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Master's degree Project in Logistics and Transport Management

Game of Drones

Viability Study of Drone Deliveries in Swedish Rural Last Mile Transport

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Abstract

Problem discussion and objective: Despite its well-established networks of service points, Swedish logistics carriers are still facing many last mile challenges in terms of satisfying customers and becoming more sustainable while also being profitable. These challenges are expected to escalate especially in Swedish rural areas which cannot be solved by conventional methods. A drone is an unmanned aerial vehicle (UAV) which is an innovative transport mean featured with high flexibility and efficiency. It is regarded as a potential transport method in rural areas with poor infrastructure. Therefore, this study aims at examining the viability of drone deliveries in B2C last mile logistics in Swedish rural areas.

Methodology: This study firstly carried out a systematic literature review in the existing academic articles focusing on drone deliveries. Then, five Swedish rural municipalities were selected for conducting detailed research on and provided the ground for simulations. The simulation conceptualized the delivery routes in a real-life setting between service points and churches in order to compare the delivery time between vans and drones.

Results and Conclusion: The results show that although drone delivery has many development opportunities, it is not ready to be implemented at the present stage but may become a feasible solution in the future. Firstly, the legal framework supporting the integration of drones into logistics networks is well under way. Secondly, most of the delivery routes in the simulation are found to be time-saving with drones. But it has become less competitive due to its current technical constraints, in scenarios such as increased service coverage, ground vehicles driving in high-speed, or harsh weather. Thirdly, drones are more environmentally friendly than conventional vehicles. Fourthly, Swedish customers expect the home delivery of better service quality which poses additional opportunities especially in rural areas. Which makes drones to be a potential cost-effective solution for carriers with increased service level. Lastly, public acceptance currently of drone logistics is limited especially in Swedish rural areas of ageing society, which could be solved by deploying correct public relationship strategies with the maturity of previously discussed aspects.

Keywords: Drone, UAV, Last mile, B2C, Logistics, Rural area, Sweden

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Abbreviations

B2B	Business to Business
B2C	Business to Customer
ED	Euclidean distance
FMCG	Fast Moving Consumer Goods
GDP	Gross domestic product
GHG	Greenhouse gas
LGV	Light goods vehicle
UAV	Unmanned aerial vehicle

1. INTRODUCTION

In this chapter, the background of the study is firstly introduced with a brief description of the last mile problem followed with a presentation of different types of drones with its business history of logistics implications. Further, the last mile challenge is elaborated in urban- and rural areas which induces the rural last mile challenge between developing- and developed economies. Then, the rural last mile problem focusing on Sweden is discussed which leads to the purpose of this study. Finally, the research questions are presented, and an outline of the thesis is illustrated.

1.1. Background

1.1.1. The last mile challenges

Last mile delivery is the final step of the supply chain where the goods are delivered to its recipient either at the recipient's home or at a service point. It is the major difference in e-commerce and traditional business in the Business to Consumer (B2C) context. (Rizet, et al., 2010; Gevaers, Van de Voorde & Vanelslander, 2014) This step usually involves three types of stakeholders: 1) customers, 2) merchants, 3) carriers, and each of which has their own expectations and challenges. As for customers, the parcel is expected to be shipped at a lower price with shorter waiting time; considering merchants, the complexity of last mile delivery is high due to the trade-offs between cost and service level; carriers face the challenge of meeting the demand of customers and merchants while maintaining their own profitability. (Lee, et al., 2016; Mangiaracina, et al., 2019)

Further, last mile delivery is regarded as one of the main contributors in terms of cost, effectiveness (i.e. service level), and environment in the entire supply chain. (Rizet, et al., 2010; Gevaers, Van de Voorde & Vanelslander, 2014) More specifically, the cost of last mile delivery can account for up to 50% of total logistics costs depending on scenarios according to Vanelslander, Deketele and Van Hove (2013). Consequently, the cost plays a determining role in logistics effectiveness as it impacts performances including speed, lead time, punctuality and delivery customization, etc. that in turn impacts the overall service quality. (Mangiaracina, et al., 2019) From the environmental perspective, the impact of last mile delivery is mostly associated with traffic congestion, noise, and air quality (Morganti, et al., 2014; Macioszek, 2018).

With the increasing demand of freight transport generated by the rapid growth of e-commerce, it is necessary to find a cost-competitive and more sustainable transportation that also provides satisfied service level in last mile logistics (Brotcorne, et al., 2019; Janjevic & Winkenbach, 2020) Just like the concept of having deliveries by drones to your balcony (Brunner, et al., 2019), many believe that commercial drones will be part of the future transportation network as they are flexible especially in areas where the transportation infrastructure is limited (Markvica, et al., 2018; Tiwapat, Pornsing & Jomthong, 2018). SESAR (2018) estimates that at least ten times more drones will be part of daily life by 2035 providing a variety of services. But using drones for last mile delivery has long been a controversial topic in the logistics industry (Rosen, 2019).

1.1.2. Drones in logistics

A drone, also known as an unmanned aerial vehicle (UAV), it is a pilotless aircraft that is fully autonomous. Due to its unique features and abilities, the practise of drones is versatile across many sectors including infrastructure, agriculture, construction, photography and more. For different purposes, there are different types of drones with varied levels of range and endurance. (Heutger & Kückelhaus, 2014)

For logistics industry, the drone that is used for practise are primarily electrical multi-rotors. (Heutger & Kückelhaus, 2014) It is featured with vertical take-off and landing which is regarded as a suitable method for last mile deliveries in both urban- and rural areas. Multi-rotor drones are often short ranged with a limited payload capacity. (Zhao, 2017; Tian, et al., 2018) The drone in *figure 1* for example has a maximum range of 20 km and a maximum payload of 12 kg.

Figure 1. SF Ark Octocoper Drone. (Source: SF Technology, 2020)

1.1.3. Business history of drone logistics

Over the years, numerous experiments have been conducted by large logistics enterprises as well as e-commerce giants regarding drone deliveries around the world. These attempts were focused on the integration of drones into their supply chain, see *table 1*. Some of the tests appear to imply that logistics drones are ready for practical use in B2B and B2C last-mile deliveries in the U.S [5], China [1], [2], [3] and specific countries in Europe [4], [6].

Table 1. Summary of the business history of drone logistics.

2013	• *Amazon* announced its drone program "Prime Air".
	• *La Poste* planned to use four-rotor aircraft to deliver newspapers.
	• *UPS* tested the delivery service by drone.
	• The headquarter of *DHL* completed the outdoor test of drone delivery.
	• *SF Express* conducted drone tests and entered the pilot phase.
2014	• *Google* revealed Project Wing has already been in work for at least 2 years.
	• *La Poste* tested delivery of packages by drones in mountainous areas.
	• *DHL*'s 2nd generation UAV Parcelcopter2.0 is licensed by the German Federal Ministry of Transport and Aviation Authority for express delivery test flights.
	• *DHL* delivered medicine to Juist island by drone.
2015	• *La Poste* verified the reliability of drones operating in freezing weather.
	• *La Poste* completed a test of a drone delivery terminal.
	• Project Wing failed and *Google* turned to a different drone design.
	• *Amazon* has come up with a plan to regulate traffic for drone deliveries in order to get the test license from the authority.
	• *Matternet* tested the first drone delivery system in Zurich to transport blood and pathology samples to labs.
2016	• *DHL* completed the integration of UAVs and intelligent parcel cabinets.
	• *Amazon* completed its first drone test in the UK.
	• *La Poste* achieved autonomous delivery of parcels by drone after obtaining permission from the aviation regulator.
	• *JD Logistics* set up a UAV operating & dispatching center in Suqian, Jiangsu, carried out trial operation, and planned to promote in entire Jiangsu. [1]
	• *UPS* partnered with *Zipline* to use drones to deliver humanitarian supplies in Rwanda.
	• *Matternet* worked with UNICEF to test drone delivery in Malawi.
2017	• *UPS* conducted its first commercial drone test.
	• *UPS* tested the delivery mode of "Truck+Drone" in Tampa, Florida.
	• *Amazon*'s first drone delivery operation in the US.
	• *SF Express* built its UAV operation center.
	• *SF Express* tested its self-developed heavy UAV.
	• *Swiss Post* used UAVs to deliver urgent medical goods between

	hospitals and planned to expand the business scope in 2018.
2018	● *SF Express* obtained a regional drone aviation operating license.
	● *JD Logistics* tried to use drones to deliver fresh products.
	● *JD Logistics* officially launched its regular UAV pilot operation in Guang'an, Sichuan.[2]
	● *SF Express* tested drone delivery to transport agricultural products in Ganzhou, Jiangxi, which is able to serve 200 thousand people (The pilot period is 2 years).[3]
	● *Flytrex* became the first company in the world to drone-deliver directly to customers' backyards in Reykjavik.[4]
2019	● The drone delivery business of *UPS* was approved by the Federal Aviation Administration (FAA).
	● *UPS* worked with CVS Health to deliver prescription drugs to customer's homes by drones.
	● *UPS* partnered with *Matternet* started to move medical samples over North Carolina by drones.
	● *Google Wing* got the drone delivery license from the Federal Aviation Administration (FAA) and offered drone delivery services in Christiansburg, Virginia.[5]
2020	● *SF Express* used logistics drones (Ark Octocoper Drone) to send emergency medical supplies with a total weight of 70 kg to the affected area after COVID-19 suddenly broke out in Wuhan.
	● The drone delivery service that is operated by *Swiss Post* has resumed after a disruption caused by two crashes. The improved UAV system has completed more than 2,000 test flights in Switzerland, with a flight range of more than 17,000 kilometers.[6]
	● The UK government will start with delivery of medical supplies using drones due to the urgent situation of COVID-19 shortly.

1.2. Problem discussion

1.2.1. Last mile problem in different contexts

If carefully investigating the last mile problem, it can be found that there are significant differences in urban- respective rural areas. Cost simulation based on Belgium finds that the logistics cost of a last mile delivery to be 7.75 EUR in rural areas and 2.25 EUR in urban areas. (Gevaers, Van de Voorde & Vanelslander, 2014) The lower population density in rural areas leads to more severe negative impact than that in urban areas, even the average distances travelled by delivery vehicles are similar. It is also found that the consumption of e-commerce per capita is higher in rural areas than in urban areas (Boyer, Prud'homme & Chung, 2009; Cárdenas, Beckers & Vanelslander, 2017), since rural customers are able to gain access to a wide-ranging product assortment at a lower price level compared to their local brick and mortar stores while also being able to compensate their travel time. (Sousa, et al., 2020)

Moreover, rural logistics is more complicated than urban logistics in developing countries, such as China. UNDP (2016) concludes an extreme heterogeneity in terms of economic development between different Chinese rural areas. The data concludes the province that scored the highest living standards index is Zhejiang, which is almost doubled than the province of Tibet that scored lowest. The investigated living standard including road coverage is found to be significantly low in mountainous areas, primarily in West China. Without enough road coverage, these rural areas lack many prerequisites for a mature conventional logistics network which leads to low distribution efficiency. Also, the impoverished population with low education level has limited access and knowledge for modern technologies such as computers. Moreover, deliveries can only reach township level whereas the majority of rural population still lives in villages. (Zhang & Lu, 2018; Jiang, et al., 2019)

Apart from these barriers, there are many similarities in both economic contexts. The major issue in a last mile problem is dispersed population (Boyer, Prud'homme & Chung, 2009). Additionally, rural customers expect their parcels to be charged at a good price and delivered within a certain time frame, which denotes the challenge for traditional carriers to deliver small quantities over a longer distance, especially problematic for products in the cold chain of the grocery sector. (Sousa, et al., 2020)

1.2.2. How is last mile a challenge in Swedish rural areas?

Despite the challenges in different contexts discussed so far, the drone is considered to be a viable solution for the near future. This study chose to focus the developed economy – Sweden as there has been no prior research on drone deliveries in Swedish rural areas. This choice will be motivated further in the rest of this chapter.

Firstly, Sweden has potentially increasing demand for e-commerce, which can be proven by the growth of turnover in Swedish e-commerce. The growth in traditional brick and mortar business is only 45 % compared to 1230 % in e-commerce during 2003 and 2018. (Trafikanalys, 2019a) This in turn generates large package flow that is constantly in increase, especially small parcels weighing under 31.5 kg (Trafikanalys, 2018).

Secondly, an efficient and effective management of last mile logistics is therefore necessary for meeting the increasing freight volume. Sweden has built a mature last mile delivery network in the form of densely distributed service points across the country, which results in approximately half of its population living within 1 km to the closest service point according to Trafikanalys, 2018. This is contrary to other European cities that are still undergoing rapid developments of this concept. Service point is usually provided by an existing retail business such as supermarkets and one of its major functions is to be operated as an inventory so that customers can pick up their packages within the given time. It is presumed that the driver of the maturity of this network in Sweden is intensive labour costs. (Liu, Wang & Susilo, 2019) Service points have naturally become the most common delivery option for B2C e-commerce in Sweden (Postnord, 2019).

Despite having a well-developed network of service points, a **third** reason is the change of customer behaviours. Previous studies show that Swedish customers tend to have lower expectations on delivery method and waiting time compared to that of other countries (Konkurrensverket, 2016), and less people demand home deliveries (Ehandel, 2017). However, Test fakta (2016) finds that the number of complaints by customers regarding parcel deliveries has increased significantly in recent years. Postnord (2019) in its annual report states that customers have started to increase their expectations regarding parcel deliveries. It is found that home delivery has become preferable when this option is feasible, in terms of customer's availability at home and the reasonable price level. In line with PTS (2019a), customers expect to have cheaper or even free and faster delivery options and returns.

As for the **fourth** reason, the delivery quality is found to be relatively low. Service points with limited inventory space are not structured and home delivery is either coordinated. In Northern rural areas, large packages are being left outdoor in snow (SVT, 2019) and many similar complaints (SVD, 2016; SVD, 2019) The consequence of carriers' limited knowledge on rural deliveries is wrong forecast on delivery time and carriers hardly find an effective last mile solution as the delivery vans are often half empty. Furthermore, the delivery option for rural areas is less available among small e-merchants. (PTS, 2019a; 2019b)

Finally, Sweden is the third largest country in the EU in terms of area but ranks as 14^{th} based on its population (Svenskhandel, 2019) and 87 % of its population lives in urban areas today (SCB, 2019). Swedish rural areas are featured with longer travel distances to many facilities including service points and less developed public transport network, indicating a higher car driving demand compared to that in urban areas (Bahr, 2009; Liu, Wang & Susilo, 2019). Which results in a much higher number of private cars per household than that in urban areas. Moreover, these cars are generally less environmentally friendly, as the majority is older and larger with higher fuel consumption. Also, there is limited access to more environmentally friendly fuel options among local fuel stations. According to Trafikanalys (2019b), 91 % of the distance travelled by private cars consumes diesel and petroleum while the rest consumes alternative fuels in 2019. Moreover, it is found that rural people are reluctant to change their travel pattern to public transport even as fuel price increases. (Bahr, 2009)

In summary, opportunities brought by digitalization also set higher requirements on logistics management in a more competitive market. It is demanding to have fast, cost-effective as well as sustainable logistics solutions that also satisfy customers. The existing research regarding drone deliveries is sparse and a research gap of drone deliveries in Swedish rural areas can be observed. Therefore, this thesis will attempt to reduce this research gap with a viability study of drone deliveries in Swedish rural areas. In order to provide insights encompassing different rural areas in Sweden, five municipalities with adequate representative rural characteristics were chosen from Swedish official classification of "rural areas": Sorsele, Ragunda, Torsby, Tanum and Borgholm. Further, the data was gathered from these areas in order to generate a more towards real-world quantitative simulation trying to scientifically investigate the viability of drone deliveries in Swedish rural areas.

1.3. Research objective and Questions

The objective of this study is to investigate the opportunities and challenges of implementing drone deliveries in the current B2C last mile logistics network in Swedish rural areas. The outcome aims at providing academic insights that reduces the current knowledge gap.

Based on background descriptions, problem discussion and the objective of this study, two research questions are proposed:

RQ1: *What advantages and disadvantages do drone delivery have versus traditional transportation?*

RQ2: *Can drones become a viable B2C last mile logistics solution in Swedish rural areas?*

1.4. Delimitations

This study is delimited to last mile logistics of B2C e-commerce in Swedish rural areas. As the study has chosen to examine five cases, i.e. Swedish rural municipalities, the case study and the experimental study will therefore not concern areas outside the cases. Further, the case study and the experimental study do not lay focus on a specific freight carrier, nor a specific online merchant. In this study, the term *drone* has been chosen to use for uniformity. Lastly, technical specifications of drones are only briefly considered here.

1.5. Thesis outline

This study is outlined as *figure 2*.

Figure 2. Thesis outline. (Own illustration)

2. THEORETICAL FRAMEWORK

This chapter firstly introduces the Swedish logistics market with a background description. Then, different delivery setups using drones and its outcomes are described. Following this the research of advantages and disadvantages regarding drone deliveries in different contexts with a focus on logistics are presented. Lastly, this chapter finished with a section summary to present the pros and cons of drone deliveries for subsequent analysis.

2.1. Background description of Swedish market

2.1.1. Market share

The Swedish postal and package delivery sector had been state monopoly until 1993. The deregulation of this market did result in higher efficiency and service level as well as reduced cost for customers. However, there has never been any actual competition ever since. Although the formal entry barrier is low, it requires enormous investments in different stages of the supply chain such as sorting and distribution. (Framtidensdistribution, 2019) In Swedish parcel delivery market today, Postnord has a market share of 60%, DB Schenker respective DHL 15 to 20 % and the rest is divided by Bring, Bussgods, UPS and others (PTS, 2019a).

Postnord's dominant market position (PTS, 2020) is the result of well-developed infrastructure networks as well as systematic and strategic acquisition with discounts for expansion of operations to new markets as a state-owned (60 % Swedish authority and 40 % Danish authority) company. Its primary responsibility is to provide a general postal service for collection and distribution of letters and parcels weighing under 20 kg. (Framtidensdistribution, 2019) In terms of rural deliveries, it provides an additional service "lantbrevbäring" in the form of home deliveries, which requires the recipient to actively book delivery of packages by telephone or through Postnord's website. The recipient also needs to be able to receive and, if necessary, also acknowledge the shipment. (PTS, 2019a; Postnord, 2020a) It has three types of service points all over the country where it provides general service, service for business (sometimes also allows for private customers) as well as service for pick-up only. The number of service points in sum is 2,098 in 2019, see *table 1,* where the last type of service point has been significantly increased.

With similar market share, both DB Schenker and DHL have a total of service points of 1,513 respective 1,640. While Bussgods shares the rest of the market with other companies, it also has the highest logistics coverage in Northern Sweden (Bussgods, n.d.) primarily in four counties (Jämtland-, Västernorrland-, Västerbotten- and Norrbotten county). Its network has also extended to the south through cooperation with other logistics carriers. (PTS, 2019a)

Table 2. Total service point towards private customers 2019.

Carrier	Type of service point	Total service points 2019 (2018)
Postnord	General service point	1,587 (1,574)
	Service point for business	237 (241)
	Service point only for pick-up	274 (164)
DB Schenker	General service point	1,513 (1,444)
DHL	General service point	1,640 (1,580)
Bussgods	General service point	307 (323)
Source: PTS, 2019a		

Framtidensdistribution (2019) in its political proposals addresses the issues of increasing competition and diversity in the production and distribution market, pointing out that Postnord with the market dominance is incapable of adapting to the developments brought by digitalization and technological evolutions.

2.1.2 Market growth

In 2018, the total sale of Swedish e-commerce channels is 77 million SEK which represents 10% of the total retail sales. *Figure 3* shows the growth of turnover in e-commerce, Gross domestic product (GDP) and retail trade during 2003 and 2018 in Sweden. Swedish e-commerce has increased with 1230% when retail trade and GDP with 45% respective 53% during the period.

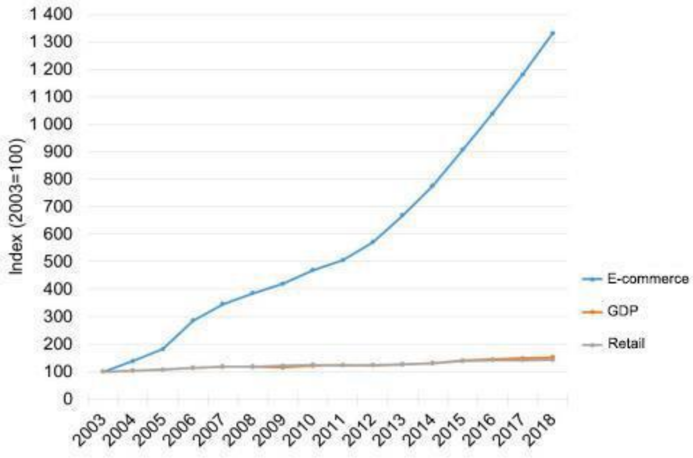

Figure 3. Growth of turnover in e-commerce, GDP and retail trade during 2003 and 2018.

(Source: Trafikanalys, 2019a)

When comparing the annual growth of online- to offline sales, the difference is significant. See *figure 4*. In 2017, online sales grow with 94 % in contrast to 6 % in offline sales. Later in 2018, the growth of online sales increases with more than 100 %. The growth of e-commerce declines in 2019 as the durable goods section recaptures the sales through offline channels. Further, Svenskhandel (2019) confirms that there is an increase of 335 % in online sales compared to an increase of 18 % in physical retailing from 2005 to 2017.

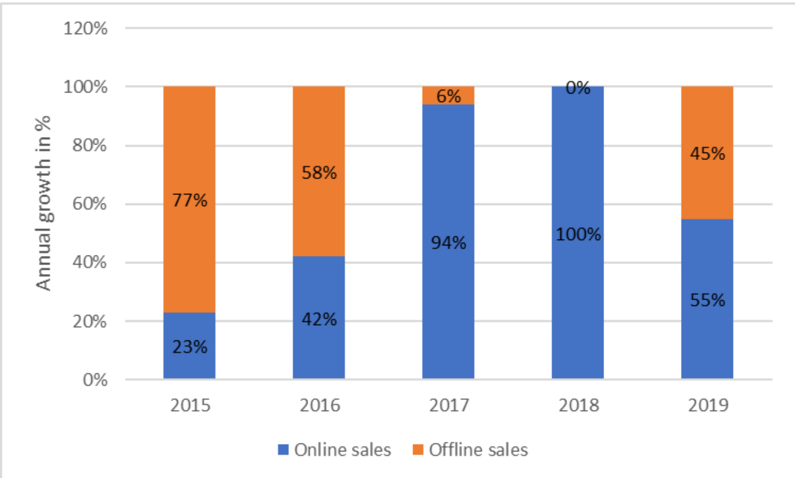

Figure 4. Annual growth of online- and offline sales between 2015 and 2019. (Source: Postnord, 2019)

As a result of increased online sales, Trafikanalys (2018) indicates that approximately 99 million packages weighing between 0 and 31.5 kg had been sent in the year of 2017 with an increase of 20.7% compared to the previous year. *Figure 7* shows the flow of packages in volume between 1995 and 2017. See *figure 5*.

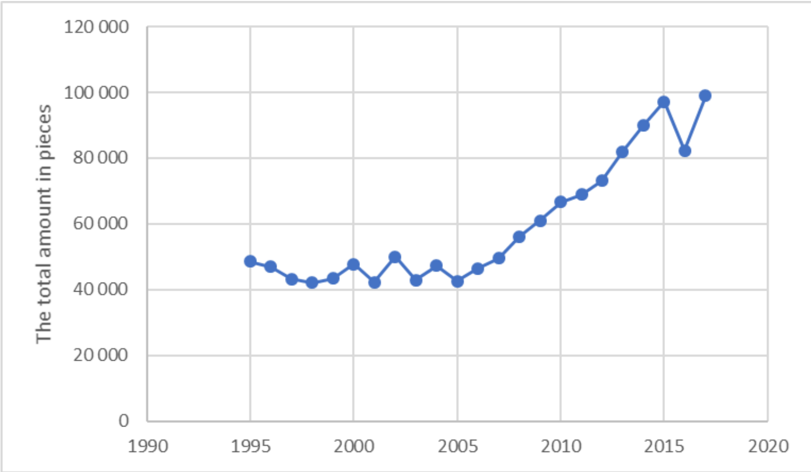

Figure 5. The volume of package flow between 1995 and 2017. (Source: Trafikanalys, 2018)

2.1.3. Market segmentation

In traditional marketing, the goods/service is marked with whether search-, experience- or credential category. Search products are those that can be evaluated easily before purchase, such as clothing and furniture, while experience products of their intangible nature are related to those that are not easily assessable before the purchase, such as restaurants and broadbands. Credential products include legal advice, education, etc. (Ostrom & Iacobucci, 1995; Hsieh, Chiu & Chiang, 2005) With the emergence of e-commerce, these categorizations have been redefined and realigned in an online marketing context.

Figure 6 presents an overview of performance in different sectors on the basis of Swedish e-commerce in 2019. Among all, the online sales of books distinguish largely from others as it is a typical search product that is relatively cheap which also covers several customer groups. Also, its distribution is comparatively easy due to its compact appearance. (Sandén, 2001) Thereafter, consumer electronics comes in the second which consists of a relatively large proportion of typical search products. The online sales of clothes and shoes contribute to around 20 % of the total sales, but also generates amongst others 20 % of returns (CSPB, 2019). In traditional business, clothes and shoes are obvious search products which customers have access to fitting rooms at retail stores, while in online business, they become naturally experienced products. (Trafikanalys, 2019a)

In terms of online sales growth rate, pharmaceutical products show the highest followed by FMCG (Fast moving consumer goods) that includes non-durable household goods and other consumables (Brierley, 2002; Majumdar, 2004). Since the re-regulation of the pharmacy sector, the previous monopoly had been replaced by many competitors, amongst others, online pharmacy retailers that cover around 95 % of the country. (TLV, 2020) While the FMCG sector includes both search- and experience products, it puts additional challenges such as cold chain for the last mile delivery. (Trafikanalys, 2019a)

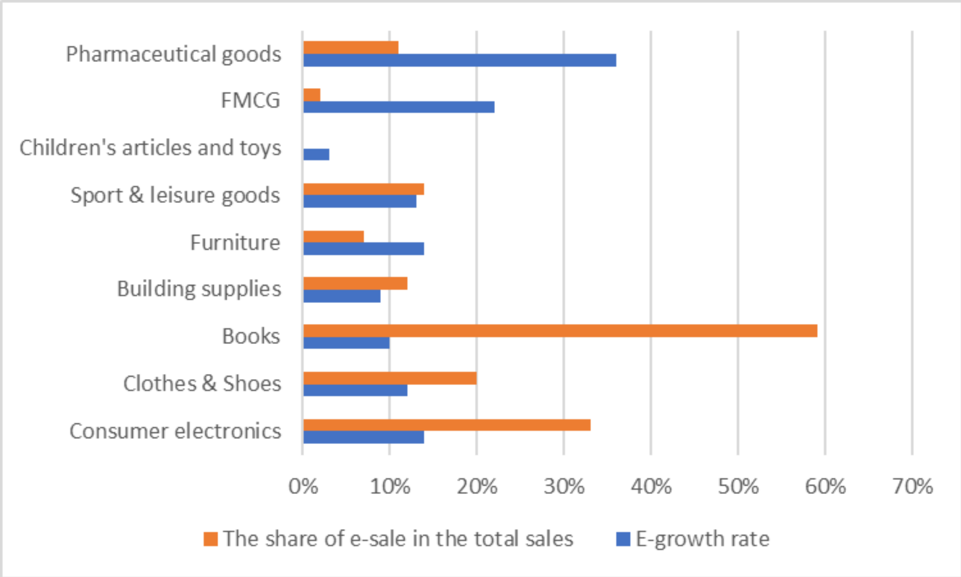

Figure 6. Statistics of e-commerce in different sectors in 2019. (Source: Postnord, 2019)

2.1.4. Current last mile solution

As mentioned previously, Sweden has a mature network of service points across the country in the B2C logistics. The advantage of a service point is the high flexibility it provides for customers. In general, 89 % of the population lives within 5 km from a service point and around 50 % within 1 km. Only 4 % of the population lives more than 10 km. Southern Sweden has a relatively higher accessibility to such a place compared to that in Northern Sweden. (Trafikanalys, 2018; 2019a) Furthermore, it is found to be challenging when expanding the network through establishing a new service point, even though the demand exists. In urban areas, the challenge is usually associated with space, but in rural areas, the suitable stores where carriers can build a trustworthy relationship is few. (Konkurrensverket, 2016; 2018)

Besides the most common option, there are several other services offered by logistics carriers and e-merchants such as pick-up at store (Click & Collect). Customers can order products online and pick-up at a physical store. For example, the home electronics giant Elgiganten offers Click & Collect within one hour and 50 % of its customers choose this service as it contributes to a time-efficient purchase (Ehandel, 2018); H&M (Market, 2019) also indicates an increasing number of its customers choosing this service since the launch in autumn 2018. For grocery chains which consist of time-sensitive products, Willys established pick-up stations right outside its stores even for cold chain products (Handelstrender, 2016). This option is usually most expensive for customers but cheapest for merchants (Trafikanalys, 2019a).

Another delivery method is home delivery which does not cost customers for transport but the most expensive for merchants. The lead time is usually 1 to 3 days depending on whether the goods come from a store, a nearby logistics hub, or from a central warehouse. Moreover, there are other innovative modes such as Insta box, crowd-shipping, and digital lock etc. (Trafikanalys, 2019a). Postnord (n.d.) in an interview states that they strongly focus on digital lock, smart box and akin methods for the future last mile solutions, but due to the complex nature of safety issues, drones are currently not their interest.

2.1.5. Consumer preference

In a survey of ranking the importance of delivery methods in online shopping context, deliver to service point accounts for 83 % while both bookable home delivery and deliver to postbox for 47 %, deliver to smartbox (e.g. Instabox) for 16%. The respondents also rank optional delivery methods with 82%, followed by quick delivery (1 to 2 days) with 64 % and optional carriers for 51 %. See *figure 7*. (Postnord, 2019)

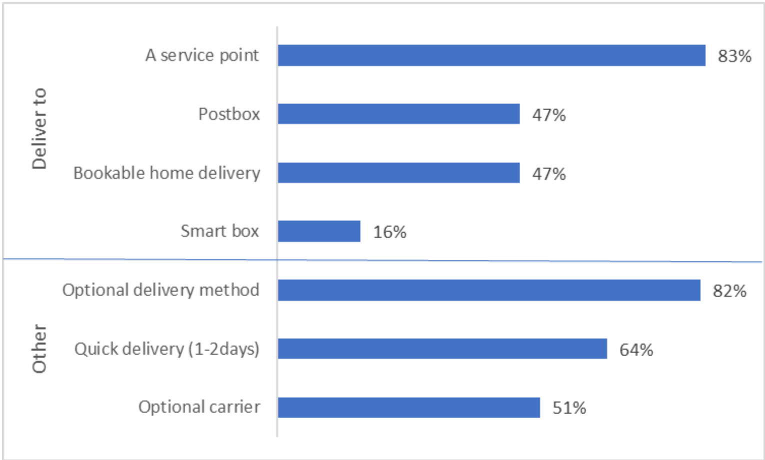

Figure 7. Results from survey of ranking important characteristics of deliveries by customers.

(Source: Postnord, 2019)

Postnord (2019) presents the comparison between the number of deliveries that were carried out and corresponding expectations of the customers. See *figure 8*. It is categorized with three types of delivery methods: self-pick-up, home delivery with receipts as well as without receipts. Pick-up at a service point is the most common option (65%), it is however less preferred among customers (38%). Other pick-up options such as in-store and smartbox have an overall much lower level of expectations as well as the number of deliveries done. In home delivery with receipts, more people prefer evening time (10%) in contrast to the reality (2%). In home delivery without receipts, more people prefer postbox (28%) in contrast to what is actually done (17%). Same with the option ”leaving at the door”.

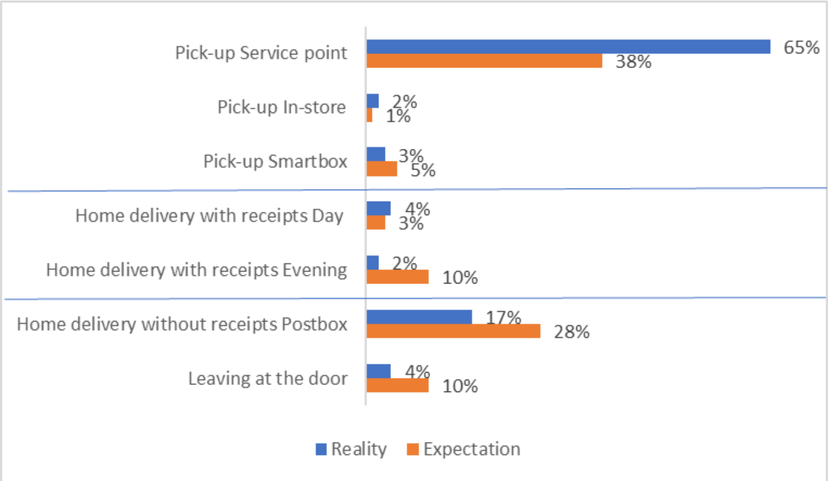

Figure 8. Actual action vs. Customer expectation in delivery methods. (Source: Postnord, 2019)

The result from a survey on the latest purchase through traditional- respective online channels suggests an increasing trend with increased age groups, that is, older people make more purchases through traditional business channels than younger people. Accordingly, it shows a decline in terms of online shopping with the increasing age groups (*Figure 9*) (Postnord, 2019). There is also a minor difference in purchasing habits between female and male. Women tend to order more frequently and spend more money, while men usually spend more money on one order (Trafikanalys, 2019a).

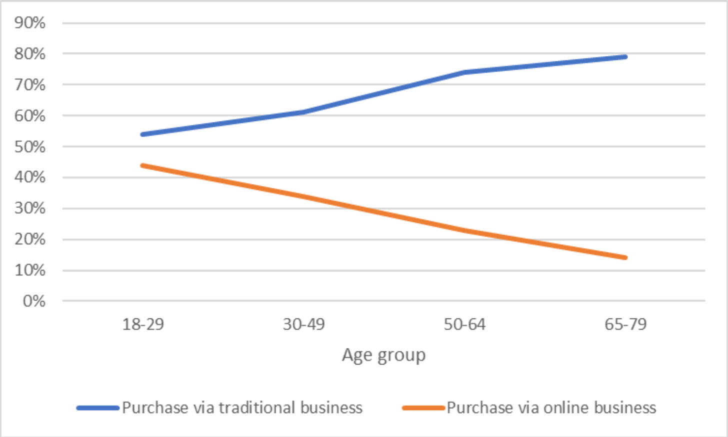

Figure 9. The share of respondents on their latest purchases via traditional respective online channels.

(Source: Postnord, 2019)

The proportion of e-shoppers and spend varies significantly in different counties. As shown in *figure 10.* The number of e-shoppers in the counties is between 60% and 70 % in general, and Gotland county has the lowest proportion which could be due to its geographical location (Postnord, 2019). The motives for e-shopping are varied. For inhabitants in urban areas such as Stockholm, the accessibility of home delivery and the convenience to returns are emphasized. While for those who live in less populated areas, the reason is more options offered online compared to local stores. It is also discussed that the relatively low level in Gotland is partly due to its aging population (i.e. ranked highest in average ages in the country) and partly due to general e-shoppers tend to be younger. In general, the proportion of rural living who shops online is 67% compared to an average of 66 % for people living in other areas. (Trafikanalys, 2019a)

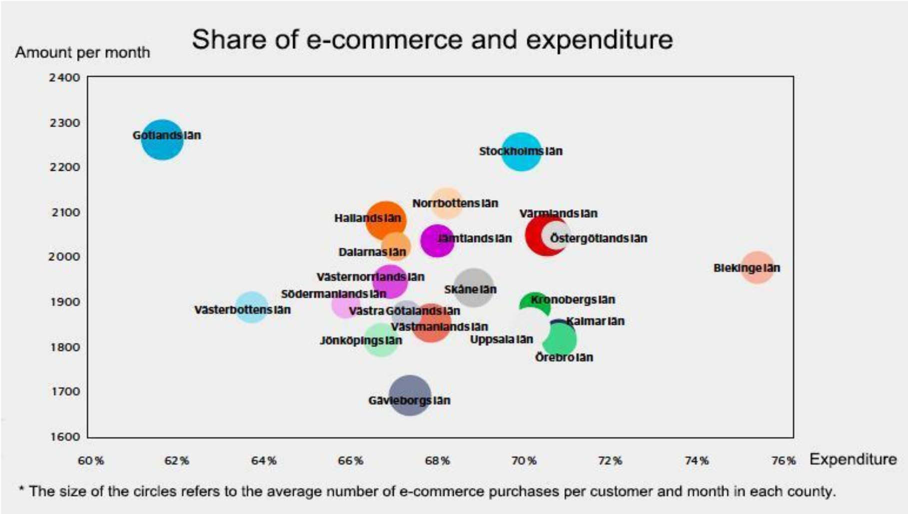

Figure 10. The share of e-commerce and expenditure in 2019. (Postnord, 2019)

Trafikanalys (2019a) concludes that e-commerce has the potential in reducing traffic volume in terms of personal trips made by cars with the purpose of shopping. Compiling the Swedish National Travel Surveys between 2011 and 2016, it is found that the main purpose for shopping results in one trip per week in general where 62 % are grocery shopping, that is FMCG goods. The round trip of travel distance for grocery shopping is 11.4 km compared to 32.2 km for other trips. Regarding transport methods, 63 % drive, 21 % walk, and 6 % use public transport. Also, a trend that people travel longer distances when they make less trips is obtained. (Trafikanalys, 2018)

2.2. Research of drone delivery setup

Various setups of drone deliveries in last mile logistics have been studied in recent years. Amazon filed a patent of a multi-use drone docking station where it operates as a distribution center to facilitate drone deliveries by providing a series of services for drones in 2016 (Michel, 2017). Goodchild and Toy (2018) conclude that there are certain prerequisites in a delivery system of using only drones to be beneficial: small service zones (e.g. close to a depot) or small numbers of recipients or both.

Based on the concept of drone fulfillment centers, a study of potential drone coverage in last mile delivery among EU-28 countries finds that the service only reaches around 7 % of the citizens based on the current technology. With improved technologies, this service coverage can extend to 30 %. The coverage could be heterogeneous due to differences in population and land-use patterns. Also, some EU countries are found to be profitable from this concept: the UK, Germany, Italy and France. The result also suggests Sweden to be one of the lowest in terms of coverage and economic return. (Aurambout, Gkoumas & Biagio, 2019)

Swanson (2019) simulates a model for comparing delivery time between drones and vans on a delivery distance up to 15 km based on a concrete grocery retailer. The result shows that the difference between the drive time and the drone time increases along with the delivery distance increases. Besides, the conclusion also suggests that certain variables should take into account such as 1) the time it takes during loading- and unloading process, as drones have a different setup with other ground vehicles. Also, 2) the time it takes to interact with customers as the ground vehicle is usually driven by a staff while the drone is unmanned, which in turn may lead to delay for the following deliveries or an overall increased delivery time. Besides the hard values, the business should also consider its soft values such as customer service philosophies and business strategies when applying drone deliveries into the supply chain.

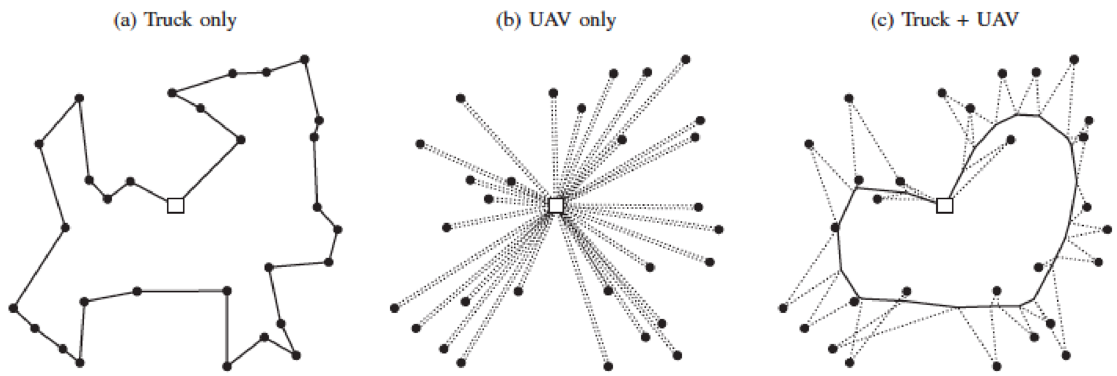

Figure 11. Topology comparison. (Source: Carlsson & Song, 2018)

Other studies find the potential of a hybrid delivery mode of trucks and drones since both transportation modes provide complementary features in terms of speed, weight, capacity and range. In this kind of system, as shown in *figure 11(c)*, trucks will operate as a mobile depot for drones to start its route and return for reloading cargo and recharging its batteries. (Agatz, Bouman & Schmidt, 2016; Hu, Hu & Xu, 2019) Findings from the simulation of one drone and one truck shows the ratio of the speed of the drone and the truck highly affects the overall delivery efficiency (Carlsson & Song, 2018). When Campbell, Sweeney and Zhang (2017) study multiple drones equipped on one truck for an assigned delivery route, they find it to be more beneficial in suburban areas compared to truck-only mode. Also, the scale of benefits is highly dependent on the operation cost of drones and trucks and customer density. (Campbell, Sweeney & Zhang, 2017)

Moreover, another type of a hybrid delivery mode proposed by Wang, Poikonen and Golden (2016) is multiple drones and multiple trucks. The result of the simulation suggests the number of drones per truck and the relation between the speed of drones and that of trucks are decisive for the overall efficiency. However, another simulation study (Sacramento, Pisinger & Ropke, 2019) suggests the determining factor instead of the ratio of the speeds is the drone's loading capacity and the number of customers along the route.

2.3. Advantage of drone delivery

2.3.1. Improving delivery efficiency

The traditional transport mode of "vehicle + courier" is not only highly dependent on road infrastructure, but also affected by variables such as the traffic paralysis caused by congestions in urban areas. In some rural areas, the infrastructure is still under development which increases the difficulty for deliveries carried out. These inconveniences result in longer delivery time and higher cost can be compensated by using drones, as it operates in the air where it is not limited to topography or geography. (Zeng, 2019; Dai, 2020) Consistent with Zheng (2017), drone deliveries are highly efficient when it is performed within areas close to a depot, or within the range of a mobile depot.

According to tests conducted by Amazon, its Prime Air allows drones to deliver within a range of 16 km from its distribution centre with a loading capacity less than 2.27 kg to customer's door in half an hour. 86% of the products sold at Amazon.com are able to meet these requirements (Zheng, 2017). With its densely distributed warehouses, Amazon estimates that 20% of its e-commerce orders can be delivered by drones (Lee, et al., 2016).

2.3.2. Saving costs

Compared with traditional air transportation such as cargo aircraft and helicopters, the cost of drones is lower in terms of manufacturing-, labour-, fuel-, as well as other related costs (ZTO UAV Team, 2019). More importantly, drones also provide substantial savings compared to traditional ground transport (Lee, et al., 2016; Campbell, Sweeney & Zhang, 2017; Sacramento, Pisinger & Ropke, 2019). For example, in urban areas, the last mile delivery is often costly and complex due to traffic congestions. It is estimated that the cost of delivering a small package can be reduced to as low as 1 USD, in contrast to the express delivery offered by Amazon in cities like New York at a price of 7.99 USD. (Zheng, 2017)

In rural areas, the delivery tends to be time-consuming which in turn results in increased delivery cost due to non-centralized logistics caused by low population density and poor infrastructure network. Especially in the case of China, the rural delivery costs are usually five times higher than that in urban (Ren, 2019), while in Europe and US this ratio goes on a triple basis (Boyer, Prud‘homme & Chung, 2009; Gevaers, et al., 2014). The potential savings drone can contribute to are considered to be a competitive solution in rural deliveries. (Ren, 2019; Dai, 2020)

2.3.3. High flexibility

Drone deliveries are also featured with high flexibility which eases deliveries in rural areas (Lee, et al., 2016), as predicted by Joerss, et al. (2016) that the rural area with a population less than 50,000 inhabitants will be dominated by drones for same-day delivery. Its capability of conducting frequent deliveries in small batches characterized what the current express logistics desires. Especially for the delivery of urgent items in rural areas, drones can provide significantly more efficient and personalized service than traditional methods (YTO research institute, 2018). Also, scholars find the high flexibility of drone deliveries in combination with trucks can significantly improve the overall delivery efficiency in rural cold chain logistics (Deng, et al., 2019).

2.3.4. Low environmental requirements

In some remote areas, the nature of harsh environment with poor infrastructure conditions makes it difficult or even impossible to access with traditional vehicles, so that products can only be delivered by couriers on foot. However, the drone has strong environmental adaptability and manoeuvrability. For example, it can operate normally even if the temperature is lower than -10°C and rotor aircraft can realize vertical take-off and landing (Ren, 2019). Therefore, logistics drones, instead of traditional delivery tools, are less affected by the restrictions above, especially suitable for use in rural areas with complex topography.

2.3.5. Capacity synergy and optimization

On the basis of scientific planning, the comprehensive application of Internet+, UAV, robot and other emerging technologies can realize capacity synergy and optimization. In order to handle the orders quicker and replenish continuously, Amazon, Wal-Mart and other enterprises have established intelligent and efficient urban distribution centres for drones (such as Amazon's UAV tower) on account of building advanced IT- and intelligent warehousing systems to optimize logistics processes. (ZTO UAV team, 2019) As concluded by Mohammed, et al. (2014), the integration of drones with smart cities can benefit any country if deployed effectively and efficiently.

In addition to different setups using drones presented previously, the drone also has the potential of collaborating with other transportation means such as rail- and water transport as to be part of the intermodal transport. Markvica, et al. (2018) argue a future network to be the combination of different innovative transports, in which drones focus on local distribution. Using drones for last mile delivery combined with ground transportation will make the service capability of modern logistics reach a new level, and the overall efficiency, cost and transportation capacity will be optimized and reconstructed as well. (ZTO UAV team, 2019)

2.3.6. More environmentally friendly

Drone-based deliveries are considered to be able to reduce GHG emissions and energy consumptions in the freight sector if carefully deployed (Stolaroff, et al., 2018; Chiang, et al., 2019). As found by Park, Kim and Suh (2018), drone deliveries are able to reduce environmental impact by 13 times more effective in rural areas than in urban areas. From the perspective of reducing CO_2 emission, drone delivery is found to be beneficial in rural areas with low customer density compared to conventional vehicles but not in dense urban areas compared to electric vehicles (Figliozzi, 2017). A full life stage study concludes that the production of drones is the main contributor to emissions rather than its logistics activities (Koiwanit, 2018).

Goodchild and Toy (2018) state that the amount of emissions is highly dependent on energy consumption of drones, that means the distance it travels and the number of recipients it serves. Delivery vans with a capacity of approximately 380 times more than drones are also 8 times more efficient in energy consumption depending on travel distances and loading units, that to say, in highly populated areas (Figliozzi, 2017). Consistent with Kirschstein (2020), it is less energy efficient in dense urban areas, but it is much more efficient in energy consumption in rural areas. Moreover, the conclusion suggests using only drones in delivery is not worthwhile in the energy consuming viewpoint in most scenarios (Kirschstein, 2020).

2.4. Disadvantage of drone delivery

Even numerous researches along with experiments demonstrate the benefits of drone deliveries in commercial context, but its application on a large scale is still challenged by many factors. Three major barriers addressed by Heutger and Kückelhaus (2014) are regulatory issues due to lack of legislations, limited public acceptance caused by privacy and safety concerns from constrained knowledge of emerging technologies and the unclear nature of the existing legal system, as well as the immature technology that are often correlated (Anbaroğlu, 2017; ZTO UAV Team, 2019). The regulatory and social issues regarding drones are argued to be more challenging than its technological development, especially in the US and Europe (Floreano & Wood, 2015).

2.4.1. Lack of complete legislation

Different countries apply different regulation approaches regarding the degree of commercializing drones varying from permissive to outright ban. It is found four factors to be commonly included in regulating drones: 1) pilot's license, 2) aircraft registration, 3) restricted zones, and 4) insurance. (Jones, 2017)

In the US, the current drone regulations are not mature enough to cover all possible matters, as there are concerns that are not yet addressed by existing policy (Barlow, et al., 2019). In Chinese logistics sector, there still lacks a comprehensive and standardized legislative system for drones, including the regulation of certificating permission for operation and a regulated supervision system (Zheng, 2018). But it has already shown a clear trend that accelerates the development towards such a system in response to freight drones (Liang, et al., 2018; Wang, et al., 2020). India is one of the countries that strictly banned commercial drones (Jones, 2017) due to lack of proper legislation and uncertainty regarding security. The greatly anticipated National Drone Policy was released not until late 2018, but the commercialization of drones in India still remains an uncertain future. (Srivastava, et al., 2020)

Sweden belongs to the countries that follow a permissive approach in regulating its aviation framework. The legislation on commercial drone use is considered to be relatively unrestricted. That is to say, following proper procedures in the form of any operational guidelines, licenses acquirement, registration and insurance, there should be no hinder of commercial drone use. (Jones, 2017) According to Transportstyrelsen (2019), different regulations are applied to drones in different categories. But there are currently two basic rules to follow: 1) the permission is required when flying drones out of sight and higher than 120 meter over the ground; 2) it is not allowed to fly drones in a way that it generates any risk for other aircrafts, people, animals, environment or property. Additionally, the new regulations regarding drones will be applied to all EU countries from July 2020. The new regulations are said to be similar to the current legislations, but a new set of categories will be deployed depending on the risk degree of flight. (Transportstyrelsen, 2019)

Zheng (2017) and Jones (2017) argue that restrictions regarding logistics drones flying beyond visual line of sight and over crowds will largely limit the capability of drones. As part of the European ATM (Air Traffic Management) Master plan, SESAR (2018) proposes a set of action plans with the bold vision of safe integration of drones into all environments including BVLOS (Beyond Visual Line of Sight) operations. Zheng (2019) concludes the necessity of establishing corresponding legislations in different countries through an extensive number of experiments.

2.4.2. Safety and privacy concern

The safety of drone deliveries involves three aspects: the safety of the drone per se, the safety of the parcel and the public safety. Apart from its technical defects, the safety of drones can also be affected by external factors during the flight. For example, any obstacles in the air including high rise buildings, high voltage lines, civil flights and other potential attacks by animals or human beings. However, the remote control of drone deliveries does not allow the operator to have full manipulation over the entire flight. (Liu, et al., 2019; Dai, 2020) At the end of 2017, Amazon patents a self-disintegration drone trying to address any related risks (Sina Tech, 2017). Cargo safety is mainly concerned with whether the goods will be damaged in transit (Liu, et al., 2019). Yuan and Rodrigues (2019) propose a solution of minimizing damage when delivering fragile packages by drones.

Further, the public safety concerns the impact of previously mentioned potential risks if drones fail to deal with mechanical difficulties, which can result in widespread public concerns (Liu, et al., 2019). Multiple accidents have been recorded such as two intruded drones nearly crashing into an airline of 264 passengers at Heathrow Airport in London in early 2019. Also, Swiss Post's medicine delivery service by drone had been suspended indefinitely after two delivery crashes (McNabb, 2019). In Ontario alone, there were 33 drone collisions in the first six months of 2019, according to Transport Canada (2020).

Besides public concerns in terms of safety, inappropriate and irresponsible use of drones such as privacy disturbing, transportation of illegal material, or worse can result in increased privacy issues (Russell, Goubran & Kwamena, 2019).

2.4.3. Immature technology

In the technological perspective, the capacity of drones has long been a major concern in the logistics sector. The electric drones as the mainstream among freight drones largely limit its payload capacity (Liang, et al., 2018; Dai, 2020). For instance, the maximum range and payload capacity for Parcelcopter 4.0 from DHL are 65 km respectively 4 kg, for Prime Air 2.0 by Amazon are 24 km and 2.2 kg, for Ark Octocoper of SF Express are 20 km and 12 kg respectively. At present, drones usually carry a load of less than 15 kg for last mile deliveries point to point. The technical limitation often does not allow a drone being used for multiple deliveries at a time but equipped with a certain weight of parcels for a single delivery. Due to this delivery characteristic, it is hard to coordinate each distribution and even harder to have it to be fully loaded. That to say, it is difficult to maximize a drone's capacity. (Liu, et al., 2019)

Besides, drones have limited resistance to severe weather and extreme temperature. In a field test conducted by NASA, several drones were blown more than 100 feet off their scheduled flight path, forcing them out of the assigned working areas (Liang, et al., 2018). The result from a study concludes that drones operate in harsh environmental conditions such as lower temperature will consume more energy (Scanavino, Vilardi & Guglieri, 2019). Consistent with the findings from Yao and Wang (2014) that the capacity of lithium batteries that are mainly used on logistics drones reduces by 40 % when temperature goes from 23 ℃ to -20 ℃. This weakness greatly shortens the travel distances which in turn impacts the delivery performance. It also results in higher costs as the delivery process may need to be solved by using ground vehicles. (Markvica, et al., 2018; Liu, et al., 2019)

which shortens the travel distance and impacts the delivery performance, and the delivery process may need to be solved by using ground vehicles which results in higher costs

Another technical challenge is the coordination system, which enables the drone to accurately locate its route and destinations. Traditional drones are loaded with GPS modules to coordinate, which cannot be received easily. It is especially challenging in terms of the accuracy in rural areas where the topography may largely consist of mountainous terrain (Zheng, 2017). Additionally, Dayarian, et al. (2018) point out that urban environments consist of a large number of high-rise buildings and busy civil aviation routes may not be suitable for drone delivery. In addition, cybersecurity issues pose challenges to drones, as their operation depends on the relevant system, which is vulnerable to cyber-attacks (Dahiya & Garg, 2019).

2.4.4. High upfront investment

Lastly, it involves high upfront investments in preliminary and continued R&D, infrastructure such as specialized distribution centres for drones and personnel training costs, even though the manufacturing cost of drones is relatively cheap. All of these factors obstruct the development of drone logistics directly or indirectly. Therefore, its implementation is only attractive for large logistics- and e-commerce enterprises with strong financial resources. (Zeng, 2019)

2.5. Section summary

In this part, the existing research of drone logistics in attributes, advantages and disadvantages (shown in the *table 3* below), and implementation field are carefully collected and further summarized systematically. The scenarios with development potential of drone logistics tend to have the following characteristics:1) lack of access to transportation; 2) with high or increasing customer demand of home delivery service that is not well satisfied yet; 3) the goods carried by drones are time sensitive, small in size and relatively high in value. In addition, in the analysis section, some of the viewpoints in these studies will be cited as the theoretical and practical basis for a part of the criteria.

Table 3. Pros & Cons of drone delivery.

PROS	High efficiency	● Not affected by traffic congestion.
		● Linear routes shorten the delivery distance and improve the speed of distribution.
	High flexibility	● Characteristics of small batch, high frequency, and high speed.
	Cost-saving	● Lower manufacturing costs, labour costs, fuel costs, and other operating costs compared with traditional air transportation.
		● Land resources saving and lower construction & maintenance costs of infrastructure compared with road transportation.
		● Lower last mile delivery costs due to the reduced complexity of delivery.
	Low environment dependence	● Easy access to areas with inconvenient road condition and/or complex terrain.
		● Vertical take-off and landing (rotorcraft only)
	Environmentally friendly	● Energy consumption and pollutants emission reduction.
	Capacity synergy & optimization	● Coordinate with other activities in Smart Logistics.
		● As a complement to the traditional mode of transportation.
CONS	Lack of legal supervision	● Operation license system for logistics drone
		● Supervision system for logistics enterprises
		● Clear standard system of UAV for logistics industry
		● Legal responsibility for the implementation of logistics drone
	Immature technology	● Limited battery capacity
		● Limited load capacity
		● Positioning function is greatly affected by daylight.
		● Unstable signal reception
	Inadequate security	● Uncertainty of remote control
		● Very limited tolerance to severe weather and extreme temperature
		● Threat of external attacks
		● Risk of package falling
		● Possibility of personal privacy invasion
	High upfront investment	● R&D costs
		● Infrastructure costs
		● Personnel training costs

3. METHODOLOGY

This chapter presents and motivates the methods adopted in this study. Firstly, the research strategy is presented. After which, two types of research methods – multi-case study and experimental study employed are presented separately. Finally, research quality is discussed.

3.1. Research strategy

The main purpose of this study is to research opportunities and challenges of implementing drones in last mile B2C logistics in rural areas in Sweden through the following aspects: economical, environmental, technological, legislative and social. The existing academic research on drone logistics is in a scarce quantity since drones are an emerging technology in recent years. This study is therefore classified as an exploratory study due to its unexplored nature. Further, in order to examine drone logistics in a specific context – B2C last mile in Swedish rural areas and generate more comprehensive insights regarding the context, a mixed design of multiple-case- and experimental study has been adopted. This study aims to develop rather than test a hypothesis, that is, drone deliveries could become viable in certain Swedish rural areas (Collis & Hussey, 2013).

This study has used a mixed approach of both qualitative and quantitative research. The qualitative approach that emphasizes words and texts is employed in the search of relevant literature, articles and reports. It builds the ground to which the proceeding study will be directed to and clarifies the different aspects to be investigated. It aims to answer to RQ1: *What advantages and disadvantages does drone delivery have versus traditional transportation?* The quantitative approach is the quantification of numerical data and analysis, which has been adopted to create criteria for selecting the case, to collect data for the cases and to process data for the experimental study in order to answer RQ2: *Can drones become a viable B2C last mile logistics solution in Swedish rural areas?* (Bryman & Bell, 2015)

Bryman and Bell (2015) mentions the link between theory and research in which the term *theory* refers to the understanding of observed regularities. The first and foremost issue to think about is what form of theory in relation to the research: deductive, inductive or abductive. Deductive reasoning is the experiment of existing theories by observations and empirical findings. In contrast, inductive reasoning induces theories from the topic of interest based on observations and empirical findings. Finally, abductive reasoning seeks to find the best explanation of the subject in a way combining the previously mentioned two types but avoiding each of their weaknesses. The exploratorative nature of this study directs it more towards inductive reasoning. But the authors were able to build observations on their particular interests using a deductive approach in the form of literature search and review. Therefore, this study has adopted abductive reasoning that leans towards inductive direction.

Idiosyncrasy in the research impacts the information retrieval and collection as well as the synthesis of the relevant literature which indicates the necessity of determining its epistemological- and ontological assumption in the subject area. (Durach, Kembro & Wieland, 2017) The epistemological thinking of the study refers to what one might understand about the reality while the ontological assumption is the nature of reality. It is divided into two main paradigms – positivism and interpretivism. Positivism concerns the single and objective nature of reality that emphasizes on the general and average knowledge to produce explanations. While interpretivism stems from the multiple and subjective nature that concerns particular contexts to generate understandings. (Collis & Hussey, 2013) Therefore, this study is directed more towards interpretivism.

3.2. Multiple-case study

Yin (2009) states that two or more cases tend to produce more powerful and compelling reasoning than a single case study. The number of cases should be declared in order to make the research effective and the result produced by cases is anticipated to be similar (a literal replication) or conflicting based on assumptions (a theoretical replication). It is suggested that for literal replication there might be 2 or 3 cases whereas a set of 4 to 6 cases might be designed for theoretical replication. (Yin, 2009) Considering the broad latitude range of Sweden indicating a large difference in climate between its South and North. (SMHI, 2019) This study therefore postulates a theoretical replication of the cases in which the number of cases is suggested to be 4 to 6. Therefore, five municipalities have been selected among the officially classified rural areas in order to represent different geographical locations.

Yin (2009) also mentions that the research design for case studies should include five elements: 1) the research question, 2) the proposition, 3) the unit(s) of analysis, 4) the logic linking the data to the proposition, 5) the criteria for interpreting the findings. In this thesis, this research design is primarily aiming at *RQ2* which focuses on *how* perspective of drone deliveries. The proposition describes the authors' research core interest as the scope of the study, that is the B2C context in Swedish rural areas. Also, it presents the motivation to why this topic is worth investigating. The units of analysis are the five municipalities: Sorsele, Ragunda, Torsby, Tanum and Borgholm. In order to support the links between the data and the proposition, the preliminary findings of *RQ1* provides fundamental aspects for the proceeding of collecting, reviewing and summarizing data retrieved from different sources. As for the final element, there are no criteria determined for interpreting the findings due to the sources of data used are considered to be reliable enough for this study, as well as the authors' limited time and resources.

3.2.1. Secondary data collection

Systematic review is defined as an approach through systematically collecting extensive secondary data in a replicable, scientific and transparent way in which bias is minimized. (Bryman & Bell, 2015) This research follows the procedures proposed by Hussey and Collis (2013) to conduct the search and review: a list of database, search engines, and websites were prepared for the search; the keywords were defined by research topic and scope; the results of the search that were considered as relevant were kept in record including the authors, article title, publication year and publication location with abstracts and relevant findings; further these articles were scrutinized in order to sift out what were useful; moreover, relevant references from the examined articles were also checked. Finally, the search will be continued throughout the study in order to keep the information up to date.

The sources used for searching were 1) Scopus, 2) University of Gothenburg search engines, 3) Google, 4) CNKI and 5) Baidu Wenku. In terms of search language, 1, 2 and 3 were primarily for searching sources in English, 4 and 5 were exclusively used for Chinese. In terms of data types, 1, 2 and 4 were used primarily for retrieving academic journals, conference papers and reports, articles and books; 3 and 5 were for searching articles regarding relevant business topics in media, commercially produced statistics and further search of statistics.

Additionally, databases of the government agency SCB (Statistics Sweden) had contributed a large amount of quantitative data to this study. A systematic review of data in all subject areas in these databases was conducted in order to generate more relevant information for the study.

- ***Systematics literature review***

Based on the research questions and propositions, a set of subject keywords were determined that were later constructed into search strings in different combinations. For example, drones AND ”supply chain” AND ”rural area”. See *table 4*. The limitation excludes an important criteria *time* due to the novelty of this technology in which the existing studies on its applications of interest are relatively sparse.

Table 4. Keywords

Subject area	English	Chinese
Transport means	Drone, UAV, “unmanned aerial vehicle”, UAS, “unmanned aerial system” “autonomous vehicle”, “autonomous fleet”	无人机
Supply chain	“supply chain”, “last mile”, logistics, “cold chain”, transport, B2C, B2B	供应链，最后一英里，物流，冷链，运输，B2C，B2B
Geography	rural, ”rural area”, ”remote area”	农村，农村地区，偏远，偏远地区，山区，贫困山区
Other	·challenge, opportunity, advantage, disadvantage, benefit, obstacle · legal, regulation, EU · environment, emission · social, perception, public · economic, viability, feasibility	• 挑战，机遇，好处，坏处，优势，劣势，瓶颈 • 法规，立法 • 环境，排放，环保，污染 • 社会，民众接受 • 经济，可行性，可持续发展

The initial search was restricted to the field of article title, abstract and keywords using search terms from all three subject areas which only produced limited results, that in turn generated lesser relevant sources of use. The authors decided to extend the field of search to all fields, which resulted in a higher number but still limited. Thus, the combination of keywords for search was mainly from the subject area of transport means and supply chain in the subsequent search as the number of outcomes was augmentative. Additionally, even the source with its focus outside the subject area of interest were considered as relevant and the parts of the articles were used in this study. Finally, the inclusion criteria for this search was only the keywords from the table, as every piece of information that was able to obtain was considered to be essential.

- ***Case selection***

As discussed in Research design, the cases were selected based on two aspects: 1) official category of rural areas and 2) rural areas in different geographical locations across Sweden. This aims at trying to develop a more comprehensive context for the objective of this study.

According to SKR (2019), Sweden is divided into 21 regions and each region consists of several municipalities. There are 290 municipalities in total that are categorized into three main groups (A – large cities, B – medium-sized towns and C – small towns) based on structural parameters such as population and commuting patterns. Within each main group, several subgroups are further divided (A1-2, B3-6 and C7-9), see appendix 1. (SKR, 2017; 2019) The last two groups (C8 and C9) that are categorized as *rural municipalities*[1] generates a preliminary list of 55 municipalities. The only difference between these two groups is whether or not the municipality has a visitor industry[2]. This factor is considered to not have a negative impact on this study in light of the focus to be B2C last mile logistics.

The next step was to further determine the rural municipalities with more people living in its rural areas (as rural municipalities are still classified into urban areas[3] and rural areas). Based on examination of data retrieved from SKR (2017) and SCB (2019), linking the research questions and the proposition of this study, 7 of the 55 municipalities were chosen. This segregation was based on the total population in each municipality's own urban areas being less than 50 % which helps to refine those municipalities with more population living in their rural areas comparatively.

Finally, the 7 municipalities were illustrated in *figure 12* to make the final decisions. Sorsele, Ragunda and Borgholm were chosen for a distinct reason due to their geographical positions in the region as well as no other municipalities in short distance. In addition to Borgholm

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[1] Rural municipalities:" *municipalities with a population of less than 15,000 inhabitants in the largest urban area, very low commuting rate (less than 30%).*" (SKR, 2017)
[2] Visitor industry: fulfilment of at least two criterias: number of overnight stays (at least 20 nights / person), retail-, restaurant-, or hotel turnover per head of population for a minimum amount of 90,000 SEK respective 10,000 SEK / person. (SKR, 2017)
[3] Urban area:" *a continuous area with at least 200 inhabitants*". (SCB, 2019b)

belonging to part of the island Öland, it is also the only municipality that locates along the east coast, which might conjointly provide different perspectives. Torsby, Sunne, Årjäng and Tanum are located relatively close to each other, among others Torsby, Sunne and Årjäng all belong to Värmland county. Torsby was chosen due to its lowest average population density (2.8 inhabitants per square kilometer) whereas Sunne and Årjäng with 7.1 respective 10.3. Finally, in order to contribute to a more comprehensive case study, Tanum was selected due to its comparatively small area despite its close position to Sunne, Årjäng, and Torsby.

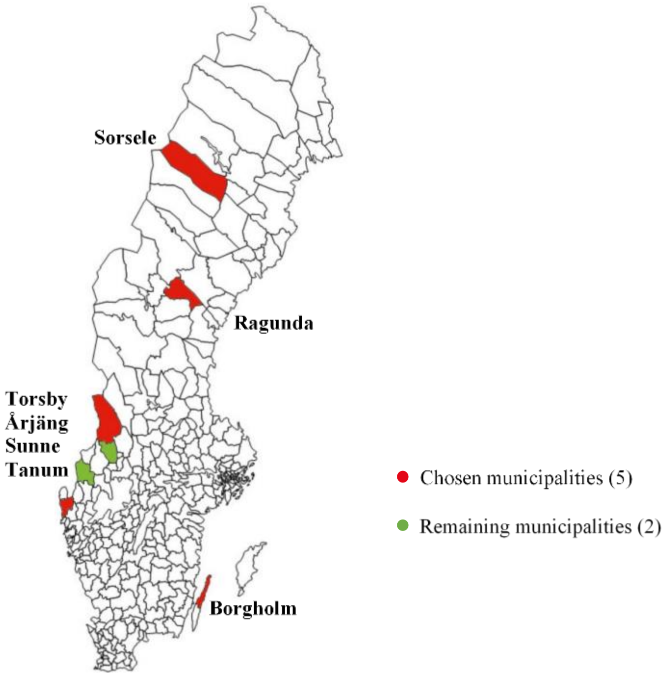

Figure 12. Municipality selection. (Own illustration)

- ***Case study***

SCB's database was the primary source in this part of the study regarding population and demography. Google Map was used for screen shots of the municipalities which were then taken as the base map for their own illustration. These illustrations presented a visualized overview of the population density in each urban area and service point locations. Population density was illustrated through circles with different colours representing the density interval. The size of the circles did not have meaning. The mapping of service point locations was based on the service point search functions supported by each postal service provider: Postnord, DHL, DB Schenker and Bussgods.

3.2.2. Secondary data analysis

Secondary analysis was applied for quantitative data analysis. According to Bryman and Bell (2015), secondary analysis involves the process of re-analysis of data collected by other researchers or other organizations amid their business. The data that was identified as relevant were then exported as Excel files which facilitates the succeeding secondary analysis in Excel. Hermeneutics approach was adopted for qualitative content analysis. This method focuses on subjective interpretation of texts for an in-depth understanding in order to investigate the researched phenomena. (Bryman & Bell, 2015) The authors tried to interpret documents, articles and reports from varied sources towards the research objective of this study with the consideration of the context in which those were written.

3.3. Experimental study

This study adopted an experimental design that deploys data simulation in different scenarios with a real-world setting, which is often referred to as field study or field experiment. (Bryman & Bell, 2015) The concept of this experimental study is to contrast delivery distances made by drones and ground vehicles between the same starting- and receiving points. The output is intended to declare in what ways the delivery distances using respective transport means are different. Therefore, the simulation will apply certain assumptions:

1. This simulation limits to the transport leg after the parcel has been loaded onto the vehicle or the drone to it reaching the recipient.
2. Each shipment using either methods consists of one package. Although vehicles often perform milk run tasks, which is less likely applicable in rural areas due to the sparse population. Thus, this assumption is reasonable.
3. The size and the weight of the parcel is assumed to be within the drone's capacity.

3.3.1. Delivery route design

- ***Starting point (A)***

As mentioned before, pick-up at the service point is the most common and most widely used way of receiving packages in Sweden. The location of each service point is business crucial for a logistics company, therefore, its selection involves a careful, comprehensive and scientific assessment that includes profound factors (i.e. business environment, service level and network construction cost) and many other factors (e.g. package volume, policy and legislation and the role of the service point in the construction of the overall network as well as transportation costs, the population, traffic conditions and urban planning requirements etc. (Zhang, Zhan & Qu, 2011). Thus, service points are deemed as ideal starting points for both drone and ground deliveries and it is marked with *A* when presenting findings. Finally, a summary of all service points in the five municipalities are presented in *appendix 2*.

- ***Receiving point (B)***

At the other end of the delivery route, the coordinates of the church will be collected to represent the receiving points and it is marked with *B* when presenting findings (*appendix 2*). As of 2018, there are 3,903 churches throughout Sweden, and Svenska kyrkan has 5,899,242 registered members, accounting for 57.7% of the total population of the nation. In all the five selected municipalities, registered members even reach about 70% of their urban population. (Svenska kyrkan, 2019) Besides, the location of the church is often chosen to be close to as many residents as possible (Claire, 1954; Jin, 2012). Thus, it is reasonable to use the church to represent the recipient's home as the receiving point since the distance in-between is short enough to be ignored in the simulation.

- ***Delivery route***

In the simulation, the setup of the delivery route between A and B mainly follows two steps. Firstly, two criteria were applied for eliminating receiving points (i.e. churches) that were not feasible for building delivery routes: 1) the churches that are located within 400 meters to a service point as it is the acceptable walking distance (Yang & Diez-Roux, 2012), 2) the churches with a straight-line distance of more than 10 km from a service point based on the maximum range given by SF Technology (2020).

Secondly, the remaining churches that meet the requirements were paired with service points one by one to form delivery routes, in which way setting as many routes as possible to increase the relative accuracy and authenticity of the simulation since it simulates more possible scenarios.

In addition, in order to provide more data support for Analysis section, additional distribution routes will be calculated for other purposes. For further exploring whether the driving speeds have an impact on comparisons, different driving speeds were used to simulate different scenarios, based on the speed limit of 70 km/h in non-urban area in Sweden (European

Commission, 2015). Also, even some of the routes are beyond the referenced range, those are deemed as essential to be included for simulating scenarios affected by highway and river directions. These additional routes will be marked out with *.

Finally, as the routes were coordinated using real-time based Google Map, there could be multiple routes presented with different distances and travel times. Even in some cases the recommended route seemed to have longer distances, the authors chose to follow the given advice considering the dynamic real-world setting. Also, this variable was considered as less relevant for the purpose of this simulation as it did not affect straight-line distance and this distance still being the shortest after all.

3.3.2. Algorithm

All calculations will be made in the assistance of Excel. A summary of definitions for different variables used is presented in *table 5* and the algorithm of each will be explained later. The data was retrieved from Google Map.

Table 5. Variable definitions.

Variable	Description	Unit of measure
ED	Euclidean distance by drones	km of straight-line distance
ND	Network distance by ground vehicles	km of road route distance
ADDS	Average drone driving speed	km per hour
ASDS	Average surface driving speed	km per hour
DDT	Drone delivery time	Minutes
VDT	Vehicle delivery time	Minutes
Ratio	Ratio of ED to ND	Ratio
TD	Time difference of drone- and vehicle routes	Minutes
DPDD	Dominant proportion of drone deliveries	Ratio

- ***Euclidean distance (ED)***

The delivery distance of drones is defined as Euclidean distance (ED) which is the distance between two points in an m-dimensional space, or the natural length of a vector. In two-dimensional and three-dimensional space, ED is the straight-line distance between two points (Tax, Duin & De Ridder, 2004). Since drones fly at low altitudes without being restricted by the direction of the road (Zheng, 2018), ED is suitable for the delivery distance of logistics drones.

The formula of Euclidean distance (ED) in two-dimensional space is defined as $[(x_1-x_2)^2+(y_1-y_2)^2]^{1/2}$, where (x_1,y_1) and (x_2,y_2) are the coordinates of the two points (Ciaschini, et al., 2019). However, geographical coordinates, which are different with geodetic coordinates, cannot be directly applied to the above formula. The distance of a degree of longitude is different in different degrees. A degree of longitude is widest at the equator with a distance about 111 kilometers, which gradually shrinks to zero as it meets at the poles. For the latitude, each degree of latitude is approximately 111 kilometers apart with slight differences which are not that obvious. For instance, the length of a degree is 110.567 kilometers at the equator, 110.948 kilometers at both tropic of cancer and tropic of capricorn, and 111.699 kilometers at each of the poles (Rosenberg, 2020).

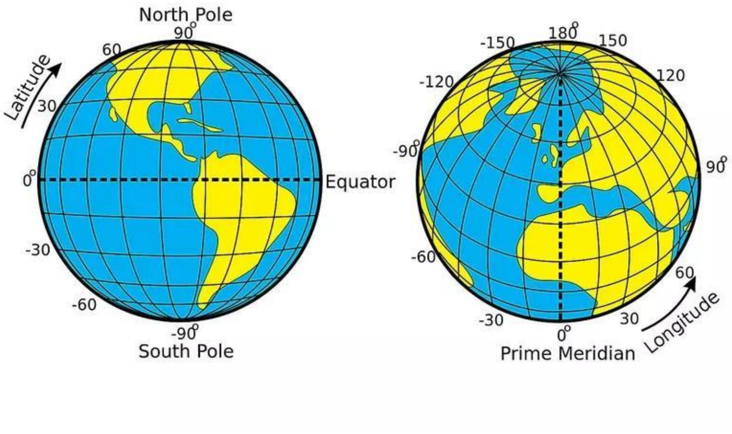

Figure 13. Latitude and longitude of the earth (Source: Djexplo, 2011)

In such a situation, the deformation of the original formula is introduced to calculate the approximate distance between two points with their geographic coordinates (CEA, 1977).

$$ED = 111.199 \times \sqrt{(\varphi_1 - \varphi_2)^2 + (\lambda_1 - \lambda_2)^2 \cos^2(\frac{\varphi_1 + \varphi_2}{2})} \tag{5-1}$$

(φ_1, λ_1): geographic coordinate of the starting point

(φ_2, λ_2): geographic coordinate of the receiving point

- ***Network distance (ND)***

The delivery distance of ground vehicles is defined as Network distance (ND) and it is the road distance which the vehicle travels through in the distribution process.

- ***Average surface delivery speed (ASDS)***

The selection of a specific ground vehicle for the simulation was not made, as the estimated road distance and time between two points are shown in Google Map. Also, for further exploring whether the driving speeds have an impact on comparisons, ASDS of 30-, 40-, 50-, 60- and 70 km/h was applied to simulate different scenarios.

- ***Average drone delivery speed (ADDS)***

The average drone delivery speed that is introduced into the calculation is 43.2 km/h according to Swanson's research in 2019.

- ***Drone delivery time (DDT)***

The drone delivery time (DDT) is calculated by ED and ADDS.

- ***Vehicle delivery time (VDT)***

Vehicle delivery time (VDT) is obtained in two ways: 1) derive the estimated time displayed by Google Map directly; 2) calculate different ASDS respectively by ND.

- ***Ratio***

Ratio is the proportion of ED to ND and it is calculated with ED dividing by ND.

- ***Time difference (TD)***

Time difference is the difference between the time used for performing same delivery routes using either transport means.

- ***Dominant proportion of drone deliveries (DPDD)***

Dominant proportion of advantageous routes (in terms of delivery time) by drones in all routes in respective municipalities. Each route was calculated correspondingly with respective ASDS and the detailed result is presented in *Appendix 3* to *7*.

3.4. Research quality

3.4.1. Reliability & Replicability

Reliability concerns whether the study is repeatable which usually involves stability, internal reliability and inter-observer consistency. (Bryman & Bell, 2015) Firstly, the study is considered to be a low degree of stability due to the dynamic nature of drones per se as well as the external factors such as the social context. This results in huge variation over time. Secondly, the internal reliability of the study is regarded as high even though multiple data were retrieved from one company – Postnord. Due to the dominant market position (60% of the total market share) of this company, the authors believe that its data can be representative to some extent of the overall market. Also, even part of the data was only available for countrywide- and provincewide measurement, it is considered as essential to include and carefully deployed. Lastly, the inter-observer consistency, that is the consistency of observations from the authors is ensured through multiple cross checks.

Replicability concerns whether the same methodology can be applied to other studies with different subjects or experiments. (Bryman & Bell, 2015) The quantitative method of this study in the form of case- and experimental study is deemed to be feasible to repeat as the methodological process has been described in the previous chapters.

3.4.2. Validity

- ***Construct validity***

Construct validity concerns how accurate the study is constructed in a way that it measures what it is supposed to be measured. (Bryman & Bell, 2015) The research focus of this study is the feasibility of using drone deliveries in last mile B2C logistics in Swedish rural areas. Correspondingly, the literature review has built a theoretical framework for the analysis of the research phenomena in the context which is provided by case study. One of the most common ways to verify construct validity is to compare a test with another test. In this case, the feasibility of drone deliveries is verified based on what is produced from 1) the theoretical framework and case study, and 2) experimental study. The theoretical understandings are tested by correlated simulations in order to increase the construct validity.

- ***External validity***

External validity refers to the level of generalizability of the results to be applied to other contexts than the research one. (Bryman & Bell, 2015) A set of five cases (i.e. municipalities) were generated in order to increase the representativeness of the Swedish rural areas in this study. The result has therefore been regarded to be generalizable to Swedish rural areas where the cases were drawn. Additionally, the research is limited to the current state of drone technology, the external validity of the result from the experimental study is restrained. However, the technological development of drones is reckoned as positive signs for the direction of the study. Moreover, the result of this study may not be applicable to rural areas in all other countries due to geographical-, demographic- and economic diversities of different countries. The external validity of the study is therefore low.

- ***Ecological validity***

Ecological validity examines whether the findings of a study can be generalized to a natural social setting, as the business research sometimes produces technically valid results which are unrelated to people's every day. (Bryman & Bell, 2015) This study is deemed to have high ecological validity as presented previously, the last mile logistics in the future will have to be integrated with innovative technologies such as drones.

4. CASE STUDY

In this chapter, the geographic and demographic aspects of the chosen municipalities are presented followed by a summarized retail trade geographic distribution. After which, the climate conditions regarding different parts of Sweden are discussed.

4.1. Geographic and demographic characteristics

4.1.1. Tanum

Tanum municipality belongs to Västra Götaland county and is located in Southern Sweden on the west coast. It has a population of 12,841 and the average population density is 14 inhabitants/km^2. 98,2% of the buildings in Tanum is in the form of small houses and there are 473 private-owned cars for every 1.000 inhabitants. (SCB, 2019)

In contrast to the average statistic of Tanum, *table 6* shows a list of six urban areas in the municipality. Grebbestad and Tanumshede have the highest population among all with 1,952 respective 1,939. But Grebbestad takes up to 0.5 % of the land area when Tanumshede takes 0.2 %. This results in a relatively huge difference in population density, namely 931 and 386. In general, 46.5 % of Tanum's total population live in the urban areas which is corresponding to less than 1.3 % of the total land area of the municipality.

Table 6. Tanum's urban areas overview.

Urban area	Proportion of total population	Population density (inhabitants/km2)	Proportion of total land area	Service points
Tanumshede	15.2%	931	0.2%	2
Grebbestad	15.1%	386	0.5%	2
Fjällbacka	6.7%	511	0.2%	2
Hamburgsund	5.5%	510	0.2%	3
Rabbalshede	2.3%	398	0.1%	0
Östad	1.7%	634	0.0%	1
Summary	46.5%	386 - 931	< 1.3%	10
Source: SCB, 2019				

According to Trafikanalys, 2018, 31% to 36% of the people living in Tanum have less than 1 km travelling distance to the closest service points. In *figure 14* service points provided by four major logistics companies are illustrated. In the Östad area there is one and only dedicated service point serving Postnord, while other areas have shared service points providing package service for two to three companies.

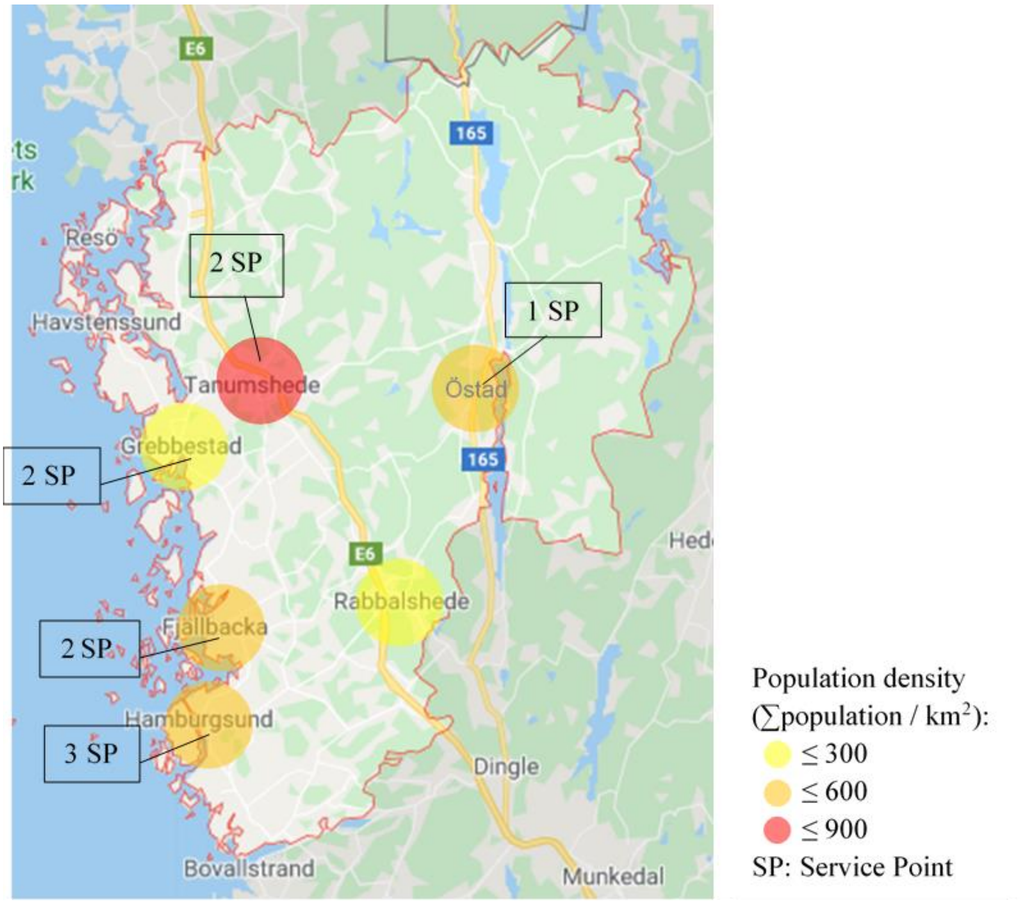

Figure 14. Population density and service points distribution over Tanum. (Own illustration)

61.3 % of Tanum is covered by forest, followed by 16.7 % of other land categories and 13,8 % is used for agriculture. Built up land and related land accounts for 4.2 % of the total area, whereas 1.7 % is road in different types: European and national roads for 11%, county roads for 35 % and other roads for 54 %. See *figure 15*. (SCB, 2019)

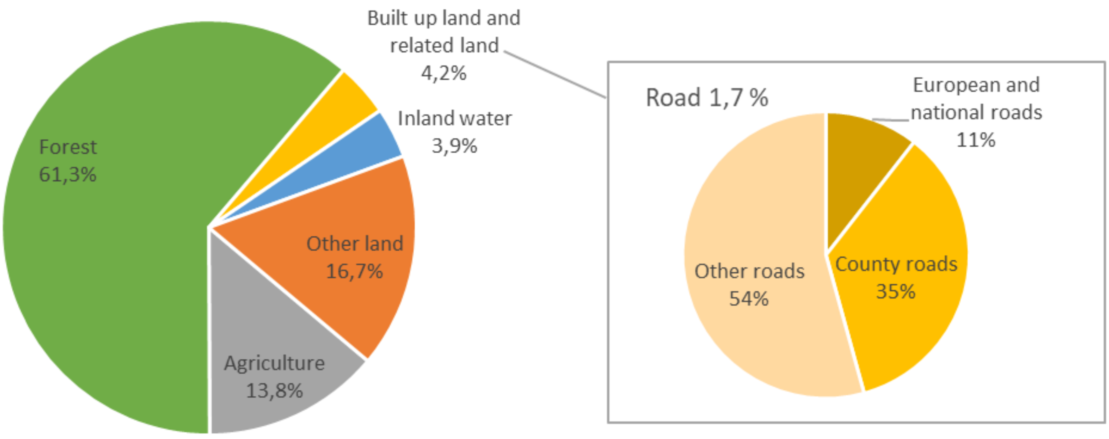

Figure 15. Land use and road type proportion in Tanum. (Source: SCB, 2019)

Studying the age and gender distribution in Tanum based on statistics given in 2019, there is a relatively even distribution of female and male. The total population in each age group has variations which the younger people between 18- and 29-years old accounts for 11 % of Tanum's total population, while the older age groups share the similar proportion between 20% and 22%. See *figure 16*. Additionally, the average age among Tanum's inhabitants is 46.3 years old in which for male and female is 45.4- respective 47.2 years old. (SCB, 2019)

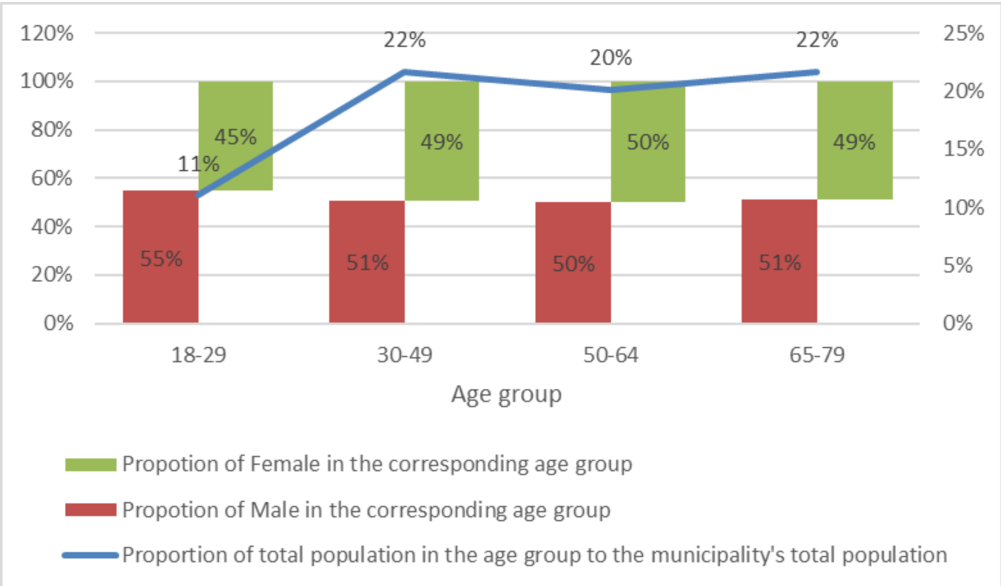

Figure 16. Population distribution by age and gender in Tanum. (Source: SCB, 2019)

4.1.2. Borgholm

Borgholm municipality belongs to Kalmar county and it is part of Sweden's second biggest island which is located close to the west coast. The island has a bridge that connects with main land. The municipality, Borgholm has a population of 10,839 and the average population density is 16 inhabitants/km^2. 98.5 % of the buildings here are in the form of houses and there are 473 private-owned cars for every 1.000 inhabitants. *Table 7* summarizes Borgholm's urban area characteristics. 49.4 % of the population lives in three urban areas – Borgholm, Rälla and Löttorp whereof the largest urban area Borgholm takes up to 40.1 %. (SCB, 2019)

Table 7. Borgholm's urban area overview.

Urban area	Proportion of total population	Population density (inhabitants/km2)	Proportion of total land area	Service points
Borgholm	40,1%	478	1.3%	3
Rälla	3.9%	418	0.1%	0
Löttorp	5.4%	135	0.6%	2
Summary	49.4%	135 - 478	2.0 %	5 (+1)
Source: SCB, 2019				

In Borgholm, 31 – 36 % of its population lives within 1 km to a service point according to Tranfikanalys (2017). In its largest urban area, there are 3 service points that are either dedicated (serving only Postnord respective DHL) or shared (serving DB Schenker and Bussgods). See *figure 17*. In urban area Löttorp, there are 2 shared service points serving all companies, and in Byxelkrok there is 1 shared service point assisting all companies except DB Schenker.

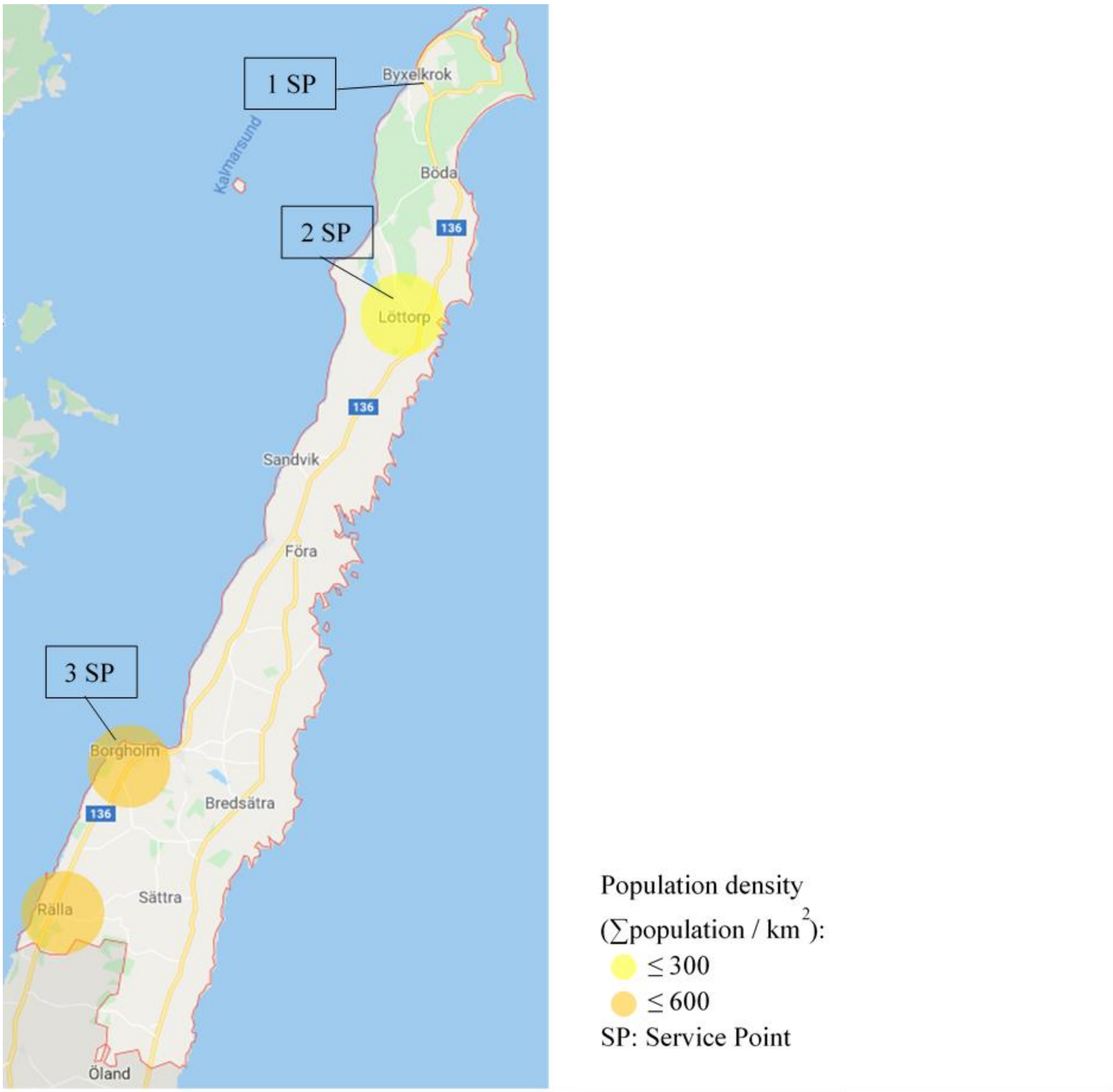

Figure 17. Population density and service points distribution over Borgholm. (Own illustration)

Borgholm has 52.9 % of its land use in agriculture and forest coverage accounts for 30.4 %. Other land takes up to 9.3 % while built up land and related land for 6.9 %. The latter category also includes 2.0 % of roads in different types: county roads for 31 % and other roads for 69 %. See *figure 18*.

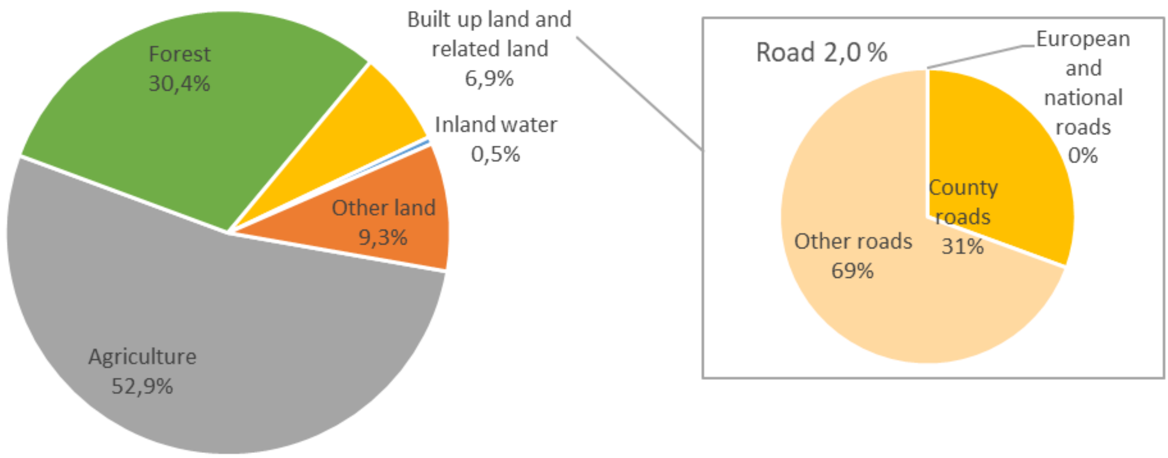

Figure 18. Land use and road types proportion of Borgholm. (Source: SCB, 2019)

The proportion of all age groups is in an increasing trend of 9 % of the population are in their 18 to 29 years old while 27 % are in their 65 to 79 years old. Besides, male and female are largely in an equal distribution, as seen in *figure 19*.

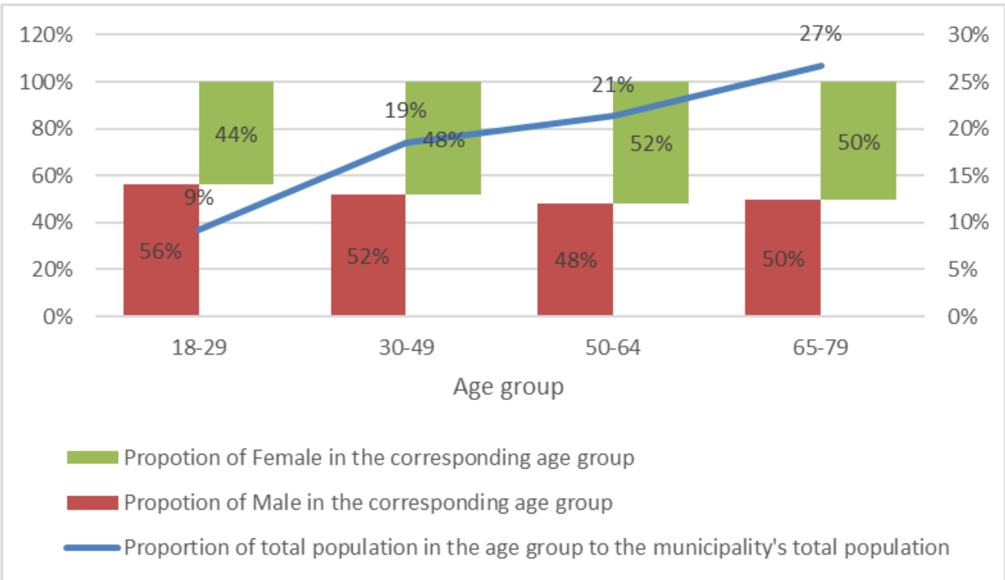

Figure 19. Population distribution by age and gender in Borgholm. (Source: SCB, 2019)

4.1.3. Torsby

Torsby municipality is located next to the Norweigian frontier in Central Sweden in Värmland county. It has a population of 11,616 and the average population density is 2.8 inhabitants/km^2.

96.2% of the buildings in Torsby is in the form of small houses and there are 460 private-owned cars for every thousand inhabitants. (SCB, 2019)

Its main urban area is Torsby where 38,5% of the all inhabitants live, followed by three urban areas that are significantly less populated. In general, all urban areas account for less than 0.3 % of Torsby's total area and more than half of the inhabitants are still living in the rural areas of the municipality. See *table 8*.

Table 8. Torsby's urban areas overview.

Urban area	Proportion of total population	Population density (inhabitants/km2)	Proportion of total land area	Service points
Torsby	38.5%	627	0,2%	4
Sysslebäck	3.7%	239	0,0%	2
Oleby	3.1%	287	0,0%	0
Stöllet	1.8%	286	0,0%	2
Summary	47.1%	239 - 627	0,2%	8 (+4)
Source: SCB, 2019				

Less than 30% of Torsby's population lives within 1 km to the closest service points. (Trafikanalys, 2018) *Figure 20* illustrates the service point distribution over the municipality. Apart from the statistical urban area, there is also one shared service point in Östmark, Bograngen, Likenäs and Ambjörby respectively.

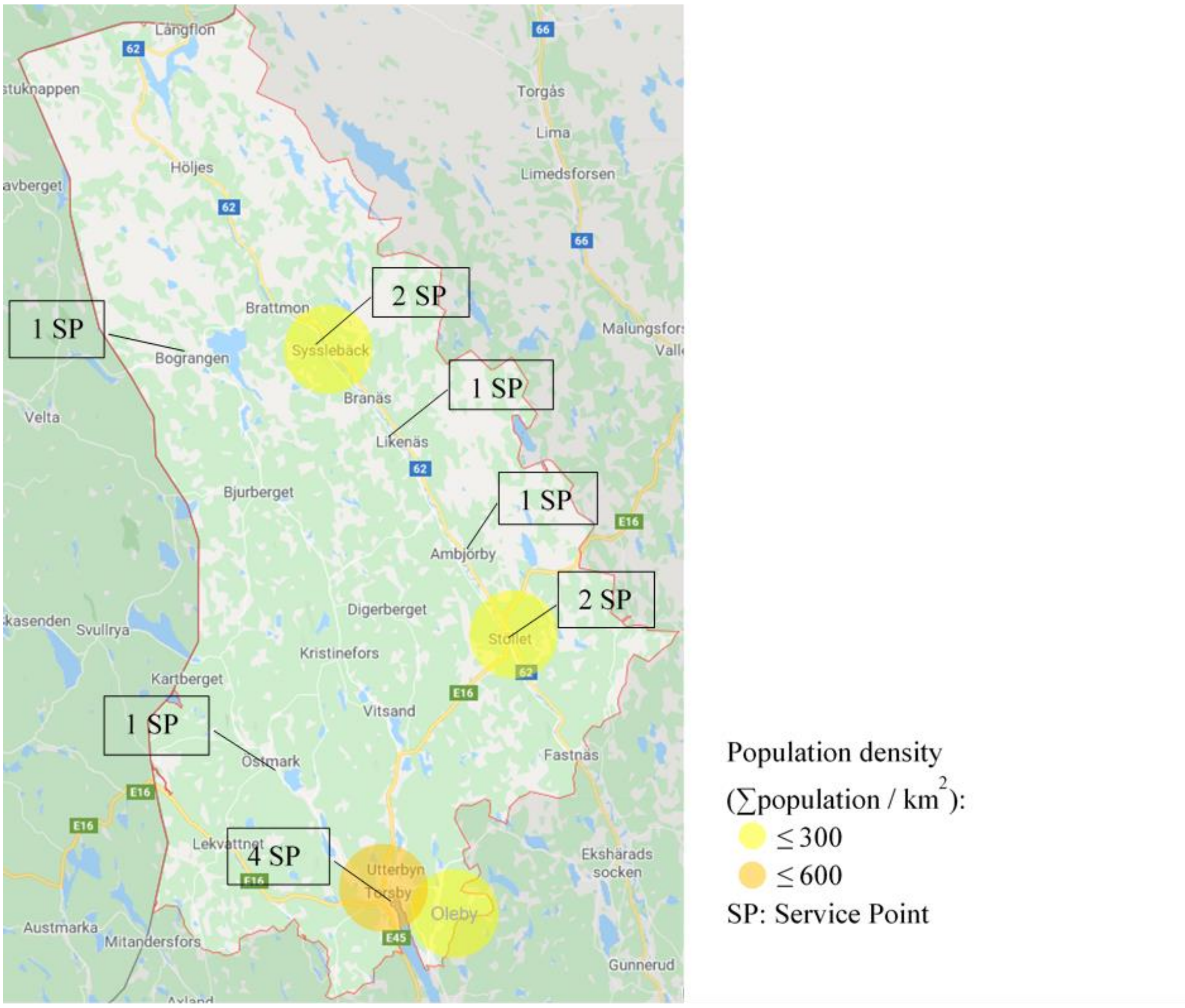

Figure 20. Population density and service points distribution over Torsby. (Own illustration)

Viewing Torsby from the topographical perspective, it is largely covered by forest 83.6 % of the total land area) together with inland water in the form of small lakes (4.5 % of the total land area). Other land accounts for 9.4 % and built up land and related land for 1.6 %. Of the latter group, 0.9 % consists of roads in different types: European and national roads for 11%, county roads for 14% and other roads for 75%. See *figure 21*. (SCB, 2019)

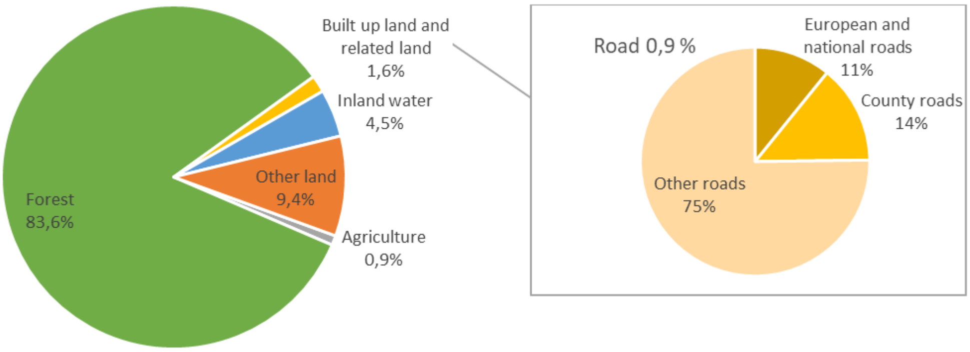

Figure 21. Land use and road types proportion in Torsby. (Source: SCB, 2019)

It can be observed that E16 runs from Western side of the Torsby to Eastern side through its largest urban area in Southern Torsby. Several county roads connect the area between North and South. The coverage of the transportation network decreases as it moves towards the north.

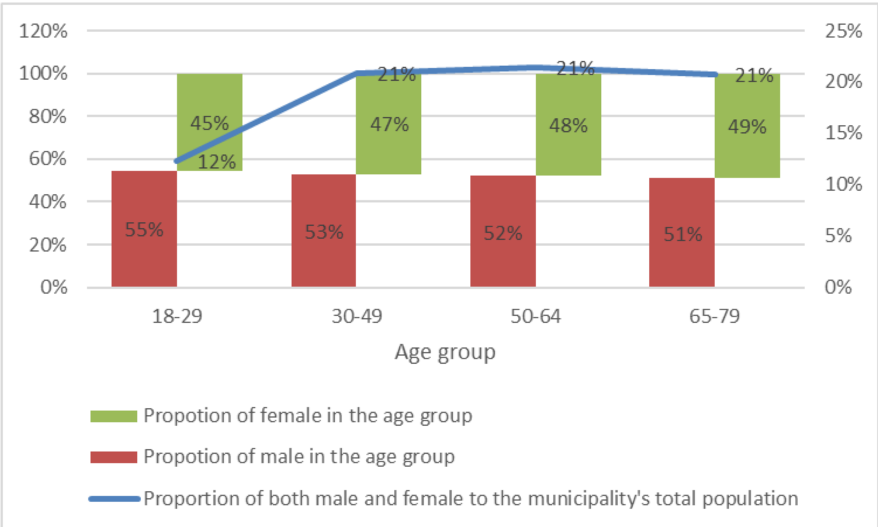

Figure 22. Population distribution by age and gender in Torsby. (Source: SCB, 2019)

Torsby has a relatively even distribution of female and male among the age groups studied. Its younger age group of 18 and 29 years old accounts for 12% in contrast to other studied age groups that share the same portion of 21% of its total population. Additionally, the average age among Torsby's inhabitants is 47.2 years old in which for male and female is 46.4- respective 48 years old. See *Figure 21*.

4.1.4. Ragunda

Ragunda municipality belongs to Jämtland county with a population of 5,284 inhabitants and its average population density is 2.1 inhabitants/km^2. 97.4 % of the building types are small houses and it is estimated that for every thousand inhabitants, there are 443 private-owned cars. There are 4 urban areas in Ragunda that live a total of 46.8 % of the municipality's population and it takes up to 0.1 % of the total land area. See *table 9*. (SCB, 2019)

Table 9. Ragunda's urban area overview.

Urban area	Proportion of total population	Population density (inhabitants/km2)	Proportion of total land area	Service points
Stugun	11.2%	557	0.0%	3
Västra Bispgården	8.9%	420	0.0%	2
Hammarstrand	22.0%	418	0.1%	3
Östra Bispgården	4,7%	203	0.0%	-
Summary	46.8%	203 - 557	0.1%	8
Source: SCB, 2019				

According to Trafikanalys, 2018, 31 – 36% of its population lives within 1 km distance from a service point. *Figure 23* provides an illustration of the population density over urban areas and service points distribution in Ragunda. These service points are either dedicated serving only Postnord or shared serving several companies including Postnord.

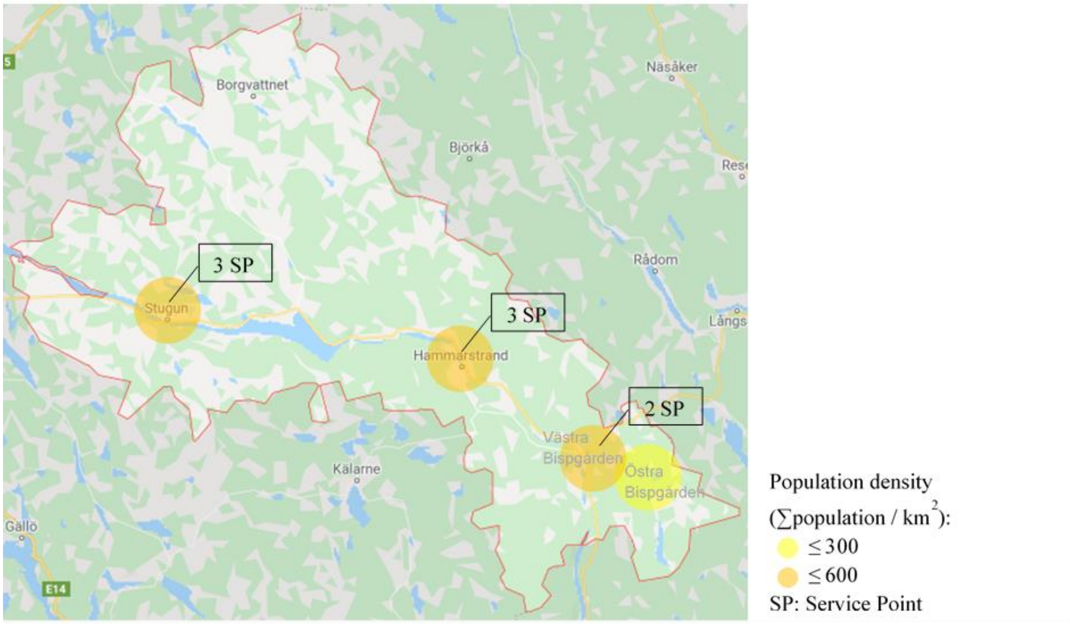

Figure 23. Population density and service points distribution over Ragunda. (Own illustration)

85 % of Ragunda is covered by forest while its built up land and related land only account for 2% whereas the total road area accounts for 1.0 %. Within the road category, European and national roads account for 10 %, county roads for 16% and other roads for the rest. (SCB, 2019) See *figure 24*.

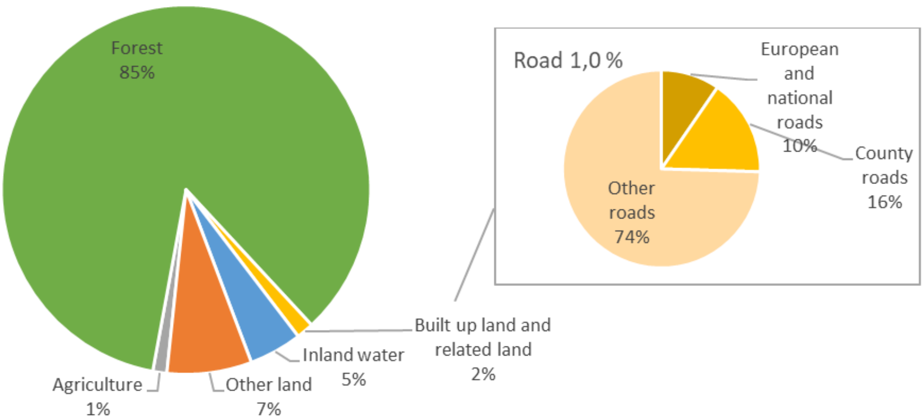

Figure 24. Population density and service points distribution over Ragunda. (Own illustration)

From *figure 25*, it can be observed that the proportion of females and male is somewhat evenly distributed across the studied age groups. The youngest age group of 18 to 29 years old has the lowest share of population (11 %) and the rest has the similar share.

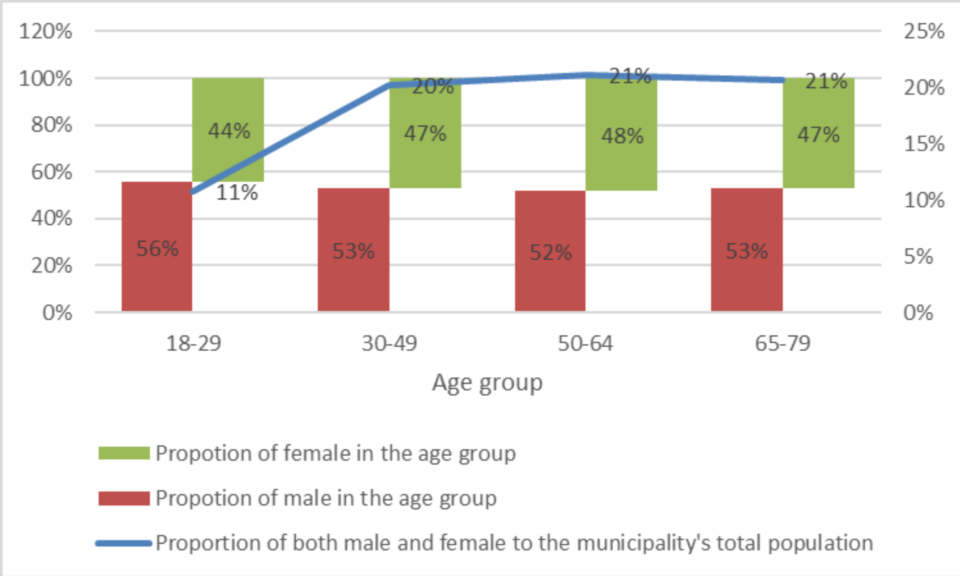

Figure 25. Population distribution by age and gender in Ragunda. (Source: SCB, 2019)

4.1.5 Sorsele

Sorsele municipality is located next to the Norwegian frontier in Northern Sweden in Västerbotten county. It has a population of 2,489 and the average population density is 0.3 inhabitants/km^2. 98.4% of the buildings in Sorsele is in the form of small houses and there are 400 private-owned cars for every thousand inhabitants. Sorsele is the only one urban area in Sorsele municipality and the area has 46.3% of its total residents. The population density is 612 and the urban area accounts for less than 0.0% of the total area in the municipality. See *table 10*. (SCB, 2019)

Table 10. Sorsele's urban area overview.

Urban area	Proportion of total population	Population density (inhabitants/km2)	Proportion of total land area	Service points
Sorsele	46.3%	612	0.0%	3(+3)
Source: SCB, 2019				

According to Trafikanalys, 2018, 31% to 36% of the population has a distance of less than 1 km to the closest service points. In its only urban area, there are 3 service points whence 2 are dedicated and 1 shared. In other non-statistical urban areas – Ammarnäs, Blattnicksele and Gargnäs, there are 1 shared service points respectively. See *figure 26*.

Figure 26. Population density and service points distribution over Sorsele. (Own illustration)

Sorsele's geography is featured largely with forest which accounts for 54.7% of its total land area, followed by 37.4 % of other land[4] and 7.4 % of inland water. See *Figure 27*. The built up land and related land only accounts for 0.4 % whence 0.3 % is occupied by roads in different types: 7% of the road area is European and national roads, 30% is county roads and 63% is other roads. (SCB, 2019)

[4] Other land categories include open mire, heathland and herb meadow, bare rock, etc. (SCB, 2019)

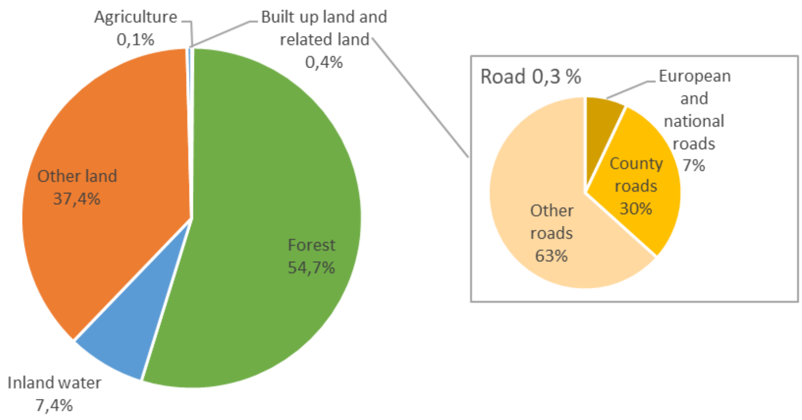

Figure 27. Land use by category and road area proportion in Sorsele. (Source: SCB, 2019)

In terms of population distribution by age and gender, Sorsele has basically a similar trend with the previous two municipalities. See *figure 28*. In the age group 18 to 29 years old, the share of male accounts for 61% in contrast to a share of 39% for females. The share of gender in other age groups is otherwise comparatively even and the youngest age group (18-29) also accounts for the least proportion while others have a similar share. Additionally, the average age among Sorsele's inhabitants is 47.1 years old in which for male and female is 46.3- respective 48.1 years old.

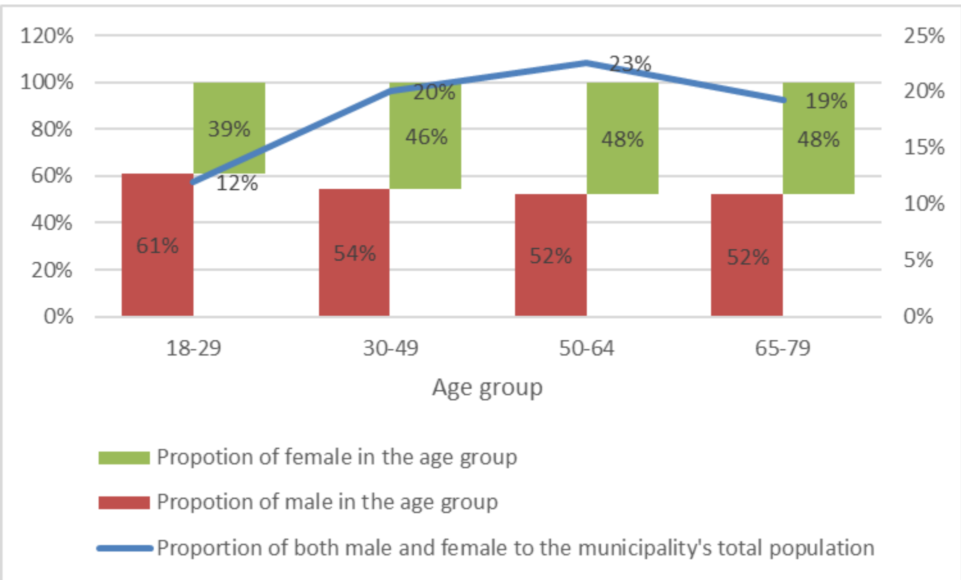

Figure 28. Population distribution by age and gender in Sorsele. (Source: SCB, 2019)

4.1.6. Retail trade geographic distribution

In terms of ground distance, as shown in *figure 29*, it presents the proportion of the population's distance to the closest commercial districts[5] in all studied municipalities. It shows a dramatic difference in Sorsele that none of its inhabitants has a travel distance within 10 km to a commercial district and the average distance to the closest one is 57.3 km. In contrast, Tanum has the shortest average distance of 5.7 km and also has the highest share of population living within the range. The rest of the municipalities share a similar trend, apart from Borgholm with a relatively high proportion of population living within 0.3 km. (SCB, 2019)

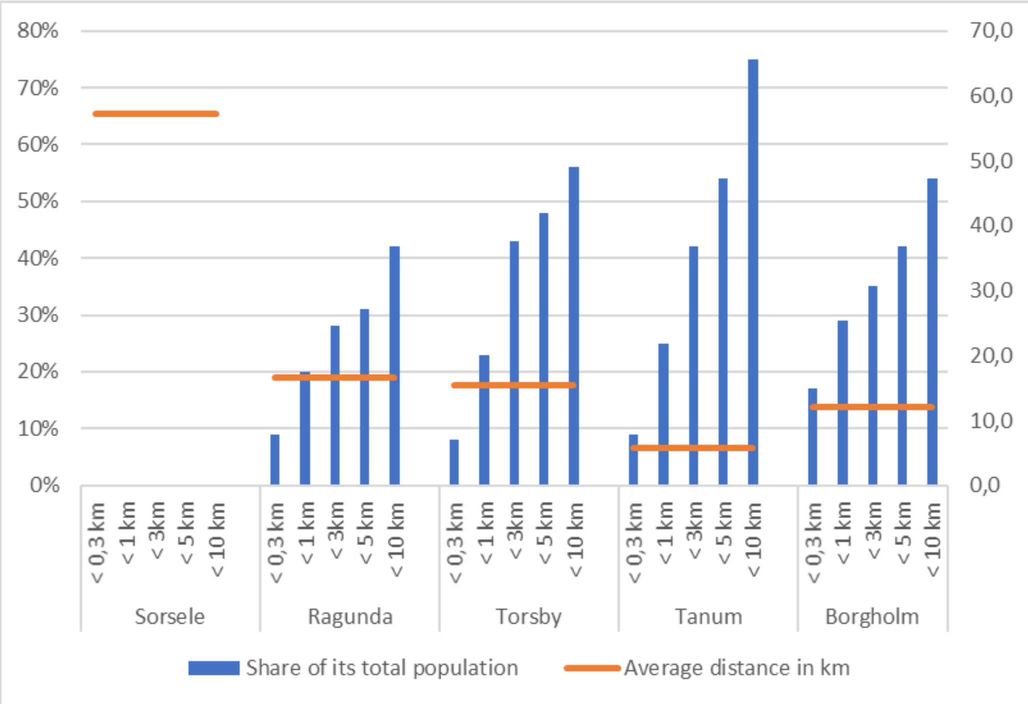

Figure 29. The share of population to the closest commercial district and the average distance in each municipality. (Source: SCB, 2019)

In terms of ED, as shown in *table 11*. For Sorsele, Ragunda and Torsby, the proportion of its population living within 1 km to a convenient store remains 54%, but the share has increased from 49 % to 55 % in 2019 to a supermarket. There are service points for package service in both types of stores. For Tanum and Borgholm, there is a decline in proportion of the population to a convenience store from 52 % to 49 % between 2010 and 2019, and a slight increase to a

[5] Commercial district is a geographical concentration consisting of either at least five retail stores or four retail stores that together have at least 100 employees. (SCB, 2019)

supermarket with 2 %. In general, there is no significant difference between 2010 and 2019 for these municipalities, considering the base population is small.

Table 11. Proportion of population that lives within 1 km (ED) to a convenient store or a supermarket.

Municipality	Convenience store[6]		Supermarket	
	2010	2019	2010	2019
Tanum, Borgholm	52%	49%	43%	45%
Sorsele, Ragunda, Torsby,	54%	54%	49%	55%
Source: Trafikanalys, 2020				

4.2. Climate conditions

Sweden is located in the northern part of Europe. It has a long coastline with the Baltic Sea in the east and the Kattegat strait in the southwest, and the Scandinavian Mountains run from north to south along the western Swedish border. The unique geographical location creates certain climatic conditions.

4.2.1. Low temperature

According to Naturvårdsverket (2019), the climate in Sweden follows the global trend that it gets warmer as the annual average temperature has increased historically. However, looking back over the past decade of temperature records, in contrast to the overall trend of continued warming (*Figure 30*), Sweden was attacked by two very distinct cold waves at the start and end of 2010, which resulted in the lowest monthly average temperature in winter months in a decade.

[6] A convenience store is often located next to a gas station. (Trafikanalys, 2020)

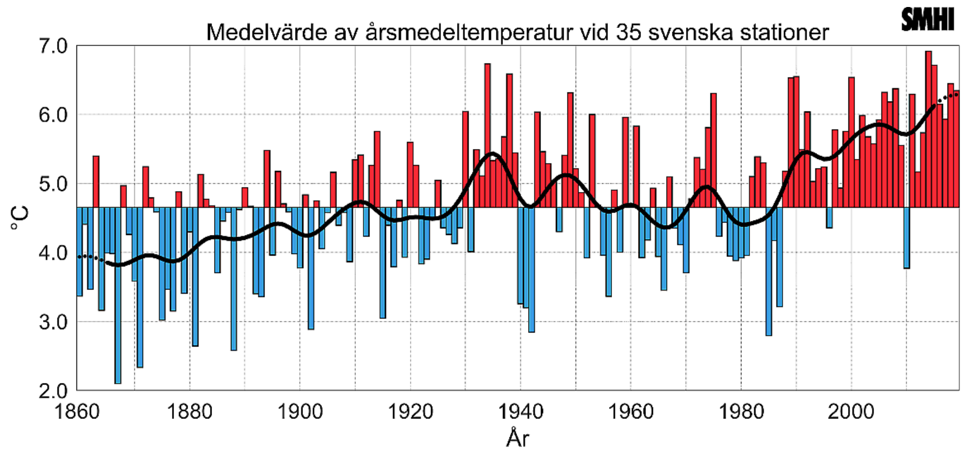

Figure 30. Annual average temperature based on 35 stations spread over Sweden. (Source: SMHI, 2020a)

In February 2010, the average monthly temperature in northern Sweden dropped to -19 °C, and even as it increased with decreasing latitude, the average monthly temperature in the warmest province was below freezing point. In December of the same year, the monthly average temperature in the northernmost and southernmost regions dropped to -16℃ and -3℃ respectively. When it comes to 2019/2020, which has the warmest winter on the whole in a decade (SMHI, 2020c), the lowest monthly average temperature in the north has risen to -11℃, while in the south it has risen to around 6 °C. See *Figure 31*.

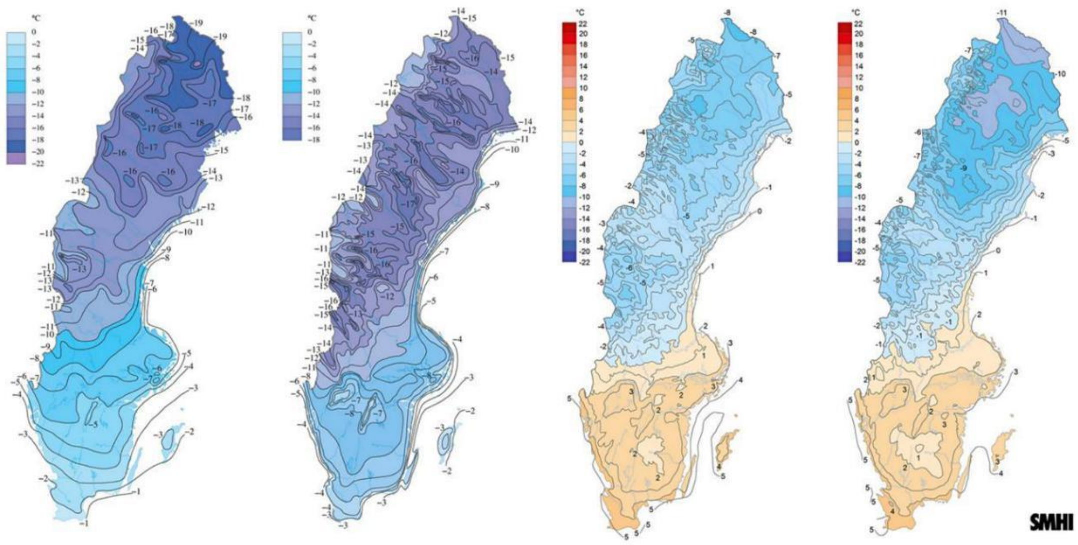

Figure 31. Monthly average temperature (From left to right: 2010. 02, 2010. 12, 2019. 12, 2020. 02).

(Source: SMHI: 2020b)

4.2.2. Precipitation

According to Köppen-Geiger climate classification (see *figure 32*), there are two prevailing climatic zones in Sweden, which are temperate / humid continental climate (Dfb) without dry season and with warm summer, and cold continental climate (Dfc) without dry season and with cold summer (PVsites, 2016). In addition, the west coast of Sweden at mid-latitude (such as Gothenburg) has a typical temperate marine climate. This is because the North Atlantic Current along the coast is strong, combined with the irregular coastline and low terrain, westerly winds and cyclones are able to penetrate into inland areas. These climate patterns allow the whole Sweden to be in a humid and mild state where heavy convective storms rarely occur. (Yang, 2010; Wang, 2010) However, comparing with the Dfb and maritime climate, the annual precipitation in the Dfc area is relatively low (250 - 500 mm) and mainly concentrated in the warm season (GSG, 2014), which means that the precipitation is not balanced around the year.

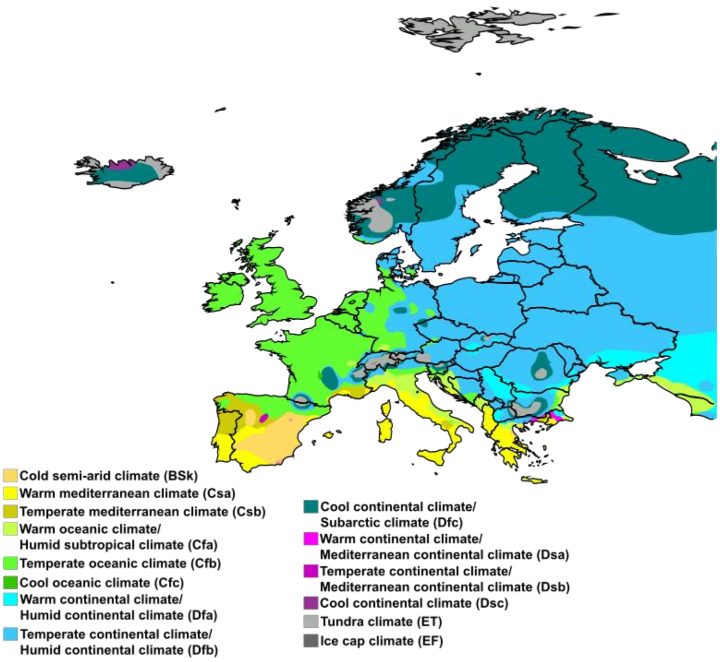

Figure 32. Köppen-Geiger climate zones. (Source: PVsites, 2016)

According to SMHI (2019a), precipitation in Sweden is expected to increase in the future during all seasons, but mostly in northern Sweden and during the winter. During summertime, the increase in southern Sweden tends to be relatively small. *Figure 33* shows projected precipitation changes for 2071-2100 in Europe compared to 1971-2000 obtained from European Environmental Agency’s research (EEA, 2017), which is consistent with SMITH's viewpoint.

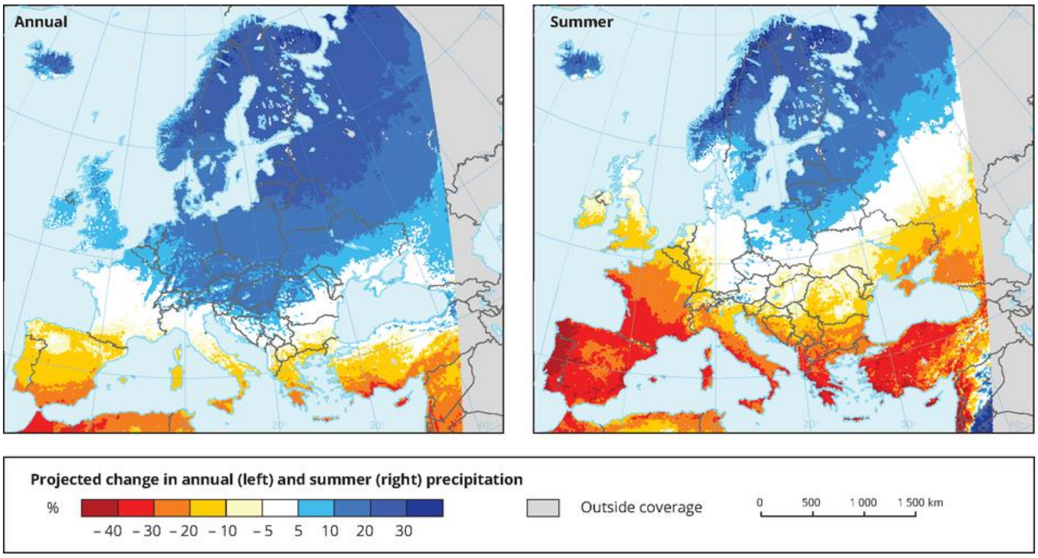

Figure 33. Projected changes in annual (left) and summer (right) precipitation. (EEA, 2017)

4.2.3. Wind speed

Figure 34 was originally published as part of the European Wind Atlas, but the data for Finland, Sweden and Norway are updated from the later study (Danish Wind Industry Association, 2003). Compared with the Western Europe continent, the average wind speed in Sweden is relatively high. The wind speed in the south and the fringe regions, including the coastlands and the regions bordering other countries in the north, is usually 5.5-7.5m/s. On the west coast, the average wind speed is more than 7.5 m/s. The yellow zones are mainly in the interior of central Sweden, where winds are relatively low.

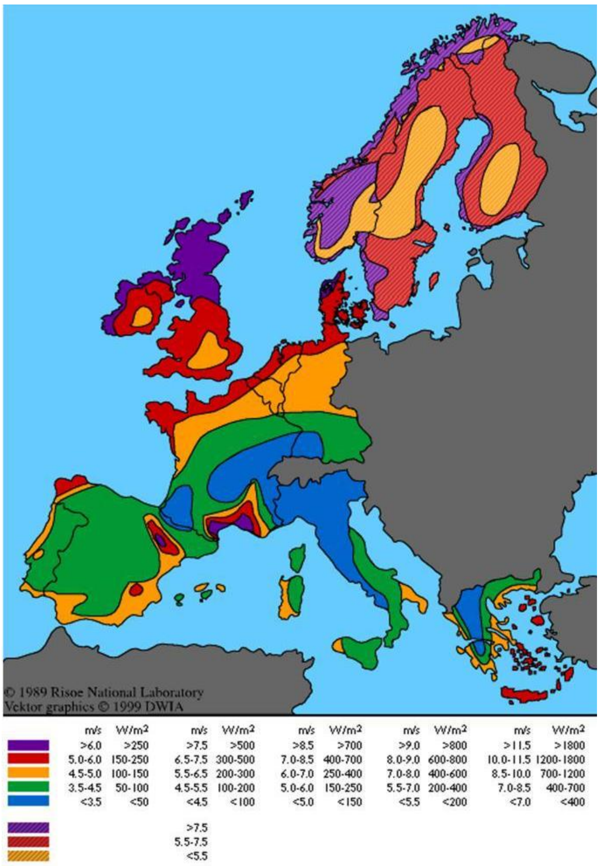

Figure 34. Wind map of western Europe. (Danish Wind Industry Association, 2003)

Wind speed closest to the ground is affected by factors such as building, vegetation and topography, which results in more sophisticated conditions where the wind direction and speed is different from the area average. (SMHI, 2019c)

5. EMPIRICAL FINDINGS

This chapter presents the empirical findings of the selected municipalities through illustrations and summarizes the results in tables.

5.1. Tanum

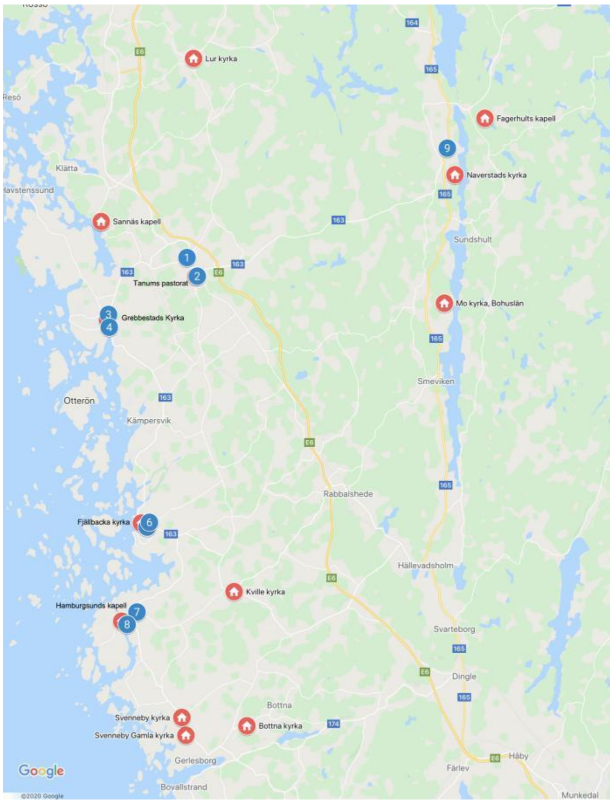

Figure 35. Distribution of service points and churches in Tanum (Own illustration on Google map)

After screening, 9 service points and 11 churches in Tanum form 23 routes (*table 12* & *figure 35*). Among these routes, drones have the advantage of distances. In terms of ratio, for the distance from SP5 to Fjällbacka kyrka, driving is 224.32% longer than that of drone, and correspondingly, driving is about 3.5 minutes slower when it comes to the time, which drone only takes about 31 seconds. It can be seen from *figure 36* that the vehicle has a longer detour distance, so the actual distance is extended. The ED from SP7 to Svenneby gamla kyrka is only about 10% shorter than the ND. For delivery time, 7 of the 23 routes are more time efficient to use vehicle delivery, which means it is more time efficient to use drone delivery on 69.57% of these routes.

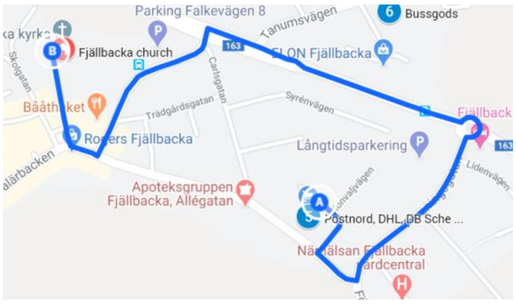

Figure 36. From SP5 to Fjällbacka kapell. (Own illustration on Google map)

The TD of the route SP7 to Hamburgsunds kapell is also a cause for concern. On this route, drone delivery takes about half a minute, while driving takes 25 minutes (*figure 37*). This is because the two points are on either side of the river that the drone can fly directly over the water, but the vehicle has to take a ferry. A similar situation is demonstrated in the route of SP8 to Fagerhults kapell, where vehicles need to bypass the lake in the middle. If the land in an area is divided by water and there is no bridge nearby to connect the both sides, it will provide beneficial conditions for drone logistics application. It is confirmed with the case of the successful application of drone deliveries in Reykjavik, Iceland due to the fragmentation of urban land by water area (Flytrex, 2020).

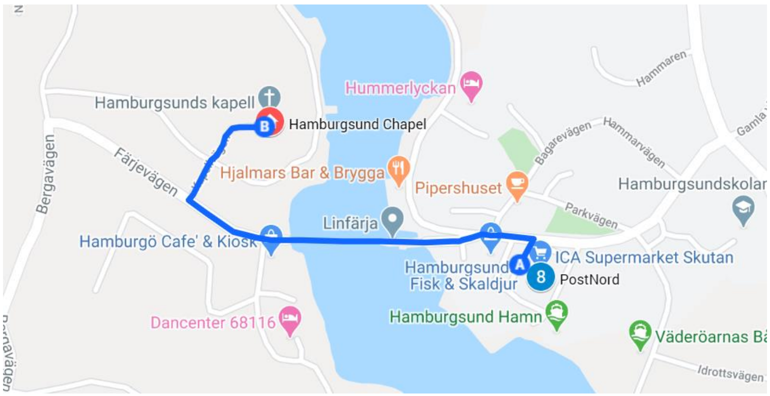

Figure 37. From SP7 to Hamburgsunds kapell. (Own illustration on Google map)

Table 12. List of delivery routes in Tanum.

Service point	Church	ED	ND	Ratio	DDT	VDT	TD[7]
ICA Supermarket Hedemyrs (SP1)	Sannäs kappel	4.87	6.8	71.58%	6.76	8	-1.24
	Tanum pastorat	1.06	1.2	87.99%	1.47	2	-0.53
Riksvägen 91(SP2)	Sannäs kappel	5.32	7.7	69.03%	7.38	9	-1.62
Tanumsvägen 1(SP3)	Sannäs kappel	4.87	7.4	65.87%	6.77	7	-0.23
	Tanum pastorat	4.97	6.8	73.06%	6.90	7	-0.10
Coop Grebbestad (SP4)	Sannäs kappel	5.54	8.1	68.35%	7.69	9	-1.31
	Tanum pastorat	5.24	7.5	69.89%	7.28	8	-0.72
Coop Fjällbacka (SP5)	Kville kyrka	5.65	7.1	79.60%	7.85	8	-0.15
	Fjällbacka kyrka	0.37	1.2	31.07%	0.52	4	-3.48
Industrivägen 2 (SP6)	Kville kyrka	5.19	6.1	85.08%	7.21	6	1.21
	Svenneby kyrka	6.00	7	85.78%	8.34	8	0.34
	Svenneby gamla kyrka	6.95	7.8	89.09%	9.65	9	0.65
	Bottna kyrka	8.28	12	68.99%	11.50	14	-2.50
ICA Supermarket Skutan (SP7)	Kville kyrka	5.85	7	83.56%	8.12	8	0.12
	Svenneby kyrka	5.66	6.5	87.14%	7.87	8	-0.13
	Svenneby gamla kyrka	6.58	7.3	90.18%	9.14	9	0.14
	Bottna kyrka	8.22	12	68.47%	11.41	15	-3.59
	Hamburgsunds kapell	0.33	0.6	54.94%	0.46	25	-24.54
ICA Östads Livs (SP8)	Naverstads kyrka	1.44	2.1	68.61%	2.00	3	-1.00
	Fagerhults kapell	2.51	5.3	47.32%	3.48	5	-1.52
	Mo kyrka Bohuslän	8.07	9.1	88.73%	11.21	9	2.21
Metkroksvägen 2 (SP9)	Kville kyrka	5.73	7.2	79.59%	7.96	7	0.96
	Fjällbacka kyrka	0.41	0.65	63.50%	0.57	2	-1.43

[7] TD presented in colour green is the time saved by drone delivery, and red means the opposite.

5.2. Borgholm

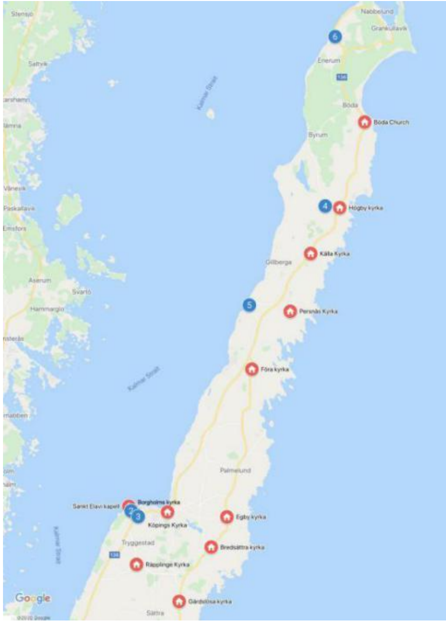

Figure 38. Distribution of service points and churches in Borgholm. (Own illustration on Google map)

In Borgholm, as shown in *figure 38 and table 13*, service points and churches are more concentrated in the southern part of the municipality, but the three churches near the southernmost tip are unexpectedly not in the service range of the drone. There are 24 delivery routes with 6 service points and 12 churches. For delivery time, it is more time efficient to use drones in 18 routes out of 24. Generally speaking, the consistency of the EDs and the NDs in these routes is high, so there are no ratios that are excessively low, and the lowest among which is 63.76% (from SP3 to Räpplinge kyrka).

Table 13. List of delivery routes in Borgholm.

Service point	Church	ED	ND	Ratio	DDT	VDT	TD
ICA Supermarket Borgholm (SP1)	Sankt Elavi kapell	1.18	1.5	78.64%	1.64	5	-3.36
	Bredsättra kyrka	8.64	11	78.54%	12.00	13	-1.00
	Egby kyrka	9.60	11	87.30%	13.34	13	0.34
	Köpings kyrka	3.32	3.9	85.14%	4.61	6	-1.39
	Räpplinge kyrka	5.24	5.8	90.28%	7.27	6	1.27
	Borgholms kyrka	0.71	0.8	88.41%	0.98	3	-2.02
Pressbyrån Borgholm (SP2)	Räpplinge kyrka	5.67	6.9	82.14%	7.87	10	-2.13
	Köpings kyrka	3.87	4.9	79.04%	5.38	8	-2.62
	Bredsättra kyrka	9.32	12	77.63%	12.94	16	-3.06
	Sankt Elavi kapell	0.53	0.75	70.49%	0.73	5	-4.27
OK/Q8 Borgholm (SP3)	Sankt Elavi kapell	1.47	1.7	86.56%	2.04	5	-2.96
	Bredsättra kyrka	8.37	12	69.72%	11.62	14	-2.38
	Egby kyrka	9.39	11	85.37%	13.04	14	-0.96
	Gärdslösa kyrka	9.86	15	65.73%	13.69	17	-3.31
	Köpings kyrka	3.14	4.2	74.65%	4.35	7	-2.65
	Räpplinge kyrka	5.04	7.9	63.76%	7.00	10	-3.00
	Borgholms kyrka	1	1.1	90.90%	1.39	3	-1.61
ICA Nära Löttorpshallen (SP4)	Högby kyrka	1.54	1.6	96.35%	2.14	3	-0.86
	Böda kyrka	9.69	11	88.09%	13.46	10	3.46
	Källa kyrka	5.18	7.7	67.33%	7.20	8	-0.80
ICA Nära Trossen (SP5)	Källa kyrka	8.43	9.9	85.16%	11.71	9	2.71
	Persnäs kyrka	4.38	6	72.99%	6.08	7	-0.92
	Föra kyrka	6.71	7.4	90.62%	9.31	7	2.31
ICA Nära Byxelkrok (SP6)	Böda kyrka	9.40	10	94.01%	13.06	10	3.06

5.3. Torsby

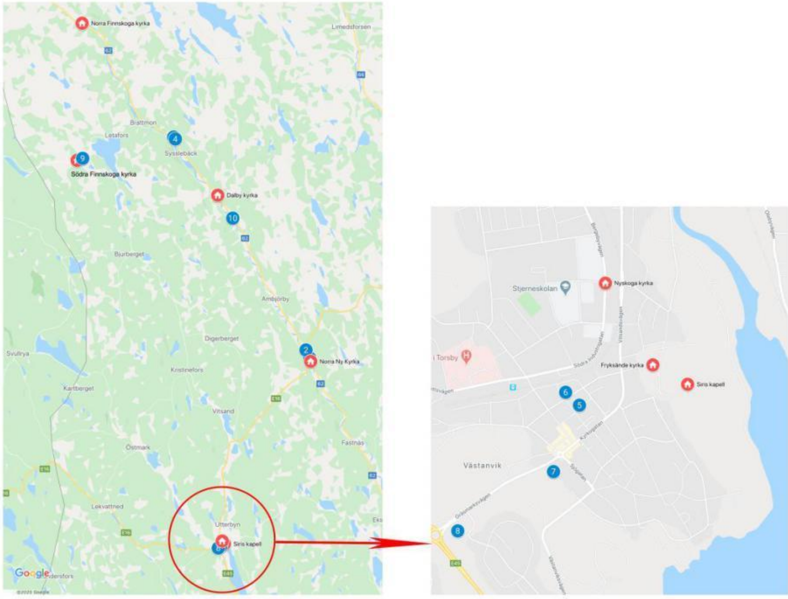

Figure 39. Distribution of service points and churches in Torsby. (Own illustration on Google map)

In Torsby, 8 service points and 7 churches make up 15 routes, see *figure 39* and *table14*. Among these routes, EDs are shorter than corresponding NDs invariably. In terms of time, only the route from SP10 to Dalby kyrka takes less time by driving, since the ED is almost identical to the ND (*Figure 40*), and the vehicle has an advantage in speed at the same time.

Figure 40. From SP10 to Dalby kyrka (Own illustration on Google map)

Due to the same characteristics of high consistency between ED and ND, SP3 to Dalby kyrka and SP4 to Norra Finnskoga kyrka, these two additional routes that are beyond the range of drones are calculated. In these routes, the advantage of vehicle delivery in terms of time is further amplified. In this scenario, if the drone is unable to further break the delivery speed limit, it will hardly have a time advantage even if it has a longer range.

Table 14. List of delivery routes in Torsby.

Service point	Church	ED	ND	Ratio	DDT	VDT	TD
Coop Stöllet (SP1)	Norra Ny kyrka	0.55	1.3	42.06%	0.76	3	-2.24
OK/Q8 MACK45 (SP2)	Norra Ny kyrka	2.03	2.7	75.25%	2.82	4	-1.18
* Coop Sysslebäck (SP3)	Dalby kyrka	11.85	12	98.77%	16.46	11	5.46
* Radioelektriska (SP4)	* Norra Finnskoga kyrka	24.04	27	89.05%	33.39	23	10.39
ICA Frykenhallen (SP5)	Nyskoga kyrka	0.58	0.95	60.63%	0.80	3	-2.20
	Fryksände kyrka	0.38	0.65	58.83%	0.53	3	-2.47
	Siris kapell	0.53	0.56	94.87%	0.74	2	-1.26
Pekås Torsby (SP6)	Nyskoga kyrka	0.54	0.75	71.51%	0.74	2	-1.26
	Fryksände kyrka	0.42	0.8	52.12%	0.58	3	-2.42
	Siris kapell	0.57	0.7	81.89%	0.80	2	-1.20
Qstar (SP7)	Nyskoga kyrka	0.90	1.1	82.10%	1.25	2	-0.75
	Fryksände kyrka	0.67	0.8	83.66%	0.93	2	-1.07
Coop Torsby (SP8)	Nyskoga kyrka	1.33	1.7	78.14%	1.85	4	-2.15
	Fryksände kyrka	1.17	1.4	83.88%	1.63	4	-2.37
	Siris kapell	1.31	1.35	96.71%	1.81	4	-2.19
Bograngen Lanthandel (SP9)	Södra Finnskoga kyrka	0.98	2.2	44.48%	1.36	4	-2.64
ICA Nära Likenäs Allköp (SP10)	Dalby kyrka	4.48	4.5	99.59%	6.22	4	2.22

However, Torsby does not seem to be a good fit for drone deliveries. Firstly, the distribution of service points and churches is polarized – either extremely dense or scattered (see ED and ND in *table 14*). The application of drone logistics can only be limited to the area within the radius of 2 km in most cases which limits the potential service coverage. Secondly, many service points and churches in the municipality are built along the river as well as on the same side of it, and the direction of the road is highly consistent with the trend of the river, which leads to the inconspicuous difference between ED and ND.

5.4. Ragunda

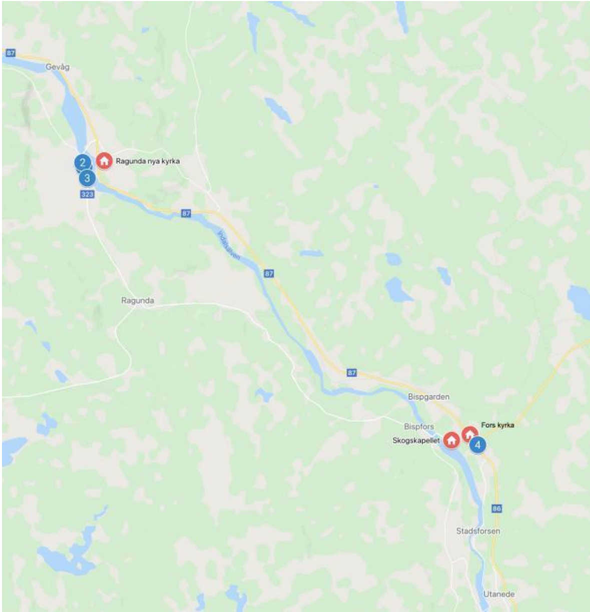

Figure 41. Distribution of service points and churches in Ragunda. (Own illustration on Google map)

In Ragunda, the number of service points and churches is relatively small, see *figure 41* and *table 15*. After screening, 4 service points and 3 churches constitute 5 delivery routes. Among these routes, drone delivery has the advantages of both distance and time. The three routes from SP1, SP2 and SP3 to Ragunda nya kyrka are all very prominent in ratio, which is 35.85%, 40.34% and 33.77% respectively.

Table 15. List of delivery routes in Ragunda

Service point	Church	ED	ND	Ratio	DDT	VDT	TD
ICA Supermarket Hammarn (SP1)	Ragunda nya kyrka	0.82	2.3	35.85%	1.14	4	-2.86
Coop Hammarstrand (SP2)	Ragunda nya kyrka	0.85	2.1	40.34%	1.17	4	-2.83
Time i Hammarstrand (SP3)	Ragunda nya kyrka	0.95	2.8	33.77%	1.31	5	-3.69
Bispgårdens Trafikbutik (SP4)	Skogskapell	1.04	1.3	79.70%	1.44	2	-0.56
	Fors kyrka	0.50	0.65	77.08%	0.69	2	-1.31

Same as in the scenario in Tanum, the starting point and the receiving point are on either side of the river, and the vehicles need to take a detour to reach the opposite bank with the help of the bridge (*figure 42*). However, there is a similar problem to Torsby in Ragunda – the limited business coverage.

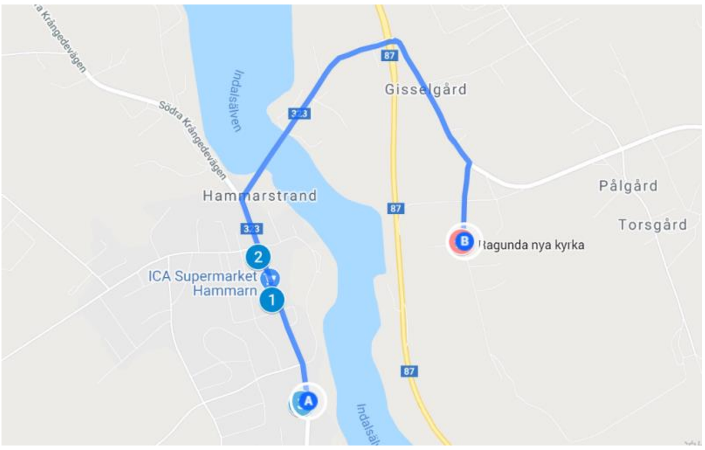

Figure 42. From SP3 to Ragunda nya kyrka. (Own illustration on Google map)

5.5. Sorsele

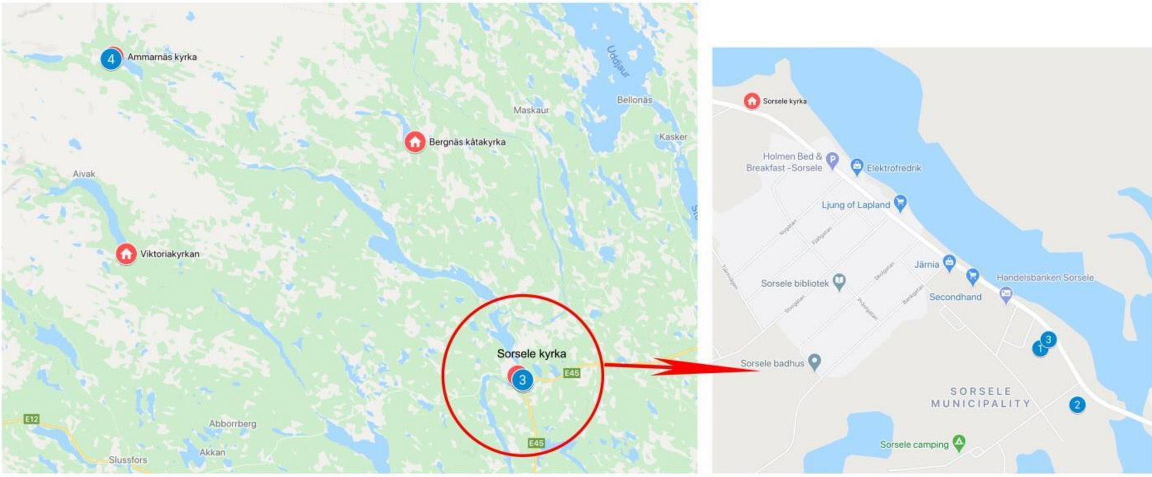

Figure 43. Distribution of service points and churches in Sorsele. (Own illustration on Google map)

In Sorsele, the number of service points and churches is significantly less, see *figure 43* and *table 16*. Three service points and two accessible churches form four very short routes. In terms of the distance, drones have advantage in all routes. However, for delivery time, the performance of drones in Sorsele is relatively poor. Also, because of the high consistency of EDs and NDs, half of the routes tend to spend more time by drones.

Table 16. List of delivery routes in Sorsele.

Service point	Church	ED	ND	Ratio	DDT	VDT	TD
ICA Nära Sorsele (SP1)	Sorsele kyrka	0.90	0.9	99.57%	1.24	1	0.24
Coop Sorsele (SP2)	Sorsele kyrka	1.05	1.1	95.54%	1.46	3	-1.54
Sorsele Busstation (SP3)	Sorsele kyrka	0.90	0.9	99.69%	1.25	1	0.24
Ammarnäs Livs (SP4)	Ammarnäs kyrka	0.46	0.6	76.10%	0.63	1	-0.37
	* Viktoriakyrkan	28.90	167	17.31%	40.14	148	-107.93
	* Bergnäs kåtakyrka	45.93	85	54.03%	63.79	74	-10.33

From a technical perspective, Sorsele does not have the mature conditions to promote drone delivery, since the routes between most service points and churches are far more than 10 km, or even more than 45 km. However, even so, Sorsele can still be considered as having great potential in developing drone logistics. To further illustrate this potential, two additional routes are demonstrated.

From SP4 to Viktoriakyrkan (*figure 44*), the ED is 28.9 km, while the ND is 167 km, which is 5.78 times longer than the former. In terms of time, the route takes 2 hours and 28 minutes to drive, compared with 40 minutes using a drone (assuming the range is sufficient). Moreover, it can be argued that the delivery route of ND would be more realistic from SP3 instead of SP4 to Viktoriakyrkan. The ND is 77.7 km which is still more than the ED of 28.9 km. Also, this should be considered as a special scenario in which different starting points are involved and it further proves the inconvenient road transport in Sorsele's rural areas.

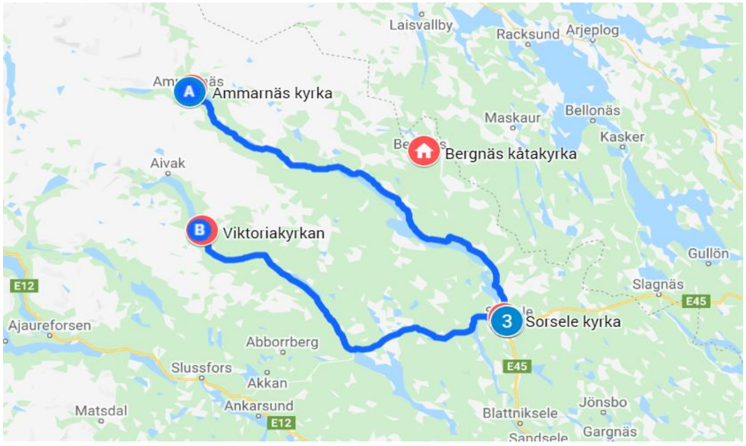

Figure 44. From SP4 to Viktoriakyrkan. (Own illustration on Google map)

Similarly, from SP4 to Bergnäs kåtakyrka, the vehicle travels about 39 km longer than a drone and takes about 10 minutes longer (*figure 45*). In this case, due to the poor road accessibility between service point and church, the road transportation is both time- and energy consuming which makes it more costly. This situation also proves that drone delivery is more suitable for use in areas with imperfect transportation facilities and poor road accessibility, but further technological breakthroughs in the endurance of the drone are indeed needed.

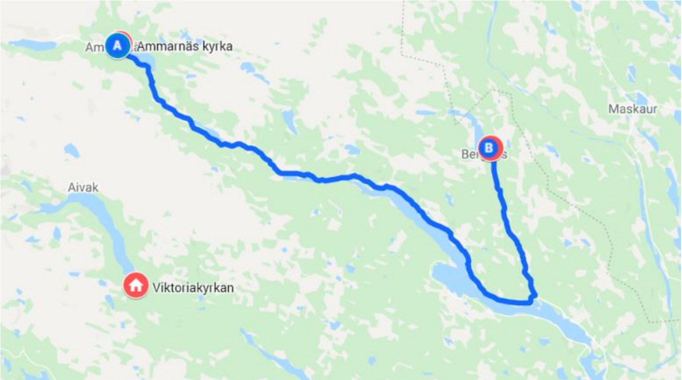

Figure 45. From SP4 to Bergnäs kåtakyrka. (Own illustration on Google map)

5.6. Simulation with different ASDS

The routes have been calculated with different ASDS (30-, 40-, 50-, 60- and 70 km/h) and the result is summarized in *table 17*. It can be obtained that the drone has the advantage in delivery time in all routes when the vehicle drives at a speed of 30- respective 40 km/h. This advantage reduces as the ASDS increases from 50 km/h.

Table 17. Dominant proportion of drone deliveries at different ASDS.

Municipality	DPDD (30)	DPDD (40)	DPDD (50)	DPDD (60)	DPDD (70)
Tanum	100%	100%	77.27%	50%	9.09%
Borgholm	100%	100%	66.67%	20.83%	0%
Torsby	100%	100%	70.59%	35.29%	29.41%
Ragunda	100%	100%	100%	60%	60%
Sorsele	100%	100%	50%	33.33%	33.33%
Average ratio	100%	100%	71.62%	36.49%	16.22%

6. ANALYSIS

By comprehensively considering the contents and results of literature review, case study and simulation, this section intends to analyse and discuss the potential possibility of implementing logistics drones in the B2C last mile delivery in rural areas of Sweden, from the aspects of legislative environment, economic benefits, humanistic and natural conditions, as well as technology maturity.

6.1. Legislative environment

For the current legislations in Sweden, drones are not strictly banned like in some countries. Instead, commercial drones need to apply for permission in order to carry out any actions. Basically, it will be an agreement of the operator and the government. As of July 2020, the new regulations will be applied to all EU countries, but legislation is supposed to be similar. Also, many trial projects have been carried out in recent years in other European countries such as France and Germany. The EU legislation aspect seems to be positive in the development of drone deliveries in Sweden. The relevant regulatory framework in Europe is under rapid development, which can be confirmed by the assessment done by PARE (Perspective for the Aeronautical Research in Europe) based on several major EU initiatives in member states. As stated, the goals of Flightpath 2050 fully support the integration of drones into the future aviation network and the development of commercial use. But up until now, the integration is still in the initial stage. (European Commission, 2018)

However, the introduction of a sophisticated legal framework for regulating commercialized drones is still challenging at the present state. Such an establishment would require a long time of research, discussion and more supportive practical experiences. Even though Sweden and the EU seem to have relatively positive and tolerant attitudes towards legislation of drones, the lagging and complicated regulatory environment is still one of the main obstacles to the further development and wide promotion of drone logistics. This barrier likewise exists globally.

Further, Sweden has been an advocate and pioneer in the use of renewable resources. For instance, the target of reaching a share of 50 % in renewable energy in 2020 was accomplished in 2012 and the current rate is 54 %. Also, the goal of 100 % renewable electricity production by 2040 (Swedish Energy Agency, 2018) and net-zero GHG emissions by 2050 in line with the EU's long-term climate strategy. (Government Offices of Sweden, 2019) From the perspective of sustainable development, it can be reasonably speculated that the positive attitude of the Swedish government in energy conservation and emission reduction may also play a positive role in promoting drone deliveries.

6.2. Economic performance

6.2.1. Higher delivery efficiency

Different from traditional deliveries made by ground vehicles, drones can compensate for surface inconveniences by using low-altitude areas which leads to a more efficient delivery performance. From the experimental study, there are 75 distribution routes including additional routes in the five selected municipalities. 46 of 75 routes have a ratio of the flight route to the road route lower than 80 % and the average ratio is 76.5 %. This scale also varies greatly depending on routes, for example, the routes in Tanum can be as low as 31.07 % and as high as 90.18 %. Drones with its advantage in an overall shorter travel distance can be obtained. Moreover, the chances of having a close to straight road route are rare in rural areas as the network is more likely to be sparse or curvy.

On the aspect of time-saving, the share of drone deliveries that are advantageous is 69.57% (Tanum), 75% (Borgholm), 93.33% (Torsby), 100% (Ragunda), and 50% (Sorsele) respectively, as well as the average ratio is 77.46%. It can be concluded that drone deliveries take less time on most routes. Nevertheless, the actual deliveries can be influenced by many other factors such as the change of speeds, road network layout, road conditions as well as loading and unloading processes, etc.

When simulating the scenario of varied ground vehicle speed against the constant drone speed (i.e. section 5.6), 50 km/h is a watershed between the two delivery modes. When ASDS is 30- and 40 km/h, the drone has the advantage of delivery time on all routes in 5 municipalities. When ASDS further accelerates from 50 km/h, the speed advantage of drones is continuously weakened and gradually surpassed (*Figure 46*). While driving at an average speed of 70 km/h, only 12 of the 74 calculable routes have a shorter delivery time by drones, accounting for 16.22%.

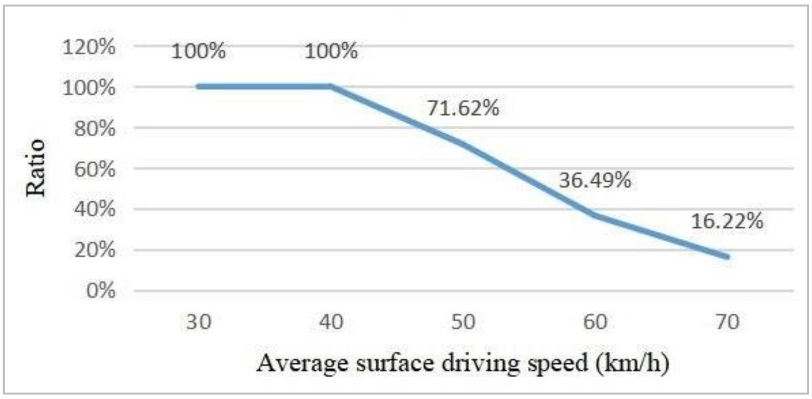

Figure 46. Dominant proportion of drone deliveries in all routes under different ASDS.

Even if the calculation results show that the time advantage of drones is decreasing with the acceleration of ASDS, it is still reasonable to believe that drones have great application potential in terms of both delivery distance and time. If the average driving speed is 70 km/h, since the low starting speed of the vehicle, the fastest instantaneous driving speed could be much more than 70 km/h, exceeding the speed limit in the non-urban area. Especially for short distance driving of only a few kilometers, it is unrealistic to drive at an average speed of 60- or even 70 km/h considering the traffic safety and road conditions. The estimated time of arrival on Google Maps is also a good evidence.

Lastly, the routes that perform exceptionally well on time-saving are characterized with long detour distance regardless of their lengths. The reasons for detour basically include: 1) the road route has too many turns due to building layout, which is the most common factor; 2) the land is divided by water area or the road is blocked by the river, for example SP7 to Hamburgsunds kapell in Tanum, and SP3 to Ragunda nya kyrka in Ragunda; 3) the road accessibility is poor, such as the additional routes in Sorsele. When the region clearly has at least one of these characteristics, drone deliveries are more likely to gain the opportunity of saving more travel time than ground transportations.

However, as the simulation only concerns the part of logistics from the parcels being loaded into the vehicle and ready for shipments till they reach the customers. There are other time-related variables that should be taken into account due to different set-ups between drones and ground vehicles, for example the loading and unloading process as well as the interaction with customers (vehicle only). Moreover, if applying drone logistics into other sectors such as grocery stores, restaurants, etc. the delivery time may involve order processing. In this study, it is difficult to determine whether these time-related variables would contribute to positive or negative impacts on the overall delivery efficiency. Also, if the volume of deliveries increases to the point where the hybrid mode of truck and drone is required, the complexity of the process would further increase. Thus, the delivery efficiency is more unpredictable correspondingly. These aspects could be further explored and addressed in the future research.

6.2.2. Market competition

In July 2019, Everdrone completed the first drone delivery between hospitals in Sweden (Everdrone, 2019), which might be the premier practice of drone delivery in the B2B field in Sweden. In terms of B2C, there have not been any trials yet. The B2C market for drone deliveries can be considered with loads of opportunities for new entrants to explore. However, expanding drone deliveries into the logistics market also challenges the traditional distribution mode – an area that is already dominated by mature business. The attempt to carve up the market share would not be tolerant. Also, the initial investment of network construction for drone logistics is extremely high which is only affordable by large enterprises with strong financial resources. Therefore, the existing business that already has a mature and developed logistics network is regarded as the perfect candidates to develop drone deliveries.

Although there are many well-known companies, the express delivery market in Sweden is still dominated by Postnord, which is not conducive to the further development and innovation of the industry. As stated in Framtidensdistribution (2019), a market will only be healthy when there is competition. For example, Chinese B2C logistics market is shared by several e-commerce companies and carriers of different sizes which results in highly fierce competition. To retain and attract more customers, e-merchants have tried to build their own logistics networks to ensure high-quality services, while logistics operators have upgraded and extended their services to achieve lower price and quicker time window.

Further, Postnord is aware of the importance of last-mile delivery and has pointed out several innovative solutions such as digital locks, smart boxes, etc. are of its interest. None of these solutions has anything to do with home delivery – the option that has received increasingly more expectations in recent years. The limitations in home delivery service such as unsuitable delivery time window, expensive cost, etc. have stopped customers from choosing this service. Also there is a high level of dissatisfaction in the service quality. Although the company has taken actions to deal with the problems, the results are clearly not positive enough. As a new transportation tool, the drone cannot only serve the last mile delivery, but also be a good supplement to the traditional transportation modes. The combination of the two may increase the current logistics service capacity to a new level. Postnord indeed has more resources and a wider range of services than any other company, but so far it has shown little interest in developing drone logistics surprisingly, which could be the potential solution to the home delivery dilemma. This might be due to the long period of being market monopoly which makes Postnord reluctant for improvements. Especially when the future last mile can only be solved with innovative transport means, amongst others drones in rural areas.

6.3. Demographic and geographic environment

6.3.1. Lower population and dispersed demand

Rural areas are often characterized by low population. Compared to the national average population density of 25.4 (SCB, 2019), Tanum among the five municipalities with the largest number of residents which is 12,841 has an average population density of 14. Sorsele with the least population of 2,489 has an average population density of only 0.3. Less populated areas usually indicate an overall less demand and limited economies of scale, due to smaller quantities of purchases and fewer packages to deliver even though the online consumption per capita might be higher. Therefore, the carriers would often confront with two paradoxical choices when using LGVs in rural logistics: 1) in order to maintain a high level of service (e.g. delivery efficiency), the delivery is carried out at a low vehicle loading rate which leads to higher cost and resource waste; 2) in order to pursue a higher vehicle loading rate which reduces the cost, the delivery cycle is extended correspondingly. These two options represent a trade-off between cost reduction and service improvement that should be weighed by business philosophies. As discussed previously, the drone has the potential to conquer this trade-off in rural logistics due to its flexibility in parcel distribution.

Another problem in rural areas is longer travel distances. As the lower the population density, the sparser the residents live and thus the longer the distance is between the houses and service facilities. This is one of the reasons why rural residents have an impressive vehicle ownership per capita that indicates a strong dependence on private cars in everyday life. Approximately every 2 to 2.5 residents own a car in selected municipalities in contrast to only every 5.2 Stockholm residents having a private car (SCB, 2019). However, this does not contribute to sustainable developments. Especially the vehicles driving in rural areas are mostly old and more intensive in consuming energy. Further, there is also a comparatively less amount of green energy stations in rural municipalities. In this regard, drones that are electricity driven could be seen as the candidates for reducing the consumption of non-renewable energy and GHG emissions. Since it can both replace deliveries made by traditional logistics vehicles and trips by private cars to service points.

6.3.2. Infrastructure construction and layout

In rural areas of Sweden, buildings are often in the form of small houses. In these 5 municipalities, for instance, the ratio of small houses accounts for 98.5% (Borgholm), 98.4% (Sorsele), 98.2% (Tanum), 97.4% (Ragunda), and 96.2% (Torsby) respectively. High rates imply that there are fewer high-rises in these areas, and residents are more likely to live in single-family detached houses than in apartment buildings, unlike people who live in more densely populated cities. Such housing and building features provide drone deliveries with more open low-altitude areas and safer flight conditions which are ideal backyard environments for receiving deliveries.

According to the annual report by M Sverige (2020) on the road quality of European-, national- and county roads in Sweden, Southern Sweden has been assessed to have higher quality in general. While Northern Sweden has relatively poor road quality, the evaluation of which is even worse than that of the year 2018. Generally speaking, the quality of the roads is deteriorating from the north to the south. When looking at each municipality respectively, the proportion of European-, national- and county roads basically shows the same trend as road quality, but with a bit bias in Sorsele (Tanum 46%, Borgholm 31%, Torsby 25%, Ragunda 26% and Sorsele 37%). In terms of road maintenance, such as snow and ice removal in winter, the government is responsible for roads of European, national and county level. The responsibility of maintaining the remaining roads is outsourced, which has long been a problem with providing effective management, especially in rural areas. (Trafikverket, 2020) Among the five municipalities, the proportion of remaining roads is 54% (Tanum), 69% (Borgholm), 75% (Torsby), 74% (Ragunda) and 63% (Sorsele) respectively. Therefore, it could be speculated more negative impacts on traditional ground deliveries due to the overall lower quality of roads in the Northern rural areas.

However, the difference of the road quality in Swedish rural areas is only domestically and it is comparatively minor. In developing economies, the regional disparity is even greater. For example, some parts of the Chinese rural areas still do not have accessible roads that allow ground vehicles to travel through. Drone deliveries would only bring limited benefits in these areas for basically two reasons: 1) lack of purchasing power and 2) very limited coverage of solely drone-based systems. On the other hand, there could be more opportunities for Swedish rural areas with relatively good infrastructure and healthy economies to promote drone deliveries. Further, it is more likely to have a hybrid delivery system when it comes to practice. Also, drone deliveries could potentially become a supplement to the scenarios of the rural roads being inadequately managed.

6.3.3. Changes in service expectation

As a logistics player in Swedish market states in Konkurrensverket (2016) that the low customer expectation largely limits the logistics development even when they are capable of offering a better service. Since there is low demand for a better service, the transport companies are reluctant to invest for further improvements. If looking at the urban B2C logistics market in China, it is not only demand-driven but supply-driven. The higher expectation in delivery efficiency among Chinese customers is one of the reasons that has led to the rapid development of same-day deliveries in certain regions.

In recent years, there have been changes in consumer behavior and demand in the Swedish market that signals the requirement of innovative logistics solutions. Based on the research by Konkurrensverket (2016) and Ehandel (2017), Swedish people who shop online used to be satisfied with the last mile solution offered (pick-up at service point with longer delivery time), and less customers had demanded home delivery service. But in the latest Swedish e-commerce report, Postnord (2019) confirms that customers would rather have home delivery if they are available for the receipt. Basically, customers are forced to compromise on one delivery method (pick-up at the service point) due to the inflexibility of another (home delivery). More specifically, home delivery that requires the availability of the recipient especially when most of this delivery service is offered during working hours, which obviously leads to less people choosing this service. There are also other reasons such as the quality of existing services that is affected by the delivery accuracy and failed first attempts, etc.

Since the researches in this study do not specify whether the respondents living in Swedish urban- or rural areas, the increased customer expectation is considered to be representable for the whole nation. Thus, it could be queried if the existing home delivery service can be done better in rural markets when it does not meet customer expectations in urban areas. It has been reported that the service points in Northern rural areas are uncoordinated with limited inventory space. Which is an evidence of the existing facilities being incapable of meeting the market demand. The situation also becomes worse during peak seasons for e-commerce. Further, there are concerns about the security of parcels when the inventory in service points is overloaded. In terms of home deliveries, many complaints have been related to the service quality such as parcels being left outside in snow or deliveries never arrived, etc.

The Swedish authority states that the future last mile will only be solved by innovative transportation (PTS, 2019a; 2019b). Despite having a mature network of service points in Sweden compared to other European countries presumably due to high labour cost (Liu, Wang & Susilo, 2019), the future last mile cannot be solved by using traditional transportation. In developing economies such as China, its highly efficient urban last mile market benefits indubitably from the low labour cost. Consistent with Joerss, et al. (2016) that rural B2C last mile will most likely be solved by drone logistics, it is reasonable to regard drones being both cost effective and service efficient in the supply chain.

From the perspective of a logistics carrier, the question of whether the demand is urgent and important enough to revolutionize the last mile transport arises. Especially in rural areas where the population and the demand are relatively sparse. The question has to be taken with a grain of salt. As Sima Qian, a great historian of the Western Han Dynasty said, "*Jostling and joyous, the whole world comes after profit; Racing and rioting, after profit the whole world goes*." Considerable profits and other conspicuous benefits are always the ideal driving forces for rapid industrial improvements. If thinking reversely, what are the reasons that there is still no logistics company involved in practicing B2C drone deliveries in Sweden so far? In addition to lack of motivation for innovations due to limited industrial competition, the reasons could be presumed to be the immature market, insufficient customer demand, and most importantly the uncertainty in the scale of potential economic returns from establishing drone deliveries at the present.

6.3.4. Changes in consumption habits

As online shopping gradually integrates into everyday life, e-commerce has changed the traditional perception of different types of products which results in different buying behaviours. One of the most typical manifestations is the clothing and footwear section, which has generated the most returns of around 20 % that causes the problem of reverse logistics. Currently, the main return option is service points. Which indicates that apart from the trips made for pick-ups, there are additional trips made to service points for returns. Either way, the number of inevitable trips could be higher. Especially in rural areas, these trips made by cars could be more frequent.

FMCG is the second largest growth area of the online retail business. The physical properties of some commodities (e.g. perishable- and frozen products) make them to be highly time-sensitive in transportation. That in turn generates greater challenges for last mile logistics, especially in rural areas (Sousa, et al., 2020). According to Trafikanalys (2019a), 62% of Swedish people's weekly trips are grocery shopping. The average round trip is 11.4 km, with a single trip distance of 5.7 km (road distance), of which 63% are by car. Considering that rural areas in Sweden are characterized by sparse population, inconvenient public transportation and high reliance on private cars, the one-way distance in rural areas could likely be significantly more than 5.7 kilometers and the driving rate could exceed 63 %.

Even with the promotion of FMCG in an online environment, it would be more challenging in logistics due to the handling of time-sensitive goods. As the home delivery would require the carrier to deliver goods in a timely manner. Also, the pick-up option would still require customers to make trips to the physical stores. The trips made by cars seem to be unavoidable anyway.

Thus, the changes in consumption habits brought by the everlasting development of e-commerce have increased the total distance of distributions by carriers respective driving by individuals driving to a certain extent. Which in turn has led to greater adverse impacts for the environment. It is impossible to compulsorily limit the number of online purchases nor the number of returns. In this sense, drone deliveries could radically reduce the number of trips by providing convenient home deliveries and returns that both satisfies the customers while being cost-effective for the industry.

6.3.5. Public acceptance in the aging society

Figure 47 structures different age groups in the five selected municipalities. Sweden is viewed as one of the countries consisting of an aging society with a relatively large share of population over 65 years old (Scommegna, 2019). Meanwhile, the average age of these areas is higher than the Swedish average. Postnord (2019) finds that younger customers purchase more online while older customers prefer brick and mortar. This point seems to disagree with the subject of this study as there is a distinct higher proportion of older population in Swedish rural areas. However, it could be surmised that the younger population is growing, and these customers have increasingly greater potential as their economy matures.

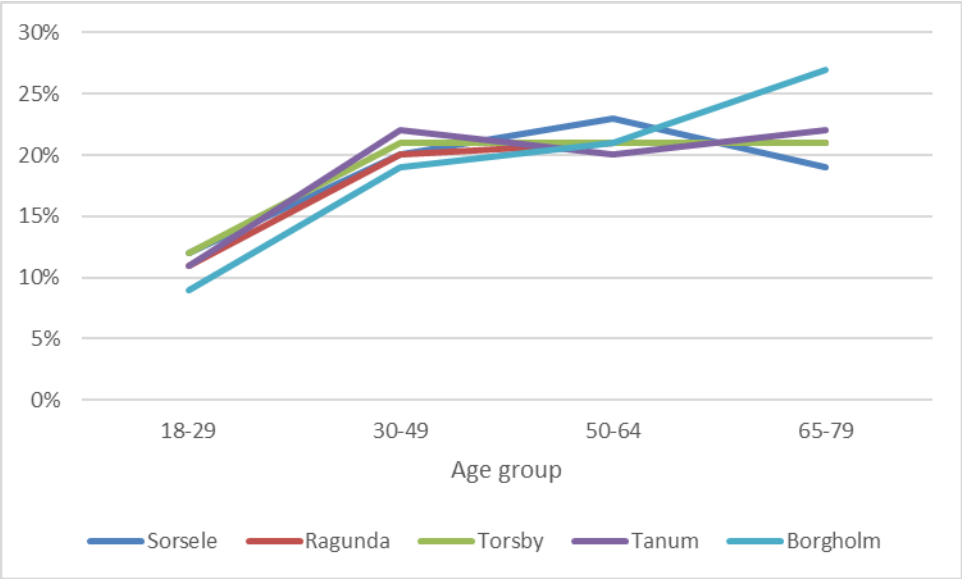

Figure 47. Age structures of the selected municipalities.

This is also consistent with the younger generation being more receptive to new technologies for instance advanced electronic devices, 5G networks, the Internet of Things (IoT), etc. It could be speculated that younger people are more open minded towards innovative transport means such as drones. One argument is that the large proportion of ageing population in Swedish rural areas could make the practise of drone deliveries to encounter greater resistance in terms of public acceptance. Moreover, the social issues are deemed to be one of the major barriers in developing drones. This obstacle is presumed by the authors to be easier to overcome when the relevant legal environment is established, and the drone technology matures. Which can be proven by Zhu (2019) that one way to address the public acceptance of drones is to promote right communication towards the right group.

6.3.6. Climate conditions and changes

The change of climate could bring both threats and opportunities to drone deliveries. For instance, low temperature can reduce battery life, wind speed and precipitation can restrict take-off, landing and flying distance of drones. Drones are more susceptible to the weather interference compared with ground vehicles. Even during Sweden's warmest year in the recent decade, the average temperature of the coldest month went as low as -5 ℃. The average monthly temperature in the northern region even reached about -20 ℃. A study by Yao and Wang (2014) shows that the power source of drones can reduce its capacity by 40 % when temperature goes from 23 ℃ to -20 ℃. For example, the case of Sorsele features relatively longer travel distance in last mile delivery. The operational range is further limited due to lower temperature (e.g. often under -10 ℃ during winter months). As a result, the implementation of drones in rural areas in the north could encounter greater operational resistance.

Under the influence of global warming, the average temperature within Sweden is slowly increasing, and the rise of temperature happening faster in the northern region compared with the southern region (SMHI, 2020d). Due to rising temperatures, precipitation is also anticipated to increase, mainly in the north and during the winter (SMHI, 2019a). Due to the maritime climate or humid continental climate, the southern and central parts of Sweden have more precipitation than the northern part with the highest level in the southwestern coast and the western mountainous areas (such as Tanum), and its seasonal distribution is relatively average. According to Köppen-Geiger climate zones, the majority of northern Sweden is in the cold continental climate (such as Ragunda and Sorsele), where rainfall is concentrated in the warm season and rarely at other periods. However, with climate change, the northern region may evolve the characteristics of significant precipitation throughout the year and abundant precipitation in the warm season. Therefore, in the coming decades, the application of drone logistics is likely to be disrupted by rainfall more frequently.

In terms of the wind, inland areas have the lowest average speed (e.g., Sorsele, Ragunda and Torsby); the west coast (Tanum), the east coast (Borgholm), the north and northwest bordering areas have the moderate wind level; while the average wind speed is fastest on the southwest coast (≥7.5 m/s). This is within the capacity range of the referenced drone in this study, as it can withstand wind speeds up to 20 m/s (Sun, 2020). Simulation made by researchers at the University of Colorado forecasts that due to rising temperature, storm tracks in mid-latitude will move north as a whole, with fewer frontal cyclones but more intense individual storms.

This would potentially result in winds of extreme speed to become more frequent in Nordic countries (CSC, 2018).

The climate change will affect the drone delivery capabilities, but the authors believe that those affects will be mitigated by improved drone and battery technology.

6.4. Technological readiness and limitation

As previously discussed, drones being more sensitive to the climate largely limits its operations which is a result of immature technologies. Basically, the weakness of drone deliveries is primarily associated with its technical constraints which was uncovered in the case study. As the referenced drone used for simulations is short ranged with a maximum operation range of 20 km, it is found that the implementation of drone deliveries in Sorsele is less operational than the other municipalities. On account of the average population density significantly differs from one another: 0.3 (Sorsele), 2.1 (Ragunda), 2.8 (Torsby), 14 (Tanum) and 16 (Borgholm).

However, the potential of drone deliveries in these rural areas can still be obtained. The delivery routes were conceptualized with service points as the starting points. With around 30 % of the population living within 1 km from a service point in the studied municipalities, it could be presumed that at least 30 % of rural population can be covered by drone deliveries if service points operate as the concept of Amazon's UAV tower. But this type of delivery system (i.e. drone fulfilment centre) in Sweden is found to be least profitable among EU countries (Aurambout, Gkoumas & Biagio, 2019). Further, a hybrid system of truck and drone is deemed as being more potential in increasing coverage than if they operate independently. The business value of an innovative technology is anyhow the driving force to escalate technological developments.

In addition, the traditional means of transportation are also simultaneously advancing while drone technology is undergoing rapid development. For example, EU policy promotes the development of clean and fuel-efficient vehicles to gradually replace low-carbon and fossil-fuel vehicles. Therefore, even only in terms of energy conservation and emission reduction, drones do not have an absolute advantage at present. Also, besides the environmental goal, new technologies such as autonomous driving are predicted to revolutionize the transportation industry by reducing labour costs and dependence on manpower control. These developments could indeed threaten the integration of drones into the logistics. But drones with its unique flexibility such as operating in the air is still advantageous in delivering certain products in particular areas. One example is many trials in transporting medical supplies. In regard to last mile B2C deliveries, drones are seen to be advantageous over ground vehicles 1) in delivering time-sensitive goods or 2) when road accessibility is limited. The examples of potential implementations could be cold chain logistics (FMCG) and reverse logistics (clothes and shoes). Also, deliveries in rural areas with poor road accessibilities or road routes that are of too long distance.

6.5. Section conclusion

In this section, the thesis analyses, discusses and evaluates the application feasibility of drone delivery in rural areas of Sweden from different aspects, and tries to induce some specific conditions and scenarios that fit drone delivery implementation. All influence factors are summarized in *table 18*.

Table 18. The influence factor of drone delivery implementation in last mile delivery in rural Sweden.

Strength	Weakness	Opportunity	Threat
·High delivery efficiency ·Short travel distance ·Time-saving ·High flexibility ·Environmentally friendly	·Limited service range ·Limited loading capacity ·High initial investment ·Vulnerable to extreme weather	·Favourable domestic legal environment ·Positive legislative attitude of EU ·Eager to energy-saving and emission reduction	·Complicated legislative process
		·No market competition	·Lack of necessary industrial competition ·Lack motivation of industrial innovation ·High industrial barriers
		·Small and dispersed delivery demand ·High dependence on private cars ·High proportion of low-rise buildings ·Unguaranteed road maintenance ·Customers have higher expectations for home delivery service ·Challenges of cold chain and reverse logistics ·Nationwide temperature rise	·Disproportionate number of elderly residents ·Public knowledge and acceptance are limited ·Increasing precipitation and extreme winds
			·Competition from new energy and clean energy vehicles

7. CONCLUSION

This chapter will conclude the study and answer the research questions. After which provides suggestions for the future.

7.1. Research question 1

What advantages and disadvantages does drone delivery have versus traditional transportation?

In a logistics context, the dual nature of drones exposes both of its advantages and disadvantages to a variety of internal- and external factors. Drones per se are more flexible and sustainable with shorter travel distance and quicker delivery time compared to ground vehicles, which makes it extra suitable for transporting time-sensitive goods in an environment with limited infrastructure. Its disadvantages relate to high upfront investments and technical constraints including limitations in service range, loading capacity and operations in contrast to traditional ground vehicles. Further, both vehicles do have potential security risks which are reflected in different scenarios.

The traditional transport has for a long time been part of the supply chain. It has a well-established external framework such as legislation, infrastructure, distribution network and public acceptance in comparison to drone deliveries. Among the external factors, legislation and public acceptance are reckoned as the major obstacles to the development and integration of drones into the current logistics.

7.2. Research question 2

Can drones become a viable B2C last mile logistics solution in Swedish rural areas?

At the present stage, drone deliveries are not a viable B2C last mile logistics solution in Swedish rural areas. However, it could be a viable solution with tremendous opportunities in the future.

Firstly, Swedish legal framework is currently not mature for commercializing drone deliveries on a large scale. But ongoing developments world-wide are clearly rapid, amongst European Commission has set vision for a fully functional flightpath for drones in 2050. Further, the

Swedish legislations of drones are confirmed to follow the standard framework promoted by European Union as of July 2020.

Secondly, drones are proven to have higher delivery efficiency compared to ground vehicles among five rural municipalities, as 77.46% of routes are found to be time-saving using drones. In all routes, drone deliveries are found to be exceptionally beneficial when the roads have poor accessibility, more detours and blocked by water. Further, rural areas with over 95% of small houses and lower road quality also promotes drone deliveries.

However, drones at the current stage have multiple technical constraints which are outplayed by traditional ground vehicles. From the simulation, the advantage of drones decreases gradually when vehicles drive at a constant speed over 50 km/h which is possible in rural areas in a real-world setting. Further, drones have limited operation range which makes it less feasible in Sorsele compared to other municipalities. Its operations are more susceptible to the climate conditions as the wind and the precipitation in Sweden are found to be less positive for drones. But the technological developments are rapid, and it can be expected to have drones with improved performance in the future.

Thirdly, drones are more environmentally friendly than conventional transport means which is especially beneficial in rural areas where the travel distance is longer. One delivery by drone could replace the trips made by the customer for pick-up or by carriers delivering to the door. Additionally, drones are electricity driven while ground delivery vans often run on fossil fuels.

Fourthly, Swedish customers have started to expect faster and more flexible home deliveries at a low or even free cost. This poses additional challenges for carriers in rural areas due to smaller economies of scales. As the business wants profitability, it is therefore uncertain whether the demand from the customers are sufficient to initiate a transport revolution in the last mile logistics. In this sense, drones could be a cost-effective delivery method that also increases the service level.

Lastly, the public acceptance of drones is currently limited, and this gap could potentially be larger in Swedish rural areas characterized by an ageing population. But this deems to be less challenging to overcome with right public relationship management when the previously mentioned aspects are mature.

7.3. Future research

As pointed out earlier, this thesis was an attempt to reduce the gap of the research on drone deliveries in Swedish rural last mile logistics in a B2C context. There are plenty of interesting topics within drone logistics that could be further investigated. Due to limited resources and time constraints, the authors were not able to simulate the model of a hybrid delivery system in order to provide more comparative data. This concept is regarded by the authors as being worth exploring in terms of the potential delivery coverage, delivery efficiency as well as many other relevant variables in Swedish rural municipalities.

This study of drone deliveries was not limited to a specific sector and the opportunities in cold chain- and reverse logistics were only briefly discussed. Due to the potential of this delivery mode is huge especially in transporting time-sensitive goods, the authors believe that drone deliveries in these certain contexts could be interesting to examine further. For example, the online grocery deliveries, the food delivery, etc.

One of the most recognizing events in 2020 was the COVID-19 pandemic which has resulted in many severe consequences at the time of writing this paper. Amongst others the increasing number of people spending more time at their homes due to quarantine. This has significantly increased the number of online shopping in FMCG- and pharmaceutical goods while reducing the purchases from other sectors in Sweden (Postnord, 2020b). The authors think that this could be one interesting aspect to further investigate – the potential of drone deliveries during extraordinary times. Such as when the interaction between people has to be kept minimum.

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Appendix 1. Classification of Swedish municipalities

Main group	Subgroup	Definition	Quantity
A. Large cities and its nearby municipalities nearby	A1. large cities	At least 200,000 inhabitants in its largest urban area	3
	A2. Commuting municipalities near large cities	More than 40 % of the working population commute to work in A1	43
B. Medium-sized towns and its nearby municipalities	B3. Medium-sized towns	At least 50,000 inhabitants in its largest urban area	21
	B4. Commuting municipalities near medium-sized towns	More than 40 % of the working population commute to work in B3	52
	B5. Commuting municipalities with a low commuting rate near medium-sized towns	Less than 40 % of the working population commute to work in B3	35
C. Smaller towns / urban areas and rural municipalities	C6. Small towns	At least 15,000 inhabitants in its largest urban area	29
	C7. Commuting municipalities near small towns	More than 30 % of the working population commute to work in C6 or more than 30 % of the employed day population lives in another municipality	52
	C8. Rural municipalities	Less than 15,000 inhabitants in its largest urban area and very low commuting rate (less than 30%)	40
	C9. Rural municipalities with a visitor industry	Municipalities in rural area that fulfil at least two criteria for visitor industry, i.e. number of overnight stays, retail-, restaurant- or hotel turnover per head of population.	15
Source: SKR, 2017			

Appendix 2. Geographical coordination of service points and churches

Municipality	Service point	Church
Tanum	ICA Supermarket Hedemyrs (58.72464, 11.32519) Riksvägen 91 (58.716, 11.33449) Tanumsvägen 1 (58.69797, 11.25425) Coop Grebbestad (58.69202, 11.25483) Coop Fjällbacka (58.59794, 11.28933) Industrivägen 2 (58.55786, 11.27987) ICA Supermarket Skutan (58.55211, 11.27097) ICA Östads Livs (58.77593, 11.56027) Metkroksvägen 2 (58.60025, 11.29108)	Tanums pastorat (58.71602, 11.33285) Sannäs kapell (58.74167, 11.24764) Grebbestads kyrka (58.6955, 11.25312) Havstenssunds kapell (58.71602, 11.33285) Lur kyrka (58.81804, 11.3311) Resö kyrka (58.81095, 11.1863) Mo kyrka (58.70333, 11.5574) Fjällbacka kyrka (58.59982, 11.28399) Naverstads kyrka (58.76347, 11.56711) Kville kyrka (58.56755, 11.36767) Hamburgsunds kapell (58.55359, 11.26603) Fagerhults kapell (58.79004, 11.59411) Svenneby kyrka (58.50816, 11.32048) Svenneby gamla kyrka (58.49977, 11.32418) Bottna kyrka (58.5043, 11.37931)
Borgholm	ICA Supermarket Borgholm (56.87564, 16.6643) Pressbyrån Borgholm (56.87926, 16.65512) OK/Q8 Borgholm (56.87381, 16.66774) ICA Nära Löttorpshallen (57.16581, 16.99153) ICA Nära Trossen (57.073, 16.85996) ICA Nära Byxelkrok (57.32422, 17.00854)	Borgholms kyrka (56.88019, 16.65622) Sankt Elavi kapell (56.88358, 16.65151) Alböke kyrka (56.94768, 16.78402) Bredsättra kyrka (56.84479, 16.79395) Böda kyrka (57.24449, 17.05965) Egby kyrka (56.87364, 16.82128) Föra kyrka (57.01275, 16.86451) Gärdslösa kyrka (56.79423, 16.73883) Högby kyrka (57.16442, 17.01661) Högsrums kyrka (56.76607, 16.59604) Källa kyrka (57.12132, 16.96618) Köpings kyrka (56.87808, 16.71841) Långlöt kyrka (56.73918, 16.72454) Löt kyrka (56.91818, 16.83818) Persnäs kyrka (57.06726, 16.9308) Runsten kyrka (56.69921, 16.69947) Räpplinge kyrka (56.82855, 16.66445)
Torsby	Coop Stöllet (60.41083, 13.27095) OK/Q8 MAC45 (60.42293, 13.25886) Coop Konsum Sysslebäck (60.73441, 12.86542) Radioelektriska i Sysslebäck AB (60.73138, 12.87071) ICA Frykenhallen (60.13583, 13.00805) Pekås Torsby (60.13636, 13.0069) QStar (60.13306, 13.0059) Coop Torsby (60.1306, 12.99791) Bograngen Lanthandel (60.70317, 12.59538) ICA Nära Likenäs Allköp (60.61584, 13.04112) ICA Nära Östmarks Handel (60.27927, 12.76023) Tempo Ambjörby (60.49741, 13.16847)	Fryksände kyrka (60.1375, 13.01416) Siris kapell (60.1367, 13.01707) Lysviks kyrka (60.01455, 13.13256) Lekvattnets kyrka (60.18765, 12.67221) Östmarks kyrka (60.27893, 12.76347) Dalby kyrka (60.64974, 12.99682) Norra Finnskoga kyrka (60.89927, 12.5938) Södra Finnskoga kyrka (60.7003, 12.57847) Norra Ny kyrka (60.406, 13.27282) Nyskoga kyrka (60.1409, 13.01021) Ekshärads församling (60.1725, 13.49774)
Ragunda	ICA Supermarket Hammarn (63.10841, 16.35483) Coop Hammarstrand (63.11, 16.3537) Time i Hammarstrand (63.10456, 16.35726) ICA Nära Stugun (63.16765, 15.60508) Stuguns Bygg & Färg AB (63.16768, 15.59903) Macken Stugun (63.16582, 15.59932) ICA Forsen Bispgården (63.02836, 16.61892)	Ragunda nya kyrka (63.11059, 16.37058) Köttsjöns kapell (63.33912, 15.9935) Fors kyrka (63.01376, 16.65646) Skogskapell (63.01172, 16.64191)

	Bispgårdens Trafikbutik (63.0101, 16.6623)	
Sorsele	ICA Nära Sorsele (65.53648, 17.53031) Coop Sorsele (65.53527, 17.53222) Sorsele Busstation (65.53667, 17.53073) ICA Nära Jonssons Livs (65.3133, 17.96234) Ammarnäs Livs (65.95825, 16.2123) ICA Nära Blattnicksele (65.34241, 17.58581)	Sorsele kyrka (65.54175, 17.51544) Ammarnäs kyrka (65.9615, 16.21842) Viktoriakyrkan (65.69925, 16.26472) Bergnäs kåtakyrka (65.85049, 17.18479)

Appendix 3. Vehicle delivery time and time difference under various ASDS in Tanum

Service point	Church	VDT (30)	TD	VDT (40)	TD	VDT (50)	TD	VDT (60)	TD	VDT (70)	TD
ICA Supermarket Hedemyrs	Sannäs kappel	13.6	-6.84	10.15	-3.39	8.19	-1.43	6.8	-0.04	5.81	0.95
	Tanum pastorat	2.4	-0.92	1.79	-0.32	1.45	0.02	1.2	0.27	1.03	0.44
Riksvägen 91	Sannäs kappel	15.4	-8.02	11.49	-4.11	9.28	-1.89	7.7	-0.32	6.58	0.80
Tanumsvägen 1	Sannäs kappel	14.8	-8.03	11.04	-4.27	8.92	-2.15	7.4	-0.63	6.32	0.45
	Tanum pastorat	13.6	-6.70	10.15	-3.25	8.19	-1.29	6.80	0.10	5.81	1.09
Coop Grebbestad	Sannäs kappel	16.2	-8.51	12.09	-4.40	9.76	-2.07	8.1	-0.41	6.92	0.77
	Tanum pastorat	15	-7.72	11.19	-3.91	9.04	-1.76	7.5	-0.22	6.41	0.87
Coop Fjällbacka	Fjällbacka kyrka	2.4	-1.88	1.79	-1.27	1.45	-0.93	1.2	-0.68	1.03	-0.51
	Kville kyrka	14.2	-6.35	10.60	-2.75	8.55	-0.70	7.1	0.75	6.07	1.78
Industrivägen 2	Kville kyrka	12.2	-4.99	9.10	-1.90	7.35	-0.14	6.1	1.11	5.21	1.99
	Svenneby kyrka	14	-5.66	10.45	-2.11	8.43	-0.09	7	1.34	5.98	2.36
	Svenneby gamla kyrka	15.6	-5.95	11.64	-1.99	9.40	0.25	7.8	1.85	6.67	2.98
	Bottna kyrka	24	-12.50	17.91	-6.41	14.46	-2.96	12	-0.50	10.26	1.24
ICA Supermarket Skutan	Kville kyrka	14	-5.88	10.45	-2.32	8.43	-0.31	7	1.12	5.98	2.14
	Svenneby kyrka	13	-5.13	9.70	-1.83	7.83	0.04	6.5	1.37	5.56	2.31
	Svenneby gamla kyrka	14.6	-5.46	10.90	-1.75	8.80	0.35	7.3	1.84	6.24	2.90
	Hamburgsunds kapell	Impossible to calculate since the vehicle needs to take the ferry									
	Bottna kyrka	24	-12.59	17.91	-6.50	14.46	-3.05	12	-0.59	10.26	1.16
ICA Östads Livs	Naverstads kyrka	4.2	-2.20	3.13	-1.13	2.53	-0.53	2.1	-0.10	1.79	0.21
	Fagerhults kapell	10.6	-7.12	7.91	-4.43	6.39	-2.90	5.3	-1.82	4.53	-1.05
	Mo kyrka BohusIän	18.2	-6.99	13.58	-2.37	10.96	0.25	9.1	2.11	7.78	3.44
Metkroksvägen 2	Kville kyrka	14.4	-6.44	10.75	-2.79	8.67	-0.72	7.2	0.76	6.15	1.80
	Fjällbacka kyrka	1.3	-0.73	0.97	-0.40	0.78	-0.21	0.65	-0.08	0.56	0.02

Appendix 4. Vehicle delivery time and time difference under various ASDS in Borgholm

Service point	Church	VDT (30)	TD	VDT (40)	TD	VDT (50)	TD	VDT (60)	TD	VDT (70)	TD
ICA Supermarket Borgholm	Sankt Elavi kapell	3	-1.36	2.24	-0.60	1.81	-0.17	1.5	0.14	1.28	0.36
	Bredsättra kyrka	22	-10.00	16.42	-4.42	13.25	-1.25	11	1.00	9.40	2.60
	Egby kyrka	22	-8.66	16.42	-3.08	13.25	0.09	11	2.34	9.40	3.94
	Köpings kyrka	7.8	-3.19	5.82	-1.21	4.70	-0.09	3.9	0.71	3.33	1.28
	Räpplinge kyrka	11.6	-4.33	8.66	-1.38	6.99	0.28	5.8	1.47	4.96	2.32
	Borgholms kyrka	1.6	-0.62	1.19	-0.21	0.96	0.02	0.8	0.18	0.68	0.30
Pressbyrån Borgholm	Räpplinge kyrka	13.8	-5.93	10.30	-2.43	8.31	-0.44	6.9	0.97	5.90	1.97
	Köpings kyrka	9.8	-4.42	7.31	-1.93	5.90	-0.52	4.9	0.48	4.19	1.19
	Sankt Elavi kapell	1.5	-0.77	1.12	-0.39	0.90	-0.17	0.75	-0.02	0.64	0.09
	Bredsättra kyrka	24	-11.06	17.91	-4.97	14.46	-1.52	12	0.94	10.26	2.68
OK/Q8 Borgholm	Sankt Elavi kapell	3.4	-1.36	2.54	-0.49	2.05	0.00	1.7	0.34	1.45	0.59
	Bredsättra kyrka	24	-12.38	17.91	-6.29	14.46	-2.84	12	-0.38	10.26	1.36
	Egby kyrka	22	-8.96	16.42	-3.38	13.25	-0.21	11	2.04	9.40	3.64
	Gärdslösa kyrka	30	-16.31	22.39	-8.69	18.07	-4.38	15	-1.31	12.82	0.87
	Köpings kyrka	8.4	-4.05	6.27	-1.91	5.06	-0.71	4.2	0.15	3.59	0.76
	Räpplinge kyrka	15.8	-8.80	11.79	-4.80	9.52	-2.52	7.9	-0.90	6.75	0.24
	Borgholms kyrka	2.2	-0.81	1.64	-0.25	1.33	0.06	1.1	0.29	0.94	0.45
ICA Nära Löttorpshallen	Högby kyrka	3.2	-1.06	2.39	-0.25	1.93	0.21	1.6	0.54	1.37	0.77
	Böda kyrka	22	-8.54	16.42	-2.96	13.25	0.21	11	2.46	9.40	4.06
	Källa kyrka	15.4	-8.20	11.49	-4.29	9.28	-2.08	7.7	-0.50	6.58	0.62
ICA Nära Trossen	Persnäs kyrka	12	-5.92	8.96	-2.87	7.23	-1.15	6	0.08	5.13	0.95
	Föra kyrka	14.8	-5.49	11.04	-1.73	8.92	0.40	7.4	1.91	6.32	2.99
ICA Nära Byxelkrok	Böda kyrka	20	-6.94	14.93	-1.87	12.05	1.01	10	3.06	8.55	4.51

Appendix 5. Vehicle delivery time and time difference under various ASDS in Torsby

Service point	Church	VDT (30)	TD	VDT (40)	TD	VDT (50)	TD	VDT (60)	TD	VDT (70)	TD
Coop Stöllet	Norra Ny kyrka	2.6	-1.84	1.94	-1.18	1.57	-0.81	1.3	-0.54	1.11	-0.35
OK/Q8 MACK45	Norra Ny kyrka	5.4	-2.58	4.03	-1.21	3.25	-0.43	2.7	0.12	2.31	0.51
* Coop Konsum sysslebäck	Dalby kyrka	24	-7.54	17.91	-1.45	14.46	2.00	12	4.46	10.26	6.20
* Radioelektriska	* Norra Finnskoga kyrka	54	-20.61	40.30	-6.91	32.53	0.86	27	6.39	23.08	10.32
ICA Frykenhallen	Nyskoga kyrka	1.9	-1.10	1.42	-0.62	1.14	-0.34	0.95	-0.15	0.81	-0.01
	Fryksände kyrka	1.3	-0.77	0.97	-0.44	0.78	-0.25	0.65	-0.12	0.56	-0.02
	Siris kapell	1.12	-0.38	0.84	-0.10	0.67	0.06	0.56	0.18	0.48	0.26
Pekås Torsby	Nyskoga kyrka	1.5	-0.76	1.12	-0.37	0.90	-0.16	0.75	-0.01	0.64	0.10
	Fryksände kyrka	1.6	-1.02	1.19	-0.61	0.96	-0.38	0.8	-0.22	0.68	-0.10
	Siris kapell	1.4	-0.60	1.04	-0.25	0.84	-0.05	0.7	0.10	0.60	0.20
QStar	Nyskoga kyrka	2.2	-0.95	1.64	-0.39	1.33	-0.07	1.1	0.15	0.94	0.31
	Fryksände kyrka	1.6	-0.67	1.19	-0.26	0.96	-0.03	0.8	0.13	0.68	0.25
Coop Torsby	Nyskoga kyrka	3.4	-1.55	2.54	-0.69	2.05	-0.20	1.7	0.15	1.45	0.39
	Fryksände kyrka	2.8	-1.17	2.09	-0.46	1.69	-0.06	1.4	0.23	1.20	0.43
	Siris kapell	2.7	-0.89	2.01	-0.20	1.63	0.19	1.35	0.46	1.15	0.66
ICA Bograngen Lanthandel	Södra Finnskoga kyrka	4.4	-3.04	3.28	-1.92	2.65	-1.29	2.2	-0.84	1.88	-0.52
ICA Nära Likenäs Allköp	Dalby kyrka	9	-2.78	6.72	-0.49	5.42	0.80	4.5	1.72	3.85	2.38

Appendix 6. Vehicle delivery time and time difference under various ASDS in Ragunda

Service point	Church	VDT (30)	TD	VDT (40)	TD	VDT (50)	TD	VDT (60)	TD	VDT (70)	TD
ICA Supermarket Hammarn	Ragunda nya kyrka	4.6	-3.45	3.43	-2.29	2.77	-1.63	2.3	-1.15	1.97	-0.82
Coop Hammarstrand	Ragunda nya kyrka	4.2	-3.02	3.13	-1.96	2.53	-1.35	2.1	-0.92	1.79	-0.62
Time i Hammarstrand	Ragunda nya kyrka	5.6	-4.29	4.18	-2.87	3.37	-2.06	2.8	-1.49	2.39	-1.08
Bispgårdens Trafikbutik	Skogskapell	2.6	-1.16	1.94	-0.50	1.57	-0.13	1.3	0.14	1.11	0.33
	Fors kyrka	1.3	-0.60	0.97	-0.27	0.78	-0.09	0.65	0.05	0.56	0.14

Appendix 7. Vehicle delivery time and time difference under various ASDS in Sorsele

Service point	Church	VDT (30)	TD	VDT (40)	TD	VDT (50)	TD	VDT (60)	TD	VDT (70)	TD
ICA Nära Sorsele	Sorsele kyrka	1.8	-0.56	1.34	-0.10	1.08	0.16	0.9	0.34	0.77	0.48
Coop Sorsele	Sorsele kyrka	2.2	-0.74	1.64	-0.18	1.33	0.13	1.1	0.36	0.94	0.52
Sorsele Busstation	Sorsele kyrka	1.8	-0.55	1.34	-0.10	1.08	0.16	0.9	0.35	0.77	0.48
Ammarnäs Livs	Ammarnäs kyrka	1.2	-0.57	0.90	-0.26	0.72	-0.09	0.6	0.03	0.51	0.12
	* Viktoriakyrkan	334	-293.86	249.25	-209.12	201.20	-161.07	167	-126.86	142.74	-102.60
	* Bergnäs kåtakyrka	170	-106.21	126.87	-63.08	102.41	-38.62	85	-21.21	72.65	-8.86