will be dismissed. Furthermore, also new falcilities will be charge and they will cost 10 kr/day to max 30 kr/day (a half of what they would pay around the station) and they will be free for 30-day SL card owners.

- *Supports Smart Growth*

The proposal is based on getting more accessible and efficient land use patterns and support other

land use planning objectives. Indeed, the choice of moving the current parking areas aims to have free the space with higher planning potential.

- *Reduces land consumption*

From six areas the facilities are reduced to three. Also the total amount of spots will be reduced thanks to the management strategies applied.

- *Supports transit*

Letting free the land close to the station, the proposal aims to open many possibilities to plan land uses especially if transit oriented. Furthermore, the new areas have a strong link with the current public transport system indeed the proposal does not choose to use a shuttle service.

- *Improved quality of service*

The proposal is made to increase user quality of service by providing better information and increasing consumer options.

LITERATURE REVIEW

The municipalities compared are: Stockholm, Gothenburg, Malmö, Huddinge and Sollentuna. The review has been done using official documents and external commitments mainly in Swedish.

During the review of Sollentuna, it has been found that the municipality has not provide with parking standards (Trivector, 2014).

MANAGEMENT POLICIES

The main trend among municipalities is to reduce the demand of car parking spots and not increase the supply. To reduce car parking demand, they bet especially on increasing bike parking (less spot-space for single person compared to car), on agreements between specialists and builders (as for Malmö, Huddinge and Sollentuna) and on the mutual synergy between strategic and action plans.

PARKING FEES AND REGULATIONS

The average ticket cost for using a spot in the analyzed park-and-ride areas is about 20 SEK / h (around 2 euros per hour) but actually, considering the whole Stockholm County, parking is free of charge almost everywhere. Stockholm has two charges: a regular and a discounted one. To get the discount fee users must start the parking in the

morning between 05 and 09 AM.

SOLUTIONS

Measures that can be used to higher the flexibility both of car and of bicycle parking areas are well listed by Huddinge and Gothenburg. In particular Huddinge instituted the Green Travel Plan: a planning toolbox implemented by employers to encourage more sustainable trip-choices among employees. Interesting is also the choice of creating test areas for automatic vehicle parking. The most innovative solution about bike parking is the installation of bike boxes by Stockholm. These blue boxes offer a repaired place for the bike and can have many accessorize as an electric recharge station.

Case Study

Adjacent to Tumba station there are six car parking spaces and three for bicycles, both kinds located on either side of the train track. The total number of car parking spots amounts to 488, the corresponding number of bicycles is 136. Surface B1, B2, B3 and B6 have a parking ban between 02-05 AM. Only areas B4 and B5 have 24-hour parking.

Car is the most common travel mode between Botkyrka and the other municipalities in the southern part of the county, indeed during weekdays car trips are about 66 percent of all trips. Car is the most common mode of traveling also for trips between districts, 72 percent, and within the same district, 52 percent. For trips to other municipalities in southern part of the County, about 70 percent travel by car.

In the investigation published by COWI in 2017, a total of 369 car registration numbers were noted. Part of the B1 area's spots (48) are missing in this compilation because they were not noticed until after the inventory was completed. Four cars are registered abroad and 21 listed as companies. Nearly half of the cars listed as owned by companies are registered in Stockholm. Corresponding to 37 percent of the cars registered, 136 are from Tumba. Considering Tumba, Norsborg, Uttran and Grödinge (all Botkyrka's districts), Botkyrka municipality as a whole reaches 291 registration numbers, 78 percent.

In mid-June 2018, a further investigation was carried out by Botkyrka municipality itself on all six

parking areas with similar results. Indeed, according to the Botkyrka's analysis, considering Tumba, Norsborg, Uttran and Grödinge, the municipality reaches 74 percent, a data very close to the 78 percent calculated by COWI. Moreover, it revealed that about 26 percent of those who park in Tumba do not live in Botkyrka municipality. After Botkyrka, the most common municipalities where car owners live are Rönninge and Södertälje (about 5 percent each). It is almost 15 and 10 percent who use the park and ride areas in Tumba but come from a municipality located respectively at north

term parking or by those working near the station. However, a check of the nearest addresses shows that none of them was parked on surface B4 / B5, on which night parking is also allowed.

In the analysis published in 2015 by the Stockholm County's traffic office, 41 percent of who lives in Botkyrka responded that they already use the public transport even if parking spots are free at the workplace. If parking at the workplace is charged than the percentage raises to 46 percent. Considering that in the survey the use of both car and

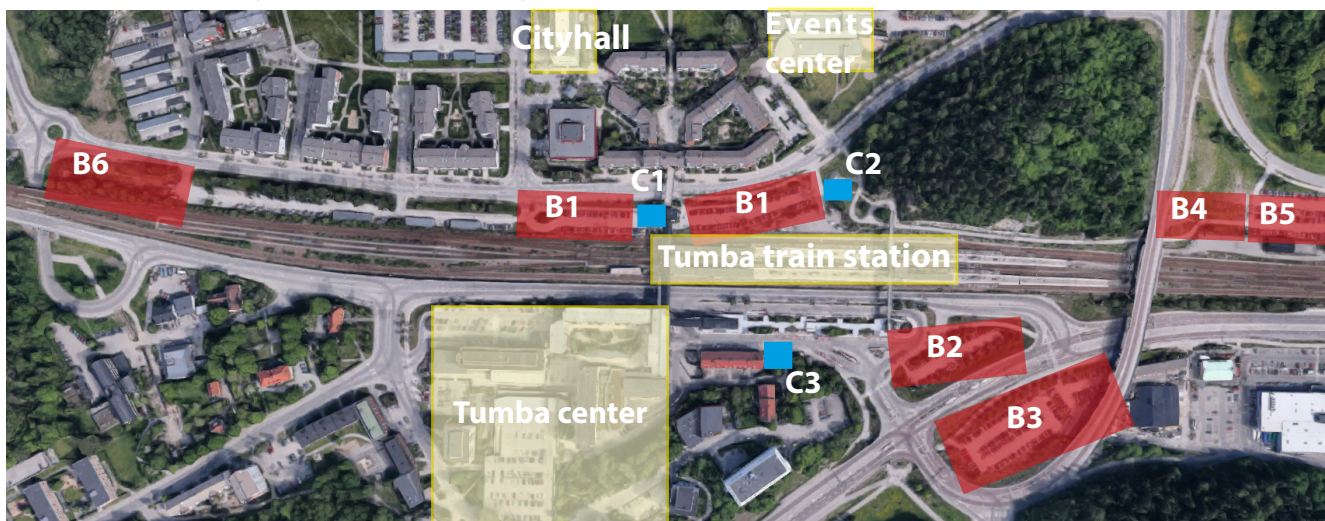


Figure 6 Park-and-ride areas location. B (bil) for car parking and C (cykel) for bicycle.

or at east of Botkyrka. The two park and ride areas located in Hans Stahle road in Tumba have the highest number of parked vehicles whose car owners do not live in Botkyrka, almost a half. According to the analysis by Botkyrka municipality, about 7 percent of the cars come from other parts of the region of Stockholm. This data was lower in the report published one year before by COWI where it reached 3 percent.

In COWI's research (2017) about 70 percent of the parked cars have an address within 5 km from the station area, which is usually considered to be the limit of acceptable bicycle distance. The prerequisites for increasing the proportion that choose the cycle should therefore be good.

The six park and ride areas are attractive also for people who do not want to commute by train or bus because the spots are free of charge and opened 24/7. It is possible that some places are used as residential parking, indeed a few cars are listed within 1 km from the station. Another possible explanation is that those sites are used as short-

term parking or by those working near the station. However, a check of the nearest addresses shows that none of them was parked on surface B4 / B5, on which night parking is also allowed.

Most of the Botkyrka's inhabitants travel daily to other municipalities in the county to study or work. Among Botkyrka's workers, 70 percent commute from the municipality, of which 37 percent commute to Stockholm. Among those working in Botkyrka, about 50 percent live in the municipality and 50 percent are inbound from another municipality. Largest commuting takes place towards / from north - northeast. To there about 25000 Botkyrka's inhabitants commute, and from north - northeast more than 8000 people commute to Botkyrka. Regarding commuting to / from south-southwest, the number of commuters and lorries is more even. About 3000 Botkyrka's inhabitants commute there and approximately 3,500 people commute from south-southwest. For trips to and

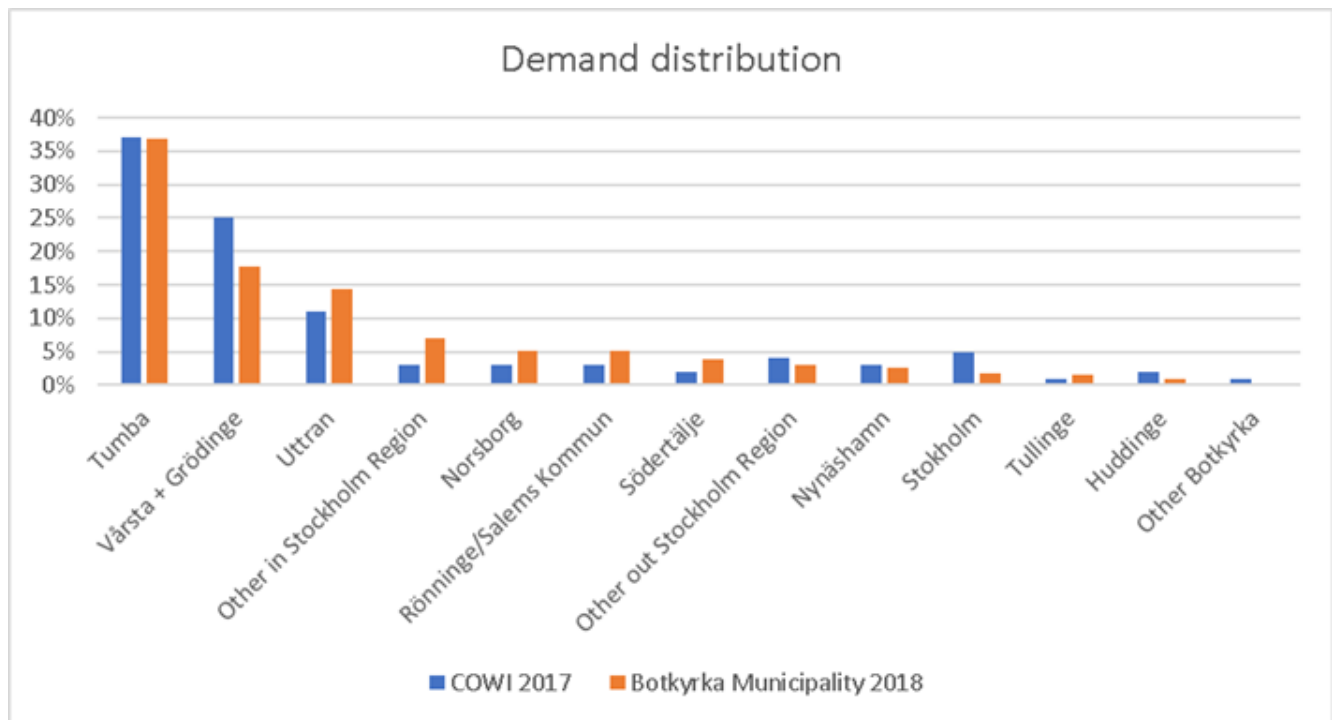


Figure 16 Comparison between COWI's data (2017) and Botkyrka municipality's (2018).

from Stockholm's inner city, public transport is the most used transport mode, 80 percent.

Further research

COMPETITION BETWEEN PARK-AND-RIDE AND PUBLIC TRANSPORT

Paquette's study (2018) shows that the 80 percent of park-and-ride users would use transit mode instead of car if the areas would not exist. There has to be a further research on where the parking areas would be placed to choose carefully where they are really needed and for a deeper validation of the spatial analysis method that this study proposes.

QUANTIFICATION OF BEHAVIOURAL FACTORS CONNECTED TO PARK-AND-RIDE USE

The lack of quantitative approaches and researches about the subject limited this research. Further studies have to give mathematical models to predict the behaviour of the users especially about the attitude to commute from car to public transport in specific case study. If a studied population have a high attitude to use public transport then park-and-ride would not be an useful parking management strategy and its application should be re-considered.

THE USE OF CURRENT TUMBA STATION'S PARKING AREAS AFTER THE EXECUTION OF PROPOSED MANAGEMENT STRATEGIES

This study proposed parking fees structured both in the short and in the long period together with regulations and other synergic strategies. From the perspective of the municipality of Botkyrka, it would be useful to apply quantitative methods using the data from the vending machines to build traffic models.

COMBINING SL CARD WITH CAR PROPERTY

This research highlights how interesting using app service would be to register user's car, credit card and intersect this data with the SL database. This would let know if the owner of the car has a public transport membership. In this way the user can pay through the app just starting it when parked and turning off the counter when goes away. Currently, app services for parking payment such as Betala-P, ParkOnOff, Easypark and Parkster don't check SL database so the user must use machines to register the SL card through NFC connection every time (s)he parks.

PARKING AREA OF THE SCHOOL IN KÄRRVÄGEN

Further investigations should study if there is the concrete possibility of using the parking area in front of the school in Kärrvägen. The most appro-

priate parking management strategy would be sharing the parking spots. If the sharing is possible, the research should study also if there is the need to increase the number of spots.

QUANTITATIVE ANALYSIS TO CALCULATE THE AMOUNT OF RESERVED SPOTS

This study proposes to reserve spots for shared vehicles, carpooling services, taxis and disable people. Further analysis should calculate the proportion of reserved spots on the total amount.

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