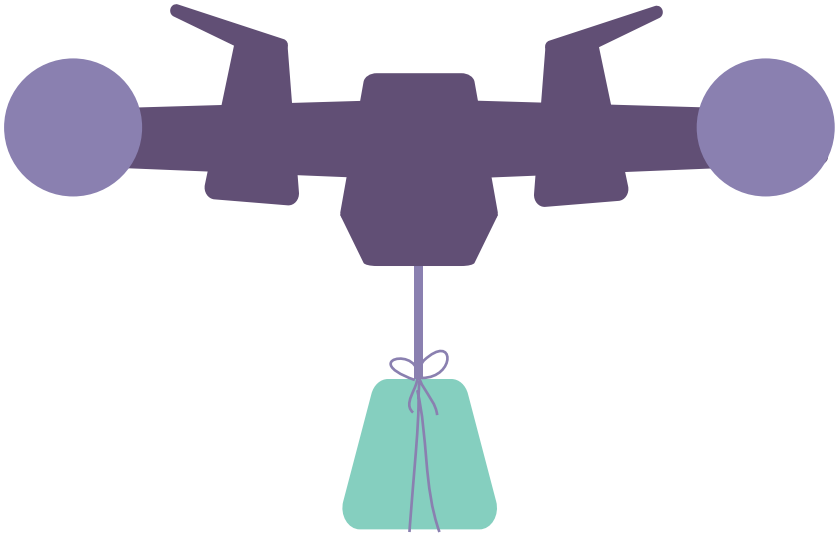
Potential Benefits of Drone Deliveries in Helsinki



Gaia Consulting Oy
2021


Wing

Impact of drone deliveries in Helsinki in 2030 if 6 % of deliveries and pickups are replaced by drones.*

Benefits for local businessess

13 M€
more sales to
local businesses of which
7 M€
to small businesses.

45 % lower costs for instant deliveries on average. Cost reduction potential of

4 M€

for local businesses.

Up to **2-3 times**
more customers within delivery reach.

Benefits for consumers

1,5 million
saved hours or **40 M€**
saved money for consumers by replacement of pick-up journeys.

55 %
faster deliveries on average.

4 M€
of reduced delivery costs. Saving potential for consumers up to
45 %

Increased product variety.
3-8 times
more businesses within reach.

Benefits for society

11 million
fewer vehicle delivery kilometers reducing congestion.

Up to **2 000 tCO2e**

The reduction in greenhouse gas emissions is equivalent to almost 350,000 electric sauna heating sessions, or an estimated annual carbon sink of about 250 hectares of forest.

38
avoided road accidents.

*Estimated population in Helsinki in 2030 is 724 000 inhabitants.

Executive Summary

Drone deliveries are an increasingly common sight across Helsinki today. Drones are fast, cost effective and accessible for companies and consumers alike. They help to reduce congestion and greenhouse gas emissions caused by ground traffic.

Currently, the last mile of deliveries is the costliest part of the global supply chain and comprises a significant portion of the total price of goods and services. These costs are borne by consumers who must invest time and resources in retrieving their packages from stores, pickup points or parcel lockers and ultimately pay higher prices for goods and services.

Based on Gaia Consulting's scenario analysis, drones have the potential to deliver six per cent of all household purchases in Helsinki by 2030. This estimate is conservative, considering the pronounced increase in online shopping as a result of the COVID-19 pandemic. The greatest potential for drone deliveries lies in the 1-10 km, instant, and same-day deliveries of small packages under 1,5 kg. Such deliveries by drone would tremendously benefit local businesses, as increased reach generally results in increased sales. Drone deliveries can benefit consumers by providing them with access to a wider selection of products and services. Finally, in the case of electric drones, their carbon footprint is significantly lower than traditional delivery services that rely on combustion engine vehicles.

Benefits of drone deliveries

Benefits for local businesses

The findings of this report show that drone delivery would expand the market reach of local and small businesses. The expanded operating area for drones could enable a company located in central Helsinki to reach 250,000 new households by 2030. The efficiency of drone delivery coupled with the reduced importance of a company's location could result in lower consumer prices and increased consumer purchasing power. In all, such developments could generate additional sales worth **13 million euros for local businesses, 7 million euros** of which would go to **SMEs**.

Benefits for consumers

Drones could also help **save consumers up to 4 million euros** in delivery fees in Helsinki alone. This is in part due to the potential for an increase in instant and same-day deliveries at lower costs. Ultimately, spending less on deliveries and pickups would enable households to save and spend more on their preferred goods and services.

It is forecast that there will be approximately 37,000 senior citizens who will need assistance with their daily shopping as of 2030[1]. Overall, drone deliveries would empower vulnerable populations with easier and expanded access to goods and services.

Moreover, drone deliveries are considerably faster than other forms of last-mile deliveries. Compared to traditional delivery methods, **drones could deliver orders 35-75 per cent faster depending on the scenario**. If drone deliveries could replace 5.6 million pickups made by consumers in Helsinki every year, consumers would save approximately **1.5 million hours of their time,** which translates to about **40 million euros**. In the case of instant deliveries, such as takeaway, consumers could save as much as 45 per cent or **4 million euros annually**, in delivery costs when compared to traditional methods of delivery.

1 Helsingin kaupunki 2016

From the consumer's perspective, the **increase in product variety would be** noteworthy. Drone delivery would not only benefit consumers in urban areas and the suburbs, but also those consumers living further from commercial centres in rural and remote locations. Depending on the circumstances, consumers in rural and remote locations would be able to benefit from instant and same-day deliveries, takeaway delivery and even an increase in access to the delivery of household items such as groceries, healthcare products and other essentials.

Benefits for society

Road congestion in Helsinki has an adverse impact on overall quality of life and produces greenhouse gases. Delivery vehicles are responsible for approximately three per cent of total kilometres travelled in Helsinki[2]. When conventional deliveries are combined with consumer pickups, the levels of congestion are exacerbated. Drones have the capability to reduce greenhouse gases in Helsinki by 2,000t CO2 as early as 2030 by replacing certain road deliveries and consumer pickups. Such a transition from ground deliveries and pickups to drone delivery would support the Finnish Government's ambitious 2045 carbon-free transport strategy, which aims to drastically reduce the number of combustion engine vehicles in Finland, while increasing the proportion of cars and vans that are recharged or refuelled with emission-free electricity or biogas by 2030[3]. The overall reduction in greenhouse gas emissions as a result of this strategy is equivalent to almost **350,000 electric sauna heating sessions**[4] or an estimated annual **carbon sink of about 250 hectares of forest**.

Unfortunately, there is a direct correlation between increased traffic and traffic accidents. While not all accidents are registered, it is estimated that 7,000-10,000 traffic accidents took place in Helsinki in 2018[5]. As drones would contribute to the **reduction of travelled kilometres related to deliveries and pickups, Helsinki should see an overall reduction in the amount of automotive accidents resulting in injuries or death.**

2 Urban Transport Group (2018): Questions, Challenges And Options On The Growth Of Urban Van Traffic
3 Toimenpideohjelma hiilettömään liikenteeseen 2045
4 OpenCO2.net -CO2-muunnin
5 Liikenneonnettomuusrekisteri Helsinki

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1. Introduction

1.1 Background and objectives

The use of drones has become more common in recent years for both non-commercial and commercial purposes. Various estimates have been made of the commercial potential of unmanned drones and, for example, in package deliveries, the drone market is projected to grow at an annual rate of 44.7% and could reach more than $27 billion globally by 2030[6].

In addition, the ongoing COVID-19 pandemic at the time of writing is an indication that there would be a demand for drone deliveries in exceptional circumstances. Grocery, retail and home delivery operators have reported an increase in e-commerce orders, congestion in services and an increase in home deliveries[7] [8]. The growth leap in e-commerce and home deliveries seen in 2020 has not been taken into account as such in the forecasts made in this report, as it is too early to assess the long-term effects of the pandemic on the market. If the trend in consumer behavior brought about by the pandemic envisages a more permanent change, drone deliveries are well placed to become even more widespread than anticipated in this work, if given the opportunity.

The technology allows for a fairly diverse use of drones, but there are still regulatory differences between countries. However, it is to be expected that regulation will be harmonized [9] and will also allow for the versatile use of drones. In Finland, regulation has also been seen to be quite flexible from an international perspective [10]. This makes Finland a particularly interesting test market for drone deliveries. In recent years, there have been several short and longer-lasting drone trials in Finland, especially in the Helsinki metropolitan area.[11] [12] [13]

The aim of this work was to identify the potential for drone deliveries in Helsinki in 2030 and thereby stimulate discussions on the wider use of drones. The benefits were assessed from the perspective of businesses, consumers and society for the product categories selected for review. A better overall understanding of the potential of drones to replace traditional forms of delivery and takeout, create new business and increase consumer choice, allows for a multi-stakeholder dialog with decision-makers.

1.2 Limitations and methods

The key starting points of the work were to limit the review geographically. As a large and sparsely populated country, Finland offers many potential targets for the utilization of drone deliveries, but in this work, the review focused on the Helsinki metropolitan area and, still further, on Helsinki. A drone's operating radius from the center of Helsinki covers almost the whole of Helsinki. Of course, this would also include parts of Espoo and Vantaa, but for the sake of clarity these were mainly excluded from the review. However, it is likely that in the future, the drone network will cover almost the entire metropolitan area.

The prerequisites for drone deliveries to replace traditional delivery and takeout methods in Helsinki in 2030 were assessed by a scenario review. The purpose of the scenario review was to form an idea of the extent to which deliveries

6 Drone Package Delivery Market
7 Korona räjäytti ruoan verkkokaupan: Jos nyt suunnittelet tilaavasi ostoskassit kotiin lähipäiviksi, olet todennäköisesti myöhässä
8 Postin pakettien kotiinkuljetukset moninkertaistuivat koronaepidemian vuoksi
9 EU dronesäännöt
10 Ilmailun tulevaisuus: Kuljetetaanko lentorahtia tai ihmisiä tulevaisuudessa droneilla?
11 Posti kokeilee robottikopterin käyttöä verkkokauppatoimituksiin
12 Droonit kuljettavat paketteja Aviapoliksessa – ”Ainutlaatuinen pilotti jopa Euroopassa”
13 Wing lennättää ruokapakkauksia droneilla Vuosaaressa jo ensi kuussa – Drone-kuljetuksista tulossa iso bisnes

could be replaced by drones in Helsinki in 2030. The review focused on product categories relevant from the perspective of drone deliveries: takeout food, grocery purchases, pharmacy purchases, and purchases of household goods.

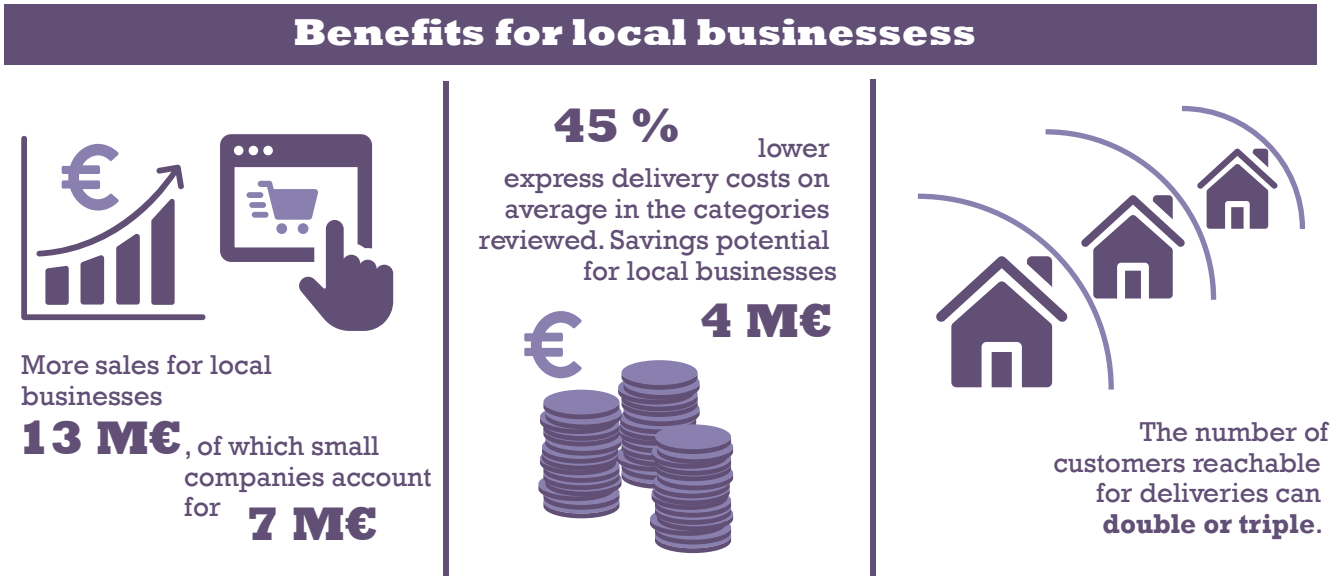
Scenarios were derived from the categories, which took into account the consumer's distance from the place of purchase, the weight of the purchase, the mode of transport used by the consumer and the urgency of delivery. With the development of battery technology, the maximum operating radius of a drone, i.e. delivery range, can be expected to increase over the years, but in this work it was assumed to be 10 kilometers. The maximum weight of purchases to be delivered was assumed to be 1.5 kg.

Based on the above assumptions, an estimate was made of the potential for drones, in 2030, to replace traditional deliveries and consumer takeouts in different product categories and as a whole. The drone potential varies by product category (takeout food 14%, grocery purchases 2%, pharmacy purchases 13% and household goods purchases 9%), but the average replacement potential is approximately 6% of all deliveries[14]. On the basis of this assessment, it was possible to estimate the benefits in euros for businesses, consumers and society.

The scenarios for 2030 and the results of the assessment are based on the forecasts and assumptions that are described in more detail in Chapter 5. The work was carried out in Spring 2020, but the plausibility of the drone scenario as well as other assumptions has been re-examined before the release of the results in spring 2021. However, most data sources have not been updated after spring 2020, because the factors affecting the outlook for 2030 are not considered to have changed radically during the year. The COVID-19 pandemic was deliberately ignored in the development of scenarios because it is too early to predict the persistence of the e-commerce trend caused by the state of emergency. The work also does not take into account the influence of external factors such as legislation. However, these factors may have implications for the potential and general use of drones, especially in the early stages.

14 The evaluation of drone potential is described in more detail in Section 5.1.

2. Benefits for local businesses



2.1 Market expansion

The delivery radius of restaurants located in the center of Helsinki for takeout food orders using food courier services is currently about five kilometers. For longer delivery distances, the costs would be so high that the consumer would not be willing to pay for them. Wolt, which offers food delivery from its partner restaurants, charges an additional fee to consumers for every commenced 500 meters for delivery distances that exceed 1.5 km[15]. Delivery times would also increase with distance, which has a negative effect, especially on the freshness of the food being delivered.

In 2030, however, drones will be able to deliver orders cost-effectively and quickly up to distances of 10 kilometers. As the drone station network develops, drones can serve people living even further away from the center of Helsinki, if the drone delivers the transported package to the next drone when it reaches the boundary of its delivery radius. In addition, delivery times would also be shorter for deliveries close by, due to the high flight speed of drones and avoidance of congestion (for more details, see Chapter 4, Benefits for Consumers).

One of the main benefits of drone deliveries is the expansion of the market area with the increase in size of the delivery area. According to the population forecast, in 2030, 724,000 people will live in Helsinki and 1.3 million people in the entire Helsinki metropolitan area[16]. Based on the current population density and average household size, in 2030, within a radius of 10 kilometers from the center of Helsinki, there will be 160,000 more households than within a radius of 5 kilometeres.[17] [18] When the review is extended to the Helsinki area, in 2030, thanks to a wide radius and network, drones will be able to reach 250,000 more households than would make economic sense without drones. As the survey area is further expanded to the Helsinki metropolitan area level, the number of new households that can be reached will increase to as many as 570,000 new households.

15 Wolt: Usein kysytyt kysymykset – Kotiinkuljetus & takeway
16 Tilastokeskuksen PxWeb-tietokannat
17 Helsinki on Tukholmaan, Kööpenhaminaan ja Osloon verrattuna tuppukylä
18 Asuntokuntien määrä ja tyyppi

2.2 Reduction of delivery costs

Because home delivery is expensive and most of the cost of the last kilometer is currently borne by consumers when they pick up their purchases themselves, it may not necessarily be profitable for businesses to provide home delivery at all. Indeed, home deliveries or their outsourcing to transport service providers may cost companies more than the additional sales generated. At a minimum, a significant portion of the additional sales will flow into transportation costs.

With drone deliveries, the cost of home delivery to businesses would be significantly reduced. This is largely due to the labor intensity of traditional modes of transport and the resulting labor costs, which are significantly lower for drones. In particular, for orders requiring immediate delivery, such as takeout food, the reduction in costs would be significant. Drone deliveries would guarantee both better margins on additional sales and would also allow entirely new companies to provide home delivery.

Compared to traditional modes of transport, for drone deliveries, the benefits of lower costs have been assumed to accrue directly to businesses and consumers. The cost savings are assumed to be distributed 50% in favor of the seller as a higher margin on the product and 50% in favor of the consumer in the form of a lower price for the final product. The calculation assumes that the transport service provider's margin remains the same regardless of the mode of transport. Therefore, the cost benefit of drone delivery to both the seller and the consumer is 45% for express deliveries and 32% for same-day deliveries, while the overall cost of drone delivery is about 90% lower for express deliveries and 64% lower for same-day deliveries. In total, businesses can, therefore, save about EUR 4 million in transport costs for home deliveries in 2030, with deliveries covering the whole of Helsinki.

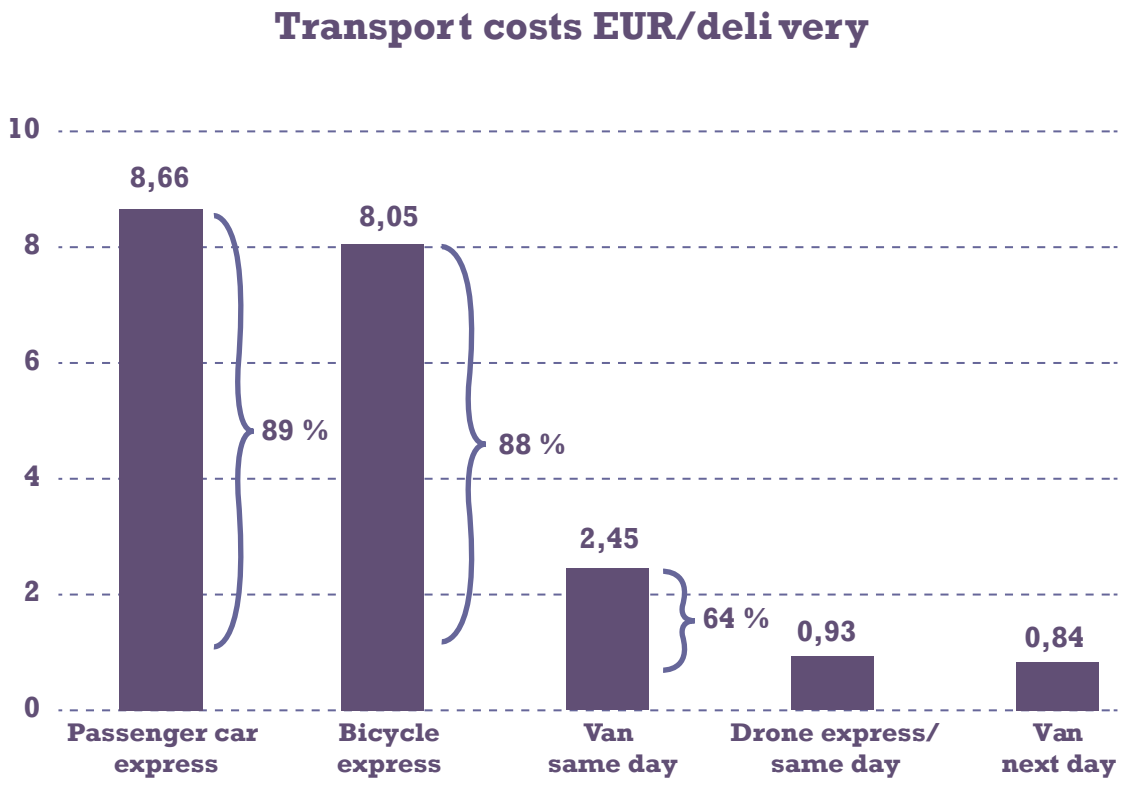


Figure 1. Absolute transport cost in euros per delivery and percentage difference compared to drone delivery.

The calculated delivery costs for different modes of transport and the cost difference compared to drone delivery are shown in Figure 1. Express delivery means delivery by courier immediately and delivery by van on the same or the next day as part of a distribution route. With regard to modes of transport, the calculation assumes that in Finland 80% of express deliveries are made by car and 20% by bicycle[19] and same-day deliveries are made 100% by van (cf. Postal delivery vans and K-ruoka e-commerce vans).

2.3 Increase in sales

Home deliveries made possible by drones will save consumers time and effort as well as money, especially if the alternative is to pick up purchased products. As a result, at least part of the increased available time and money can be expected to be channeled into additional consumption. Consumers will not only be able to buy more, but also more valuable products.

The scenarios estimate that the average purchase price for each category of product based on the total value of sales and the number of transactions will be 14-38 euros depending on the product category and the average transport cost from the calculation of transport costs. From the consumer's point of view, the total price of the average delivered purchase will be reduced by 11% due to the lower delivery fee for drone delivery. Consumer price elasticity for the product categories studied here averages -0,60[20],which means that when the price of a product falls by 11%, demand rises by 6%.

The value of additional sales in Helsinki caused by lower prices has been calculated by multiplying the percentage increase in demand by the euro-denominated drone potential in 2030 in all product categories. Increased sales of takeout food, food and groceries, as well as over-the-counter medicines and self-care products would, therefore, be estimated to be EUR 13 million per year for businesses in Helsinki. Of the increased sales, EUR 7 million would be channeled to small businesses, assuming that their 54% share of total sales in Helsinki would remain unchanged[21]. However, it should be borne in mind that low-cost and fast home deliveries, as well as increased choice, may also attract completely new consumers to order online.

2.4 Enabling deliveries for new businesses

As noted above, the affordability of drone deliveries would also allow more companies to offer home deliveries. In particular, restaurants and small and specialist shops that attract a limited audience would have the opportunity to expand their customer base and reach potential customers further away with home deliveries. This would also benefit consumers as choice increases.

For the trade and restaurant industry, location has traditionally been a key factor. With e-commerce, the importance of location for specialty goods has already diminished. Thanks to drone deliveries, the location may also be less important for grocery and food stores as well as takeout restaurants. A physical location may not be needed at all, and drone deliveries can be made directly from wholesalers, warehouses, or even home kitchens. This lowers both start-up and operating costs and is, of course, also reflected in consumer prices. Although it is difficult to make accurate estimates of the opportunities for new companies with drone deliveries, drones are expected to have a significant positive impact on business opportunities for companies in Helsinki.

19 According to Wolt most of their deliveries use a car as means of transportation. In Finnish winter conditions, the share can be even higher than 80%
20 P.Soppi (2006) Elintarvikkeiden ja ravintolapalveluiden kysyntä Suomessa. Pellervon taloudellinen turkimuslaitos.
21 Elinkeinot ja työmarkkinat Helsingissä 2020

3. Benefits for consumers

Benefits for consumers

Time savings for consumers per year from avoiding pick-up trips

1.5 million hours,

comparable to **40 M€** monetary savings.

55 %
Faster deliveries by drone.

Savings for consumers from lower delivery costs per year

4 M€

Savings on express deliveries as much as **45 %**

More choice and better selection for consumers: as many as

3-8 times

more companies within delivery range.

3.1 Reaching the most vulnerable

In Helsinki, help is needed in everyday activities by 27% of those over 65[22] and the percentage of older people in the population is growing. In 2025, it is forecast that 124,000 people over the age of 65 will live in Helsinki, and if the trend continues, by 2030, 136,000 people aged 65 and over will already live in Helsinki. An estimated 37,000 of them will need help with shopping and other transactions. The home delivery of food and groceries by drones would help those people especially who have limited opportunities for getting about and looking after errands outside the home. It would also be easier to order directly to their homes special goods that are not available from convenience stores. In 2030, elderly urban dwellers are likely to be, on average, more accustomed to using smartphones and e-commerce, so placing orders will pose fewer challenges than at present.

In addition, an exceptional situation such as the COVID-19 pandemic at the time of writing has shown that drone deliveries could significantly assist the daily life of at-risk populations, such as the elderly and those suffering from underlying diseases. Access to food and groceries, but also medicines, would be facilitated. The ordering of medicines online has increased with the pandemic and, during the state of emergency, pharmacies are obliged to arrange home delivery of medicines where possible[23]. With the help of drones, deliveries could be offered quickly and more cheaply. In the future, home transport with drones would make it possible to remain protected indoors without the risk of being exposed to pathogens that threaten health and life, even during, for example, the influenza or seasonal flu period.

3.2 Time saving

Drone deliveries are considerably faster than other modes of transport, as the drone has a maximum flight speed of as much as 120 km/h and the drone accelerates to cruising speed almost immediately. Compared to home transportation by car or bicycle, drone delivery is 35-75% faster, depending on the mode of transportation and distance. The difference in favor of the drone is greater the longer the delivery.

22 Helsingin kaupunki 2016
23 Korona siirtää apteekkiasiointia verkkoon – lääkkeiden kotiinkuljetukseen liittyy vielä haasteita

Table 1. Time saving for different delivery distances.

Home delivery 2 km	Elapsed time (one way)	Time saving due to drone	Time savings in %
Car (41 km/h)	5 min	2 min	35 %
Bicycle (20 km/h)*	8 min	5 min	60 %
Home delivery 5 km	**Elapsed time (one way)**	**Time saving due to drone**	**Time savings in %**
Car	9 min	4 min	46 %
Bicycle	17 min	12 min	71 %
Home delivery 10 km	**Elapsed time (in one direction)**	**Time saving due to drone**	**Time savings in %**
Car	17 min	9 min	52 %
Bicycle	32 min	24 min	75 %

*Tilastokeskus 2017

Table 1 shows a comparison of how much drones save time for express deliveries on delivery distances of different lengths compared to traditional means of transport. The two minutes it takes to pick up and leave the product are included in both traditional deliveries and drone deliveries. Assuming 80% of deliveries are made by car and 20% by bicycle, the average time saving is 54%. In terms of time savings, only express deliveries and consumer pick-ups have been considered, as time savings are not considered to be of great importance for same-day or next-day deliveries.

Picking up orders is time consuming and time costs are currently largely borne by consumers and households. If drone deliveries were to replace 6% of the pick-up journeys made by Helsinki consumers in 2030, or 5.6 million journeys[24], the time savings would be about 1.5 million hours or 62,000 days per year. Converted into euros, this means a saving of EUR 40 million for consumers, calculated on the average earnings in Helsinki.[25]

3.3 Reduction in delivery charges

Taking into account the total number of purchases ordered by consumers and the cost of deliveries, consumers in Helsinki will spend an estimated EUR 37 million a year on home deliveries in 2030, or about one hundred euros per household. As the cost of drone deliveries for home delivery is significantly lower than traditional modes of transport, the savings for the companies providing the deliveries will also be visible to consumers.

The calculation principle for delivery costs is described in Section 5.3. Section 2.2 explains in more detail how the benefit of lower costs compared to traditional modes of transport for drone deliveries is divided in the calculation equally between the seller and the consumer of the final product. Therefore, the cost benefit of drone delivery to both the seller and the consumer is 45% for express deliveries, such as takeout food, and 32% for same-day deliveries. For example, in terms of takeout food delivery fees, the savings for consumers in 2030 could be as much as 45% when using drones. In 2030, total savings due to drone deliveries to Helsinki households, it would be the

24 The calculation takes into account the estimated monetary consumption for purchases in Helsinki in 2030 and the assumption of the average one-time purchase price in different product categories. In addition, the assumption as to how many consumers will pick up their purchases in 2030 has also been taken into account and it is estimated how many of these could be delivered by drone.
25 Tilastokeskus 2017, corrected to the wage level in 2030 according to the GDP forecast

same as for companies, i.e. an estimated EUR 4 million.

3.4 Increased choice

The choice in terms of restaurants as well as grocery and specialty stores will grow with drone deliveries. The biggest beneficiaries are consumers living far from commercial centers, especially from the center of Helsinki. Consumers who are difficult to reach by traditional modes of transport or otherwise by road, such as those living in the archipelago, will also benefit from the increased choice provided by drone deliveries.

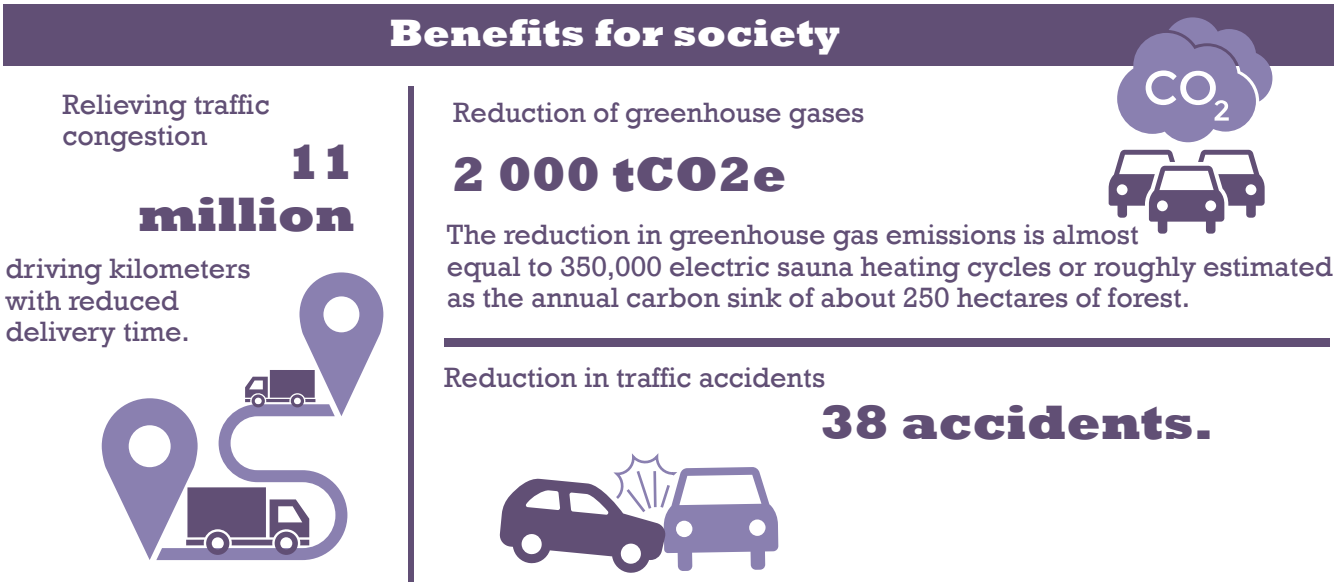
The increase in choice from the consumer's point of view has been calculated by comparing the selection of restaurants in the center of Helsinki and in different parts of the Helsinki metropolitan area on the basis of the Wolt, Foodora and TripAdvisor websites. Although the analysis in this work is limited to Helsinki, the 10-kilometer range of the drone from the center of Helsinki is sufficient to cover areas outside Helsinki as well. For example, a consumer living in Leppävaara, Espoo, who orders food at home through a food delivery service, has only about 1/3 of the restaurant offering available to those living in the center of Helsinki or in the immediate vicinity[26]. Thanks to drone deliveries, in 2030 a resident of Espoo could order food from the center of Helsinki at a reasonable cost. In this way, that person would have access to three times more restaurants and a more diverse offering than today. If the operating range of the drones were to be slightly extended, in 2030 it would be practically possible to order takeout food to Leppävaara from almost anywhere in Helsinki and Espoo. There are just over 200 restaurants in Espoo, while there are almost 1,500 in Helsinki[27]. If all Helsinki restaurants were available to a consumers in Leppävaara by drone delivery, the selection would be eight times greater than the offering just in Espoo.

If the review were extended to cover the entire Helsinki metropolitan area, the restaurant offering would increase 4-8 times for Tikkurila in Vantaa, assuming that a drone could deliver takeout food from the center of Helsinki. For Kivistö in Vantaa, the difference would be even greater, as Wolt and Foodora only deliver dishes from a few restaurants there. If we look purely at how many restaurants there are in the cities in the metropolitan area and assume that the restaurants would become available to all consumers thanks to drone deliveries, the selection of restaurants could even increase 9-fold.

Consumer choice will also increase for the range of products to be delivered by drone immediately or on the same day. In addition to takeout food, consumers could, for example, order missing raw materials or utensils for their kitchen in the middle of cooking or replace a new inner tube for a bicycle when suffering a flat tire on a bike ride. The limit is only the size of the products ordered, as long as the company supplying the products is located within the range of the drone.

26 Foodora, Wolt: restaurant searches made at different addresses in the center of Helsinki and Leppävaara, situation in Spring 2020
27 Restaurants recorded in TripAdvisor, situation in Spring 2020

4. Benefits to society



4.1 Reduction in congestion

In 2030, it is projected that 10,300 million kilometers per year will be driven in Uusimaa based on current developments,[28] 15% more than in 2020. About 30%of these driving kilometers are in the Helsinki area[29]. An estimated 3% of the driving kilometers[30] in Helsinki in 2030, or about 85 million kilometers, will be deliveries, i.e. including the delivery of online purchases to stores, pick-up points and consumers. This, combined with pick-up trips by consumers by car, is likely to exacerbate congestion in Helsinki.

However, drone deliveries could reduce the congestion caused by delivery traffic and consumer pick-up trips on the streets of Helsinki. An estimated 11 million kilometers of street travel could be avoided in 2030 by replacing 6% of delivery driving and consumer pick-ups with drone deliveries. This is a cautious, volume-weighted estimate of the potential of drones on average for different product categories.

Delivery distances have been taken into account so that a delivery distance of less than one kilometer is assumed to be 0.5 km on average, 1-5 km on average 2.5 km and 5-10 km on average 7.5 km. Public transport and cycling have not been considered to cause congestion, so replacement of these pick-up methods by drones has not been included in the calculation for reduction of congestion.

4.2 Reduction of greenhouse gas emissions

Drone deliveries would reduce deliveries and consumer pick-up trips and this would also reduce greenhouse gas emissions from driving. Emissions from a single drone delivery are significantly lower than from a passenger car or van delivery. For example, in a delivery of five kilometers, the GHG emissions per delivery are about 26g CO2e[31], for a drone, when the emissions from delivery by van are

28 Valtakunnallinen tieliikenne-ennuste 2030
29 Liikennetilastot Helsinki
30 Urban Transport Group (2018): *Questions, Challenges And Options On The Growth Of Urban Van Traffic*
31 J. K. Stolaroff et al. (2018). *Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery*. Nature Communications 9, 409.

about 960 g CO2e and for the return journey by car is about 1,440 g CO2e[32]. This is illustrated in Figure 2.

CO2 emissions are generated both in deliveries and when consumers pick up the products they buy themselves. The drone scenario provided an estimate of how much a drone would be able to replace delivery and pick-up trips made by car and van in 2030. The emission reduction has been calculated for express deliveries by car replaced by drone deliveries, same-day deliveries by van, and pick-up trips by consumers using a car and public transport. Cycling has not been considered to cause CO2 emissions. Emission reductions for other journeys have been calculated on a round trip basis, but for same-day deliveries made as part of a distribution route, only one-way mileage emissions have been calculated. Delivery distances are calculated as described in Section 4.1.

Drones have been calculated to fly in two directions with a load of 5 kg for a delivery, although in reality the return flight is likely to take place without cargo. This assumption compensates for the deficiency related to the flight speed of the drone used in the calculation. In reality, a drone flying at 100 km/h would consume more electricity than a drone flying at 36 km/h, the speed used to calculate energy consumption in this study. Emissions from the electricity used by drones have been calculated on the assumption that the emission factor for Finnish electricity production in 2030 is 37 kg CO2e/MWh[33]. The calculation of the drone's emission factor - as in the emission factors of other modes of transport - does not take into account the entire life cycle of the drone, but only the emissions during operation, i.e. the electricity used for charging.

Emission factors for cars, vans and public transport have been collected from the calculation system implemented and maintained by VTT (Technical Research Centre of Finland) for exhaust emissions and energy consumption in Finnish traffic (Lipasto)[34], but they have been modified for 2030,

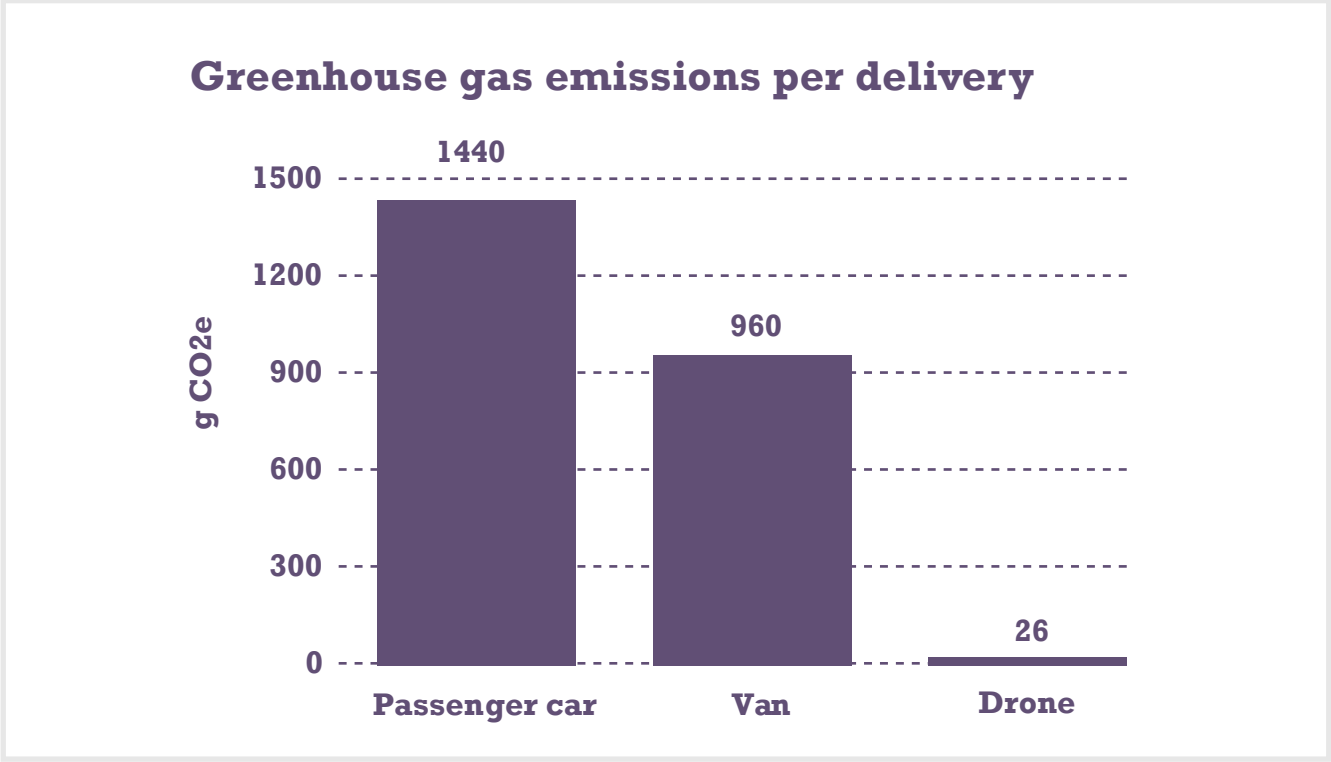


Figure 2. Greenhouse gas emissions from various forms of delivery and collection over a distance of five kilometers.

32 VTT Lipasto system
33 Modified estimate based on the Energy Industry Association's forecast
34 LIPASTO - Suomen liikenteen pakokaasupäästöjen ja energiankulutuksen laskentajärjestelmä

when most vehicles are likely to run on natural gas or zero-emission electricity. Helsinki's rail traffic already uses renewable energy today[35]. The drone emission factor is calculated according to the precautionary principle by default for a large drone carrying a 5 kg package with a battery weighing 10 kg, flying at an average speed of 36 km/h and consuming 0.25 MJ/km of energy. With current battery technology, therefore, the maximum flight radius of large drones for order delivery is only a few kilometers. On the other hand, with lighter drones (e.g. 5 kg) and smaller packages (e.g. 1.5 kg), the operating range can cover a distance of 10 km even with current battery technology.[36]

By replacing deliveries made by motor vehicles and consumer pick-ups, drones could reduce Helsinki's greenhouse gas emissions by an estimated 2,000 tCO2e in 2030. The reduction in greenhouse gas emissions corresponds to almost 350,000 electric sauna heating sessions or roughly an estimated annual carbon sink of about 250 hectares of forest. The estimate for carbon sequestration is based on the average number of hectares calculated according to different sources. Based on data from the Forest Research Institute on carbon sequestration and data from the Natural Resources Center on forest growth (0.1512 hectares of forest sequester 1 tCO2) it would require 302 hectares of forest for an annual carbon sequestration of 2,000 tCO2. Based on the research results of the University of Helsinki published in Helsingin Sanomat (a hectare of forest with its undergrowth sequesters approx. 10 tCO2/year), 200 hectares of forest would be required.[37]

Based on the target by the Finnish Ministry of Transport and Communications, the calculations assume that in 2030 less than a third of passenger cars and a fifth of vans will be powered by electricity or gas and charged with zero-emission electricity or biogas and that half of the bus traffic would be emission-free at that time.[3]
[31] If LVM' s [Finnish Ministry of Transport and Communications] target falls short, drones could reduce greenhouse gases even further.

4.3 Avoiding traffic accidents

In 2018, a total of 2020 traffic accidents were recorded in Helsinki,[4] of which 362 resulted in personal injuries. There were 14.7 personal injury accidents per 100 million vehicle kilometers. The traffic accident register covers only an estimated 20-30% of personal injuries, so a total of 7,000-10,000 accidents occurred in Helsinki. The calculation assumes that the same accident frequency will also apply in 2030.

According to forecasts, about 2,800 million kilometers a year will be driven in Helsinki by 2030[24]. Based on the drone scenarios, it is estimated that the need to drive could be reduced by approximately 11 million kilometers in Helsinki in 2030, i.e. avoiding an estimated seven personal injury accidents and a total of 38 traffic accidents per year. Trips by bicycle, on foot or by public transport are not included, as accident statistics do not include accident statistics for rail and light traffic.

While reducing personal injury is valuable and worthwhile in itself, it also has financial benefits. The cost of a single personal injury accident is roughly estimated at EUR 150,000,[38] so just by avoiding these there could be savings of approx. EUR 1 million per year.

35 HKL Ympäristöesite
36 J. K. Stolaroff et al. (2018). Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery. Nature Communications 9; 409.
37 Puun hiilenhimo mitattu nyt tarkasti: Suomalaisten päästöjen kuittaamiseksi tarvittaisiin miljardeja uusia puita
38 Liikenneonnettomuudet Helsingissä 2014–2016

5. Annexes - Description of methods

5.1 Basis of calculation

Setting the area boundary

The scope of this study is limited to 2030 Helsinki. Therefore, the results are not fully generalizable to the entire metropolitan area due to the underlying assumptions. However, on the basis of the population figures, it can be roughly estimated that the effects on the Helsinki Metropolitan Area would be about twice as great as in Helsinki.

The potential area for the use of drones is likely to expand in the future, and the evolving drone network will be able to serve residents throughout the Helsinki metropolitan area. Local drone outlets can be set up in different parts of the metropolitan area, allowing drones to be charged and packages transferred from one drone to another. The development of battery technology will also enable a wider operating range and longer deliveries.

The drone potential in 2030 building a descriptive scenario

The purpose of the scenario review was to form an idea of how much transport can be replaced by drones in Helsinki in 2030. Four potential retail categories for different drone deliveries were selected for review: takeout food, grocery purchases, pharmacy purchases, and household goods purchases. To estimate the size of the market in 2030, the OECD GDP forecast was used,[39] i.e. the value of retail sales in Helsinki in 2019 and the number of transactions for the categories examined were scaled to the future[40]. The parameters used in the calculation are mostly based on existing estimates, such as Statistics Finland's figures, or estimates that have been more loosely applied from other sources. However, for some parameters, assumptions had to be made due to lack of information. The sources and assumptions used are documented in more detail in Chapter 5.2 of the Annex.

For each category, four sub-scenarios were formed (Figure 2.) for 2030: a snapshot without drone deliveries (baseline scenario) and a snapshot in which drone deliveries have replaced a certain part of traditional pick-ups and deliveries (drone scenario). The review also distinguished between the purchases collected by consumers themselves and the purchases delivered, which together account for 100% of the category's transport. Other parameters considered in building the scenarios were the consumer's distance from the place of purchase, the weight of the purchase, the mode of transport used by the consumer and the urgency of delivery. All parameter combinations formed in the matrices were assigned a share of how many of them could be replaced by drones in 2030. When assessing the replacement potential of drones, their technical capacity was taken into account, on the basis of which delivery distances to a maximum of 10 kilometers and purchases weighing less than 1.5 kg were included in the calculations.

The outcome of the scenario review was to determine the shares of the drone potential for each product category in 2030 (as a percentage of the possibility for drones to replace traditional deliveries and consumer pick-ups). Approximately 14% of all pick-ups and deliveries in the takeout category would be possible with drones. The corresponding proportions were 2% for food purchases, 13% for pharmacy purchases and 9% for household goods. Given the size of sales volumes in the product categories, the average drone potential in 2030 in all categories was estimated to be approximately 6%. Finally, by

39 OECD 2020
40 The effect of inflation has not been taken into account in the calculations.

category the drone potential was related to the estimated value of sales in the Helsinki area in 2030 in euros and the number of transactions, on the basis of which the effects of drones on local companies, consumers and society have been assessed in this work.

Estimation of transport costs

One of the biggest benefits of drones over traditional modes of transportation is cost-effectiveness. Previous studies have estimated that express deliveries, especially by drone, can be 80-90% cheaper than deliveries by car, bicycle or other human-bound means[41,42].

In this study, the cost savings for drones have been compared separately for express deliveries by courier type by car or bicycle and deliveries as part of a distribution route by van. Traditional modes of transport are quite labor-intensive, while in drone deliveries the labor cost is very low, as one pilot can manage many drones at the same time with the help of automation[43]. Both companies selling products as well as consumers are expected to benefit from the reduction in absolute transport costs in the future. In the cost-benefit calculation made in this study the cost benefit is shared equally between businesses and consumers. The benefits and margins obtained by the transport company have not been considered.

Business As Usual scenario (BAU) 2030						Drone scenario 2030					
Pick-ups % of purchases		< 1 km	1-5 km	5-10 km	> 10 km	Potential to replace pick-ups, %		< 1 km	1-5 km	5-10 km	> 10 km
Small < 1,5 kg	Car					Small < 1,5 kg	Car				
	Public						Public				
	Bike / walk						Bike / walk				
Medium 1,5 - 5 kg	Car					Medium 1,5 - 5 kg	Car				
	Public						Public				
	Bike / walk						Bike / walk				
Large > 5 kg	Car					Large > 5 kg	Car				
	Public						Public				
	Bike / walk						Bike / walk				

Business As Usual scenario (BAU) 2030					Drone scenario 2030				
Deliveries % of purchases		Instant delivery	Same day	Standard	Potential to replace deliveries, %		Instant delivery	Same day	Standard
Small < 1,5 kg	< 1 km				Small < 1,5 kg	< 1 km			
	1-5 km					1-5 km			
	5-10 km					5-10 km			
	> 10km					> 10km			
Medium 1,5 - 5 kg	< 1 km				Medium 1,5 - 5 kg	< 1 km			
	1-5 km					1-5 km			
	5-10 km					5-10 km			
	> 10km					> 10km			
Large > 5 kg	< 1 km				Large > 5 kg	< 1 km			
	1-5 km					1-5 km			
	5-10 km					5-10 km			
	> 10km					> 10km			

Image 3. Model of product category-specific matrix.

41 BusinessInsider 2016
42 Sudbury, A. E. ja Hutchinson, E. B. (2016). A Cost Analysis Of Amazon Prime Air (Drone Delivery). Journal For Economic Educators, 16(1).
43 ARK Invest 2015

Evaluating the positive effects of drones

The impact assessment has compared the baseline and drone scenarios, i.e. how much savings and other positive effects can be achieved if drones deliver 6% of all purchases in Helsinki in 2030. The calculation of the effects has utilized more precise assumptions formed in the scenarios as to what kind of supplies can be replaced by drones. The scenario has, therefore, provided an estimate of, for example, how many delivery trips of more than five kilometers by private car could be replaced by a drone. Because the scenario has estimated that the drone potential is higher for longer pick-up distances, for example, the calculation of time-saving and CO2 emission reductions has taken into account that replacing longer pick-up distances saves more time and emissions.

When calculating the impact of drone deliveries on greenhouse gas emissions, it has been assumed that all pick-up trips made by the consumer are made specifically to pick up orders. The length of pick-up trips has been calculated as the crow flies for both the drone and other modes of transport, although in reality, for example, when picking up by car, the trip is probably clearly longer than it would be as the crow flies.

5.2 Description of background parameters to scenarios

Takeout

The starting point is information on the average amount of money spent by Finns on online food orders and deliveries per year[44]. In addition, it has been assumed that a household consumes the same amount of takeout food picked up from restaurants per year, with deliveries distributed equally, i.e. half being home deliveries and half being picked up by consumers themselves. Pick-ups are assumed to be distributed such that 60% of orders are picked up on foot or by bicycle and 40% by car[45]. When estimating the number of transactions, it has been assumed that an average of two portions are ordered at a time. The price of one serving is assumed to be 11 euros, which is the maximum value of the rounded tax benefit for a meal[46].

Food shopping

The annual food expenditure for a Helsinki household calculated by Statistics Finland has been used as a starting point[47]. The calculation uses statistics on the number of grocery store visits by the average Finn[48], on the basis of which the size of the average purchase has also been calculated. To assess the situation of grocery home purchases in 2030, the current state of one of Europe's leading e-commerce countries, the United Kingdom, has been taken as a yardstick.[49] According to the Helsinki Region Mobility Survey[50] consumer pick-ups are assumed to be distributed such that 20% of purchases are by car, 33% by public transport and 47% on foot or by bicycle.

Pharmacy purchases

In this work, pharmacy purchases are limited to over-the-counter medications, vitamins, and small medical supplies. Prescribed medications are not included in the review, as their annual transaction volumes and average prices are a challenge to estimate reliably. Data on household consumption expenditure are from Statistics Finland[51] and the number of transactions has been calculated by comparing data on average

44 Statista 2019
45 Unlike other product categories, it has been assumed that pick-up food is not picked up using public transport.
46 Ravintoetu 2020
47 Tilastokeskus
48 PTY, 2019
49 Brits spent £12,3 Billion on online groceries in 2018.
50 HSL 2019
51 Tilastokeskus

purchases[52] with the total annual amount of money spent by households. The share of e-commerce deliveries is estimated to grow in the same proportion by 2030 as grocery store purchases. The mode of collection for consumer pick-ups is assumed to be distributed, as described in the category "food purchases".

Household goods

The category includes e.g. annual household consumption of clothing, household goods, magazines and other printed matter, and household small items and tools. The annual monetary consumption of these per household is based on data from Statistics Finland[53]. The number of purchases of household goods has been assumed to be half of the number of purchases of food. The size of the average purchase in the category has also been calculated on this basis. The share of e-commerce deliveries is estimated to grow in the same proportion by 2030 as grocery store purchases. The mode of collection for consumer pick-ups is assumed to be distributed, as described in the category "food purchases".

Distances

For distances, the following breakdown have been done in the scenario:

- Less than 1 km
- 1-5 km
- 5-10 km
- more than 10 km

It is generally assumed that for the average Helsinki resident all services in the categories considered would be available within a maximum distance of 10 km, i.e. a possible drone delivery distance from their home. There are weighting differences between the different categories in the calculation. In the calculations, grocery stores and restaurants are assumed to be close to the majority of Helsinki residents, while pharmacies and shops selling household goods[54] are not assumed to be quite as frequent.

Urgency of delivery

Pick-ups by consumers themselves are all assumed to be immediate. Deliveries are, instead, divided on the basis of their urgency into immediate deliveries, same-day deliveries and standard deliveries. The proportions are assumptions and are based on estimates in another study on drones[55].

Delivery weight

Statistics on the weights of e-commerce deliveries have been applied to the distribution of package sizes[56] for household goods, while for other categories,sizes are assumptions. The packages are divided by size class according to weight as follows:

- packages less than 1.5 kg
- 1.5-5 kg packages
- packages of more than 5 kg

Delivery method distribution

Express deliveries are assumed to be roughly distributed, with 80% being made by car and 20% by bike. Same-day and next-day deliveries are assumed to be all delivered by van as part of the distribution route.

52 Harjunen, Päivi 2012
53 Tilastokeskus
54 The products in the household goods category are nevertheless those that can be bought in supermarkets and not just in specialty stores.
55 AlphaBeta 2018
56 IPC Shopper Survey 2018

Distribution of pickups and deliveries

Pick-ups refer to the collection of orders made by consumers themselves, in deliveries, orders are delivered to directly to the customer's home. In the case of e-commerce purchases, the products are often delivered to pick-up points or boxes at the post office, etc. The product's logistics chain from the store to the customer, therefore, also requires a pick-up operation by the customer. A portion of e-commerce deliveries are classified as pick-ups by consumers themselves.

Pick-ups by consumers themselves are divided according to mode of transport by car, public transport or on foot/by bicycle. Information on the primary modes of transport used by Helsinki residents is used to estimate the percentage[44] and the percentages have been further defined for each product category.

Estimates of the potential of drones to replace traditional deliveries

The potential of drones refers to their estimated potential to replace existing modes of transport. No differences have been made between the potential of the product categories in the scenario work, but it has been estimated that, for example, pick-up food transport and pharmacy e-commerce delivery have the same potential to be replaced by drone delivery when other conditions are the same. In terms of the distance between the consumer and the place of purchase, deliveries of 1-10 km have been identified as having the most potential. Deliveries of less than 1 km also have potential, but it is lower due to the ease and speed of collection by the customer. Although the maximum radius of drone deliveries has been assumed in this study to be 10 km, thanks to advanced battery technology, deliveries of more than 10 km are also realistic in the future. A denser drone network may also allow for longer range, even if battery life is not sufficient for direct delivery flights.

Immediate deliveries have been estimated to have a higher potential than same-day deliveries and the drone potential was estimated to be only for packages weighing up to 1.5 kg. The potential for drones to be a substitute for deliveries and pickups has been estimated to be the same. Also, the difference in potential between modes of transport has, in the main, not been assessed in this work, i.e., replacing pharmacy purchases made by the consumer using a car, public transport or bicycle with a drone, for example, is seen as equally possible. The exception is takeout food, which is estimated to not be picked up by public transport at all.

5.3 Reduction in transportation costs

Transportation costs have been calculated as the absolute marginal costs from the perspective of the delivery company. Costs include labor, fuel and depreciation costs, but not the delivery company's margin. The calculation is based on estimates of the costs of different modes of transport made in previous studies[36,37,57,58] which have been adjusted to correspond to the Finnish cost level by making an assumption about the cost structure and cost types adjusted to Finnish price levels. Adjustments have been made for differences in cost levels between countries for fuel and electricity used by the drone, as well as labor costs. In general, the costs of fuel and electricity are higher in Finland and labor costs lower than in the reference countries (USA and Australia).

The cost of bicycle delivery has been assumed to consist practically solely of labor costs. Instead, the cost structure of delivery by car or van is assumed to be as follows:[59]

57 AlphaBeta (2018). *Faster, Greener And Less Expensive The Potential Impact Of Delivery Drones In The Australian Capital Territory*
58 Capgemini 2019
59 Choe, T. et al. (2013). The future of freight. How new technology and new thinking can transform how goods are moved. Deloitte Review 22.

- Work 39%
- Fuel 25%
- Other costs 36%

The price level of drone deliveries has been calculated for Finnish conditions by utilizing a study conducted in the USA[60], which has estimated the cost structure of drone deliveries. More than half the costs consist of the physical parts of the drone, and their price level in Finland is assumed to be similar to that in the USA. In the USA, only 2% of the cost of drone deliveries is estimated to be labor costs and 26% is the result of charging the drone with electricity. These costs have been scaled to Finnish cost levels, assuming that in Finland labor costs are 66% of the US level[61] and that the price of electricity is 131% of the US level[62]. The remaining costs are various license fees, insurance and IT-related expenses, which account for a small percentage of the total and are assumed to be the same in Finland as in the USA. Deliveries on the next day or later are excluded from being consideration potential for drones, as they can be made more cost-effectively by van as part of an optimized distribution route.

60 D. Jenkins et al. (2017) Forecast of the Commercial UAS Package Delivery Market
61 Eurostat 2019, U.S. Bureau Of Labor Statistics 2019
62 Statista 2018

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