A SURVEY OF DEMAND AND BUSINESS POTENTIAL OF DRONE APPLICATIONS THAT ADVANCE CARBON NEUTRALITY IN SOUTHERN FINLAND

Master's Thesis
Anette Nikola
Aalto University School of Business
Information and Service Management
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Aalto University
School of Business

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Author Anette Nikola	
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Abstract

Global climate change drives the aims of some countries, cities, and organizations to become carbon neutral. The possibility to use electric drones to replace the use of combustion engine vehicles in specific use cases offers a promising approach to reducing carbon emissions. This research surveys which drone applications contribute to advancing carbon neutrality in Southern Finland and have current demand or business potential. This research was conducted as semi-structured interviews to gain a deeper understanding of the drone applications in Southern Finland, their contribution to advancing carbon neutrality, and challenges and enablers related to these drone applications. Drone applications in this research are divided into current applications and potential applications. The future use of potential drone applications can be dependent on the technological development of drones and related analytics tools, sensors, and cameras and their costs. Potential future drone applications can also be dependent on the regulation and the development of common airspace that connects unmanned and manned aviation at the EU level, as well as from the public acceptance.

This research suggests that possibilities to advance carbon neutrality with drone applications in Southern Finland come from reducing the need of people to transport and from having better source information for decisions related to the use and allocation of materials, vehicles, and work efforts. This research suggests that in the field of construction, there are various currently used drone applications. Many of these applications contribute to advancing carbon neutrality. There is also potential for future applications that could contribute to advancing carbon neutrality. In the field of agriculture, drone applications are not currently widely used. This research suggests that several potential drone applications could be used in advancing carbon neutrality in the field of agriculture.

In the field of logistics, drone applications are not currently widely used. This research suggests that logistics is one of the most challenging drone application areas, but there are potential future applications that could contribute to advancing carbon neutrality. This research suggests that there are not many current drone applications in the field of surveillance that would contribute to advancing carbon neutrality. However, it is suggested that surveillance is one of the application fields where potential applications can become widely used in the nearby future. Surveillance applications include several drone applications that contribute to advancing carbon neutrality. Similarly in the field of private security, the potential drone applications can enable contributions to advancing carbon neutrality in the nearby future. In the field of forestry management, only few current or future applications of drones were identified to advance carbon neutrality.

Keywords Drone, Unmanned Aerial Vehicle, UAV, Carbon neutrality, Sustainability

Aalto-yliopisto
Kauppakorkeakoulu

Aalto-yliopisto, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

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Tiivistelmä

Ilmastonmuutoksen vuoksi monet valtiot, kaupungit ja organisaatiot tavoittelevat hiilineutraalisuuta. Sähkökäyttöiset dronet tarjoavat mahdollisuuden korvata polttomoottorikäyttöisten laitteiden käyttöä tietyissä konteksteissa, mikä edistää hiilidioksidipäästöjen vähentämistä. Tässä tutkimuksessa tutkittiin vähähiilisyyttä edistäviä dronepalveluratkaisuja, joille on kysyntää tai liiketoimintapotentiaalia Etelä-Suomessa. Tutkimus toteutettiin puolistrukturoitujen haastattelujen kautta, mikä mahdollisti syvemmän ymmärryksen dronesovellusten hyödyntämisestä Etelä-Suomessa, dronesovellusten vähähiilisyysvaikutuksista, sekä haasteista ja mahdollisuuksista liittyen näihin sovellutuksiin. Tässä tutkimuksessa dronejen sovelluskohteet on jaoteltu nykyisiin sovelluskohteisiin ja potentiaalisiin tuleviin sovelluskohteisiin. Potentiaaliset tulevat sovelluskohteet voivat olla riippuvaisia droneteknologian ja sovelluksiin liittyvien analytiikan, kameroiden ja sensoriikan kehityksestä ja näiden kustannuksista. Lisäksi potentiaaliset tulevat sovelluskohteet voivat olla riippuvaisia yleisön hyväksynnästä droneille, regulaatiosta ja miehittämättömän ja miehitetyn ilmailun yhteisen ilmatilan kehityksestä.

Tämän tutkimuksen perusteella vähähiilisyyden edistäminen dronesovellusten avulla Etelä-Suomessa muodostuu mahdollisuudesta vähentää ihmisten liikkumista ja siitä, että saadaan paremmat lähtötiedot materiaaleihin, ajoneuvojen käyttöön ja työhön liittyviin päätöksiin. Rakennusteollisuudessa droneja sovelletaan, ja tältä alalta löytyy sovelluskohteita, jotka edistävät vähähiilisyyttä. Rakennusalalta löytyy myös potentiaalisia tulevia sovelluskohteita, joiden avulla pystytään edistämään vähähiilisyyttä. Droneja ei sovelleta laajasti maataloudessa, mutta tältä alalta löytyy potentiaalisia tulevia sovelluskohteita, joiden avulla vähähiilisyyttä pystyttäisiin edistämään.

Dronesovelluksia ei ole laajasti käytössä logistiikan alalla ja tämä ala koetaan haastavaksi. Logistiikan alalla on tunnistettu potentiaalisia tulevia sovellutuksia, joiden avulla vähähiilisyyttä pystyttäisiin edistämään. Valvonnan alalla ei nähdä olevan useita dronesovelluksia, joiden avulla pystyttäisiin nykyisin edistämään vähähiilisyyttä. Valvonnan nähdään olevan sovellusalue, joka voi yleistyä lähitulevaisuudessa. Tältä sovellusalueelta löytyy useita potentiaalisia tulevia dronesovellutuksia, jotka edistävät vähähiilisyyttä. Vastaavasti myös yksityisen vartioinnin puolella mahdolliset vähähiilisyyttä edistävät sovelluskohteet liittyvät potentiaalisiin tuleviin sovelluskohteisiin. Metsätaloudessa nykyisistä dronesovellutuksista ja potentiaalista tuleviesta dronesovellutuksista vain muutamalla on linkki vähähiilisyyden edistämiseen.

Avainsanat Drone, Unmanned Aerial Vehicle, UAV, Carbon neutrality, Sustainability

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1 Introduction

This chapter introduces the background and motivation for this research, the research objectives, and the research question, as well as the scope and structure of this research.

1.1 Background and motivation

The drone market globally is growing at a high speed. Regulators are working actively in evaluating and creating the necessary regulations for drone operations. Views about the potential of drones vary and the most optimistic scenarios estimate that drone technology will become disruptive to our societies when autonomous flights can be widely applied.

Drones have been found to have various use cases in industries such as infrastructure, agriculture, transportation, surveillance, media and entertainment, insurance, telecommunications, mining, forestry management, and environmental research (PwC 2016; EGNSS 2020: Goldman Sachs Research, n.d.). The drone market in Southern Finland is emerging and has not yet been widely researched, even though thesis projects from Universities of Applied Sciences have covered specific areas of drone applications.

Reducing carbon emissions is receiving more attention as countries, cities, and organizations are evaluating their current actions and planning their future ways of operating. Drones powered with low-carbon energy sources such as electricity can be used to conduct tasks in ways that reduce carbon emissions. This research aims to identify demand and business opportunities in Southern Finland for drone-powered services that contribute to reducing carbon emissions.

1.2 Research objectives and research question

This research is part of *Carbon neutral drone service solutions in the Southern Finland* project. The aim of the project is to pilot and promote carbon-neutral and emission-free drone services for the purposes of logistics, remote security, and environmental control, and to develop new forms of business to replace combustion engine forms of mobility and transportation. Partners in the project are Forum Virium Helsinki, South-Eastern Finland University of Applied Sciences (XAMK), and Posintra Oy.

The project is funded by the European Regional Development Fund and it is part of a drone service development project family, which consists of three projects. Even though this research is conducted for the project, the research itself has not been funded by and the research represents an independent deliverable of the project. The research provides information for the project about promising applications which can be found to advance carbon neutrality. The research question of this study is: *What kind of demand and business opportunities there are in Southern Finland for drone-powered solutions that advance carbon neutrality?*

To understand the existing demand and business opportunities, it is necessary to first understand the current limitations and possibilities of drones. It is also important to understand in which applications and industries drones have been found useful globally. With this basic understanding, demand, and business opportunities of drone applications in Southern Finland can be further researched by conducting interviews for drone service providers, subject matter experts, and customers and potential users of drones and drone services.

To survey which applications have existing demand or business potential and advance carbon neutrality, an overall view on the applications in the drone market in Southern Finland is created. By understanding the wide range of applications, the ones that contribute to reducing carbon emissions can be narrowed down and further researched. The survey can benefit drone operators and potential customers for drone-powered solutions in Finland, as it describes the industries and applications that have either existing demand or potential business opportunities.

1.3 Scope of research

Empirical research is scoped geographically to drone applications that can advance carbon neutrality in Southern Finland. This geographical scoping is in line with the project's target area. This research does not discuss other unmanned vehicles than unmanned aerial vehicles. This research discusses applications that are currently feasible or could become feasible in nearby future. This time-related restriction aims to ensure that the findings do not include use cases that would be fetched from too far from the future. This research is scoped to survey demand and business opportunities only in the commercial segment, not in military or consumer segments. In this thesis, commercial segment refers to businesses and civil governments and consumer segment refers to B2C market such as hobbyists. This view is adopted from Goldman Sachs Research (n.d.).

1.4 Structure of the thesis

This research is divided into five parts. The first chapter introduced the research. The second chapter provides a view into earlier research in carbon-neutrality, drone-powered solutions in different industries, and business models and value proposition design. At the end of the second chapter, the theoretical framework of this study is introduced. The third chapter describes the research methodology. The fourth chapter introduces the findings of the research. Current applications and applications that raise interest are categorized by industry. The fifth chapter concludes the research and describes implications to research and practice, as well as limitations of the study.

2 Literature review

This chapter discusses the findings from the literature related to carbon neutrality and commercial applications of drones. Also, literature related to business models and value proposition design is discussed and the theoretical framework used in this research is represented.

2.1 Carbon Neutrality

2.1.1 Definition of carbon neutrality

Capros *et al.* (2019) describe that climate neutrality, greenhouse gas neutrality, and carbon neutrality are commonly used terms in addressing environmental effects. Differences within the terminology are described by Capros *et al.* (2019) in the following way. *Climate neutrality* refers to the net phase-out of all greenhouse gas emissions. *Greenhouse gas neutrality* refers similarly to the net phase-out. However, the term is more specific than *climate neutrality*. *Climate neutrality* and *greenhouse gas neutrality* consider not only CO2 (carbon dioxide) emissions but also emissions related to energy, industrial processes, and non-CO2 emissions. *Carbon neutrality* refers to the net phase-out of CO2 emissions. (Capros *et al.,* 2019)
In the empirical part of this research, carbon neutrality of services and potential applications is evaluated. CO2 emissions are referred to as carbon emissions. With some applications, the discussion of carbon neutrality is replaced by discussing the reductions of carbon emissions.

2.1.2 Ways to advance decarbonization at EU level

EU's greenhouse gas neutrality targets and ways to advance reaching them are discussed in this research to provide the reader an understanding about the magnitude of change that is required to achieve greenhouse gas neutrality. As explained earlier, greenhouse gas neutrality is a wider concept than carbon neutrality.

Current ways of operating are set to lead to 4.2 Celsius of warming globally (with an estimated range from 2.5 Celsius to 5.5. Celsius) by 2100 (Hickel & Kallis, 2020). With Nationally Determined Contributions and Intended Nationally Determined Contributions under Paris Agreement, the warming is estimated to reach 3.3 Celsius (with an estimated range from from 1.9 Celsius to 4.4 Celsius) by 2100 (Hickel & Kallis, 2020). EU is committed to reducing greenhouse gas by at least 80% by 2050 (Capros *et al*., 2019). In the

Paris agreement, the target levels are higher than that, as it is stated that best efforts should be taken to limit the global temperature rise to 1.5 (Capros *et al.,* 2019). Capros *et al.* (2019) describe that in the Paris agreement, the net-zero greenhouse gas emissions should be reached in the second half of this century. According to Capros *et al.* (2019), the European Commission has proposed scenarios targeting emission reductions in 2050 by 95% and more. Capros *et al.* (2019) have been modeling different scenarios for the emission reductions. They argue that decarbonizing the EU economy by 2050 is possible technically and economically, regardless of whether the target of the temperature rise limit is 2 or 1.5 Celsius.

Capros *et al.* (2019) claim that scenarios that target 80 percent emission reductions are feasible with currently existing technologies. They describe solutions related to energy efficiency, renewables, and electrification as “no-regret” options. Currently, existing “no-regret” options are presented in table 1. “No-regret” options are options that currently exist in the climate and energy policy packages for 2030 and should be upscaled after 2030 (Capros *et al*., 2019). “No-regret” options will have a significant role in the long-term transition (Capros et al., 2019). In 80% emission reduction scenarios, energy efficiency-boosting, renewables, and electrification have a dominant role (Capros *et al*., 2019).

Table 1. "No-regret" options to advance decarbonization by Capros et al. (2019)

Energy efficiency improvement in buildings, equipment, and vehicles
Enhanced renewable power generation - Large-scale investment in variable renewables - Reliable integration of renewables (grids, market integration, storage systems, demand response)
Electrification of transport and heating when cost-efficient, e.g.: - Private transport in urban environments - Heat pumps in heating
Produce sustainably and use advanced (second-generation) biofuels
Extension in Long Term Operation (LTO) of the existing nuclear fleet where possible and geological storage of CO2 where acceptable

Furthermore, Capros *et al.* (2019) argue that decarbonization with a temperature rise below 2 Celsius is possible with scaling up the 2030 effort with additional and more intense policies and measures. These principles are currently already discussed in the EU climate and energy policy scene (Capros *et al*., 2019).

However, decarbonization scenarios that limit the temperature rise below 1.5 Celsius cannot be achieved without disruptive technological options (Capros *et al.,* 2019). These disruptive changes are described in table 2.

Table 2. Disruptive changes to advance decarbonization by Capros et al. (2019)

Reduce energy demand in all sectors beyond conventional energy savings, e.g., circular economy, sharing of vehicles and secondary materials production via recycling
Changes in the way users use energy, e.g., high electrification in industry and transport, direct use of distributed hydrogen and the way energy is distributed (grid and storage for hydrogen, liquefied hydrogen, or green house gas-free methane) etc.
Changes in the production and nature of energy commodities, e.g., - Mix hydrogen and biogas in gas distribution - Replace fossil gas by carbon-neutral methane - Replace fossil liquids by carbon-neutral fuels
Capturing CO2 from air or biomass for re-use (synthetic hydrocarbons) or underground storage (carbon sinks)
Capturing CO2 from fossil fuels combustion or industrial processes and use to produce materials (sequestering carbon dioxide)

Reasons behind why decarbonizing scenarios that limit temperature rise to 1.5 Celsius are not affordable at the EU level with current technologies include the following. A reason is that some transportation sectors are hard to electrify. Another reason is that the biomass that can be sustainably produced within the EU does not provide enough volume for decarbonizing transportation fully. Lastly, several industrial processes and high-temperature energy uses cannot be fully electrified with current technologies (Capros *et al.,* 2019).

2.1.3 Modeled scenarios for reaching decarbonization at EU level

Capros *et al.* (2019) have named scenarios of prioritized decarbonization options after 2030 as Energy Efficiency, Circular Economy, Electrification, Hydrogen, and Power-to-X. Capros *et al.* (2019) in their study explain how combinations of these scenarios can achieve net-zero greenhouse gas emissions and limit temperature rise below 1.5 Celsius. (Capros *et* *al*., 2019). Scenarios are described here to give the reader an understanding of what kinds of actions can and should be taken to advance decarbonization at the EU level.

Energy Efficiency

A scenario that focuses on achieving energy efficiency close to maximum potential, emphasizes policies for promoting near zero-energy buildings. These buildings would consider both new and renovated. In the energy efficiency scenario, strict technology standards for all appliances, equipment, and vehicles are required. (Capros *et al.,* 2019)

Circular Economy

Scenario related to circular economy advances carbon neutrality by optimizing resource efficiency, increasing material and equipment recycling rates, and as a result, reducing primary production of energy-intensive materials, chemicals, and non-metallic minerals (Capros *et al.,* 2019). The circular economy scenario includes behavioral changes, restructuring in the transport section, and emphasizing the role of liquids and gaseous bioenergy (Capros et al., 2019). Hickel & Kallis (2020) note that only a small fraction of total materials has circular potential.

Electrification

In a scenario related to electrification, electricity is the almost single energy source in all sectors in the long-term, including high-temperature industrial processes and transport modes (Capros et al., 2019). Without strong energy savings in all sectors, it would not be suitable to eliminate all fossil fuels by climate-neutral energies because of the expected demand rise for electricity use (Capros et al., 2019). According to Fevang *et al.* (2021), transportation is responsible for 30 percent of the EU's total emissions, and that 43 percent of the emission from transportation are related to passenger cars. Fevang *et al.* (2021) describe that transition to zero and low emission private transportation is essential for reaching emission targets. Capros *et al.* (2019) mention that considerable reductions in the transport sector are enabled by vehicle-sharing, improved logistics, and further promotion of public transport in the Energy Efficiency scenario as well as scenario combinations related to energy efficiency and behavioral changes.

Hydrogen

In the scenario related to hydrogen use as a widely used commodity, hydrogen production and distribution infrastructure must be developed. In this scenario, hydrogen would cover all end-uses including transport and high-temperature industries. Hydrogen would provide energy storage service. (Capros *et al.*, 2019)

Power-to-X

In the scenario related to Power-to-X, the current infrastructure, and paradigm of using and distributing energy commodities are maintained. The key is that the origin of the hydrocarbon molecules is non-fossil to ensure carbon neutrality. Capros *et al.* (2019) describe that in the production of synthetic methane and liquid fuels, carbon-neutral electricity is used, and carbon dioxide is captured in the ambient air or from biogenic sources. (Capros *et al.* 2019).

Hickel and Kallis (2020) discuss that we need all technological innovation and government policies to drive these technological innovations forward but claim that these innovations alone will not be sufficient. They argue that for the efficiency improvements to be effective, the aggregate economic activity needs to scale down too. Hickel and Kallis (2020) describe that consumption needs to reduce and recompose, with a shift to a low-carbon or zero-carbon sector.

2.1.4 Transition to low carbon energy sources

Dahal *et al.* (2018) describe that to reach carbon neutrality, the energy transition is vital at the production stage of carbon emissions because renewable energy sources are everlasting and produce only small amounts of carbon during their lifecycle. Dahal *et al.* (2018) describe that renewable energy policies are key in achieving carbon neutrality and that promoting the use of renewable energy in buildings and transportation can significantly reduce carbon emissions. Notably, the economic factors for the transition towards renewable energy sources are currently moving in the right direction to advance carbon neutrality (Dahal *et al.,* 2018).

Dahal *et al.* (2018) discuss that the transition to low-carbon energy requires considering socio-technological, infrastructural, and technological as well as institutional factors. In socio-technological factors, consumer choices and circumstances affect the end-point energy use and technological change. In Infrastructure and technological factors, it is considered that the transition to low carbon energy requires changes to physical infrastructure. In Institutional factors, various policy processes, coordination, and development of knowledge strengthening programs are required. (Dahal *et al*., 2018)

In their study, Dahal *et al.* (2018) describe that producing and distributing renewable energy sources is expected to be disruptive as they alter the way energy is produced. They also mention that new ecosystems can lead to radical changes in the role of consumers and service providers. Also, smart grids could support the integration of renewable energy sources into an interconnected, multidirectional system that allows all interaction of generation capacities, storage, transmission, grid management, and consumption.

2.1.5 Transition to low carbon mobility

Kleiner *et al.* (2017) in year 2017 describe that the market for electrified logistic vehicles was still in an early stage. Masuch *et al.* (2020) conducted a study about the electrification of fleet transportation systems. Masuch *et al.* (2020) describe that the electrification of industrial firms’ transportation systems is barely progressing. They found that the decision-making of electrifying fleets is affected by corporate reputation, the time committed needed, characteristics of the route, characteristics of the payload, and characteristics of the vehicle fleet. Also, questions about the budget, employee acceptance, political support, and requirements of the business partners affected the decision-making about electrifying the fleets.

Masuch *et al.* (2020) described that currently in the cities worldwide, the share of electric vehicles with 100 percent battery drive is less than one percent of the total vehicle population. However, Norway has been a forerunner in electric vehicle adoption. In Norway in 2020, 52.2 percent of newly registered passenger cars were battery electric vehicles and 20.4. percent were plug-in-hybrid electric cars in 2020 (Fevang *et al.* 2021). Sierra *et al.* (2020) describe that in 2018, 2.5 percent of the newly registered cars were electric vehicles. According to Sierra *et al.* (2020), International Energy Agency (IEA) estimates that the uptake of electric vehicles is “On track” to achieve the sustainable development goal target of 15 percent of the global car fleet being electric in 2030.

It is relevant to consider the emissions from electricity production. According to Leskelä from Finnish Energy, 85 percent of the energy production in Finland is environmentally friendly (Ahtiainen, 2020). Leskelä describes that the remaining 15 percent come from combined production of heating and electricity for cities and that there are clear plans for replacing these (Ahtiainen, 2020). Leskelä describes that by the time when electric cars become more common, energy production in Finland will come from emission-free sources (Ahtiainen, 2020).

2.1.6 Evaluating the role of drone technology in the transition to carbon neutrality

Capros *et al.* (2018) in their study described “no-regret” options and disruptive changes that can advance decarbonization. They also describe scenarios related to decarbonization at the EU level after 2030. When the content of these options and scenarios are compared to the known capabilities and applications of drone technology, it can be said that the effect of drones on advancing carbon neutrality in the wider context is very limited. This is because the weight of the options and scenarios is heavily on the sustainable generation of energy.

From discussed "no-regret" options and disruptive changes, drones can be seen to have possibilities in contributing to the electrification of transport. This is included in the Electrification scenario described by Capros *et al.* (2018). The electrification of transportation fleets has not been progressing quickly (Masuch *et al.,* 2020; Kleiner *et al.,* 2017). This research sees that the role of drones in the electrification of transportation could be in replacing other modes of transportation in those parts of the logistics network where the replacement would be optimal. As described later in this research, is also possible that information gathered with drones can reduce the need for people to transport.

It is worth mentioning that when applications of drones are used as supporting tools within a process, the effect on carbon emissions can be indirect or hard to evaluate. Therefore, when compared to the options that Capros *et al.* (2019) describe for advancing decarbonization, it is possible that drone applications can have a supporting role also in other options than in electrification of transportation. As a high-level example, drone applications can be used in inspecting energy production and transfer infrastructure, which could detect possible energy leaks at an earlier phase and therefore result in preventing energy losses. However, the effect of these kinds of applications can be seen as marginal when compared to the options and scenarios described by Capros *et al.* (2019).

2.2 Drone applications in various industries

2.2.1 Definition of a drone

A drone is an unmanned aerial vehicle that is remotely piloted. In some contexts, the term drone is used also to mean other unmanned vehicles such as drone ships. Another commonly used term for a drone is an abbreviation of unmanned aerial vehicle, UAV. A related term to UAV is UAS, an unmanned aerial system, which includes the UAV as well as the equipment required to control the UAV remotely.

Drones can be categorized based on how they stay in the air. The simplest categorization is rotary-wing drones and fixed-wing drones (Aro, 2018 p. 31-32.). Rotary wing drones take off and land vertically (Aro, 2018 p. 31-32.). Fixed-wing drones take off from a highway, catapult, or by throwing from a hand and land to a predefined landing area or highway (Aro, 2018 p. 31-32.). In addition to these main types of drones, there are hybrid solutions. Different types of drones have their pros and cons and are therefore drone type should be chosen to fit the target of application of the drone.

Drone sizes vary from the small ones that can easily fit a palm of a hand to large ones that can carry the weight of people or cargo. To give a better understanding of the commonly used drones, the categorization that follows EU drone regulation is described. Drones that operate in Open Category can weigh a maximum of 25 kg and are allowed to fly below 120 m altitudes (Traficom, 2021). Drone operations in the Open Category require that the pilot has the drone within a visual line of sight (Traficom, 2021). The pilot also needs to have a required license (EGNSS, 2020; Yi & Sutrisna, 2021).

If operations are not possible within the rules of Open Category, operations take place in Specific Category (Traficom, 2021). As a rule, drone operations in Specific Category are subject to approval by competent authority based on a risk assessment performed by the operator (EGNSS, 2020). Drones that weigh more than 25 kg and/or are operated beyond the pilot's visual line of sight (BVLOS) are likely to be operated in the Specific category.

If operations include flights over crowds, the transport of people, or the carriage of dangerous goods, these operations must take place in Certified Category (Traficom, 2021). Currently, it is not possible to get authorization for operations in the Certified Category as the standards of the category are not published (Traficom, 2021).

Drones can operate with different levels of autonomy: Autonomous, automatic, and having no level of automation. European Union Aviation Safety Agency (EASA) describes that autonomous drones can perform safe flights without human intervention. Autonomous drones use artificial intelligence to cope with all kinds of foreseen as well as with unpredictable emergencies (EASA, 2020). However, automatic drone operations mean that a drone is for example automated to fly a predetermined route defined by the drone operator before the flight (EASA, 2020). In addition to autonomous and automatic drone operations, a drone can be remotely piloted without any level of automation. The level of automation can relate to the category in which the drone can operate based on EU drone regulation. Autonomous drones are not allowed in the Open Category, and automated drones are allowed in all categories (EASA, 2020). In this research, automatic operations are referred as automated operations.

2.2.2 Overview of drone application market

The market for drone-powered solutions is growing at a fast pace globally. The drone market can be segmented into military, consumer, and commercial. Goldman Sachs

Research (n.d.) predicted a US$ 100 000 000 000 market opportunity for drones between 2016 – 2020. Of these segments, the military segment is the largest, and a US$ 70 000 000 000 of market opportunity was seen in this segment. The military segment is considered as most mature. Drones are used in military operations as they are considered safer, cheaper, and often more capable options to manned military aircraft. Goldman Sachs Research (n.d.) estimates that defense will be the largest market also in the future. Use cases have included intelligence gathering and chemical detection. (Goldman Sachs Research, n.d.)

The consumer segment includes drone hobbyists, and this segment was the first to develop outside the military. The market opportunity of this segment is estimated to be US$ 17 000 000 000 between the years 2016 – 2020 and it is suggested that there is room to grow in this segment (Goldman Sachs Research, n.d.). In the commercial segment, the market opportunity was evaluated to be US$ 13 000 000 000 between the years 2016 – 2020. Goldman Sachs Research (n.d.) estimates that the fastest growth opportunity comes from businesses and civil governments. Regarding the previously mentioned US$ 100 000 000 000 market opportunity for drones between years 2016 and 2020, Goldman Sachs Research (n.d.) mentions that above-market opportunity is just the tip of the iceberg as drones' full economic potential is likely to be multiple times that number, as their ripple effects reverberate through the economy. European Commissioner for Transport Adina Iona Valean described that 150 000 jobs are expected to be created in the manufacturing of equipment with additional jobs in drone-operator services (Valean, 2020).

Earlier estimates include PwC's and Goldman Sachs Research's (n.d.) estimates about the size of the market opportunity. In 2016, PwC estimated the future value of global drone-powered solutions to be over US$ 127 000 000 000 (PwC, 2016). The value of drone-powered solutions was defined as the value of services and labor that have a high potential for replacement in near future by drone solutions.

At Europe, European Global Navigation Satellite Agency, EGNSS (2020) discusses that the European drone market demand exceeds 10 000 000 000 € annually, in nominal terms, to 2035 and similarly exceeds 15 000 000 000 € annually, to 2050. EGNSS (2020) mentions that the service component of the market is growing and that European drone service revenues are expected to almost double from 32 000 000 € (2018) to 60 000 000 € (2020) and reach 150 000 000 € by 2023. In the United States, the commercial drone market has been growing strongly (McKinsey & Company, 2017). In 2017, McKinsey & Company estimated that by 2027 commercial drones will have an annual impact of US$ 31 000 000 000 - 46 000 000 000 on the USA's GDP.

When all segments (military, consumer, and commercial/civil) are considered, the United States has been the biggest market when estimated by drone spend for years 2017 – 2021. After the United States, money spent on drones has been highest in China, Russia, United Kingdom, and Australia. Estimated drone spend in different countries for the years 2017 – 2021 is represented in figure 1.

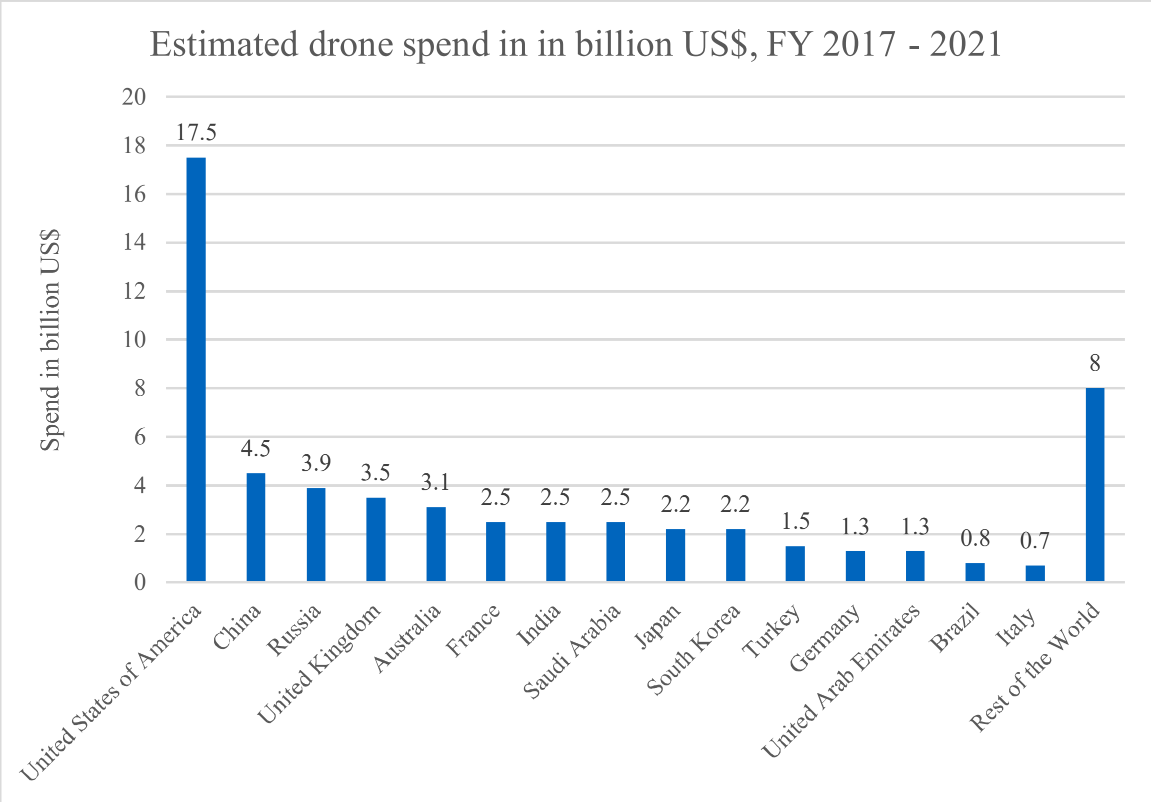

Figure 1. Estimated drone spend in different countries globally in years 2017-2021
Source: Goldman Sach Research

2.2.3 Generally recognized benefits of drone applications

Goldman Sachs Research (n.d.) suggests that current drone technology has already surpassed manned aircraft in endurance, range, safety, and cost-efficiency (Goldman Sachs Research, n.d.). They expect the next-generation drones to widen the gap between manned and unmanned aviation even further with greater stealth, sensory, payload, range, autonomous, and communication capabilities (Goldman Sachs Research, n.d.).

A variety of benefits of drone-powered solutions have been suggested. These include cost-effectiveness and low cost per kilometer (Carlsson & Song, 2018; Lentola Logistics, 2020; PwC, 2017a), low carbon emissions (Lentola Logistics, 2020; Valean, 2020), safety (Valean, 2020; PwC, 2017a; Lentola Logistics, 2020) and silence (Lentola Logistics, 2020). Speed is also considered one of the main advantages (Yoo *et al.,* 2018). Drones can fly at high speeds as they are not affected by traffic or road infrastructure (Yoo *et al.,* 2018; Carlsson & Song, 2018; PwC, 2017a). Moving logistics to air can decrease the need for car lanes and parking spots (Anbaroğlu, 2017; Lentola Logistics, 2020).

When drones are compared to manned aircraft, various benefits can be found. Training the pilots for manned aircraft costs money and takes considerable time. The absence of crew significantly reduces the cost of performing a task. Lytvyn *et al.* (2020) mention that drones are much cheaper than manned aircraft, which need life support systems, protection, air conditioning, etc. (Lytvyn *et al.,* 2020)

The possibility to operate without human intervention is seen as a benefit (Carlsson & Song 2018). Lytvyn *et al.* (2020) discuss that automatic and semi-automatic control reduces the influence of the human factor when performing the task. Lytvyn *et al.* (2020) discuss that for quick and high-quality assessment of the situation on the ground, drones are the best solution.

2.2.4 Factors that affect the further development of the drone service market

McKinsey & Company (2017) identified factors that influence UAS market growth in the United States. Factors include public acceptance, economic drivers, technological capabilities, regulation, and infrastructure. The development of these factors can be considered to hinder or advance the adoption of drone-powered solutions. Although the assessment was made for the U.S market in 2017, these factors provide a good base for generally understanding the requirements and possible obstacles that drone-powered solutions face. Understanding the limitations of drone-powered solutions is crucial for evaluating their business potential.

Some practical factors related to technology, regulation, and infrastructure will largely determine which drone applications are feasible (McKinsey & Company, 2017). McKinsey & Company (2017) described that public acceptance and economic drivers influence which applications will get investment. They describe that regulation and technological capabilities will determine when more of the applications will reach maturity. McKinsey & Company (2017) describe that infrastructure is needed to support existing and proposed applications.

Public acceptance

According to McKinsey & Company (2017), public acceptance is perhaps the most vital of these factors for the development of the drone-powered solutions market. The industry must build a lot of confidence in people to get acceptance (McKinsey & Company, 2017). Valean (2020) mentions that one reason why drones are not seen as an option is lack of awareness.

In their study, Yoo *et al.* (2018) researched what factors favor or hinder the public acceptance and willingness to use drone delivery service in rural and urban areas. They found that speed and environmental friendliness positively affected attitudes towards drone delivery of parcels (Yoo *et al.,* 2018).

Those who perceive drone delivery as faster and more environmentally friendly than traditional methods might be more likely to adopt the use of drones in delivery (Yoo *et al.,* 2018). However, perceived environmental friendliness of drone deliveries only affected attitudes positively in a group of people who live in rural areas (Yoo *et al.,* 2018). Also, it was found that privacy risk negatively affected the attitudes only in the group of people who live in rural areas (Yoo *et al.,* 2018). An explanation for this could be that in urban areas the drone deliveries are dropped on designated spots near apartments, but in rural areas, the delivery might be in the yard of a detached house (Yoo *et al.,* 2018). It was also found that performance risks such as property damage, missing goods, or danger due to the malfunction of drone delivery affected attitudes towards drones negatively only in the group of people who live in urban areas (Yoo *et al.,* 2018).

Economic drivers

Drone applications can be expected to be used in areas where the greatest economic value is found (McKinsey & Company, 2017). This can be in streamlining operations and facilitating automation and digitizing operations (McKinsey & Company, 2017). Economic benefits determine largely which of the potential drone applications are adopted first.

Technological capabilities

Some technological capabilities are still under development (McKinsey & Company, 2017). These technological capabilities include autonomous flight (McKinsey & Company, 2017; Ky, 2020), battery performance (McKinsey & Company, 2017; Ky, 2020; Casado, 2020), detect-and-avoid technologies (McKinsey & Company, 2017; Ky, 2020; Casado, 2020), integrated air-traffic-management (ATM) systems (McKinsey & Company, 2017) and location technologies (McKinsey & Company, 2017; Casado, 2020). The industry needs to continue innovating to develop these capabilities (Ky, 2020).

Some drones can fly without users directing them, but technology is still emerging (McKinsey & Company, 2017). Flying without a pilot would enable many applications, such as unpiloted surveillance of pipelines, mines, and construction projects (McKinsey & Company, 2017).

Battery performance needs to develop to enable further applications. Carlsson and Song (2018) in their studies mentioned that shortcomings include extremely low carrying capacity and short traveling radius. These both result in frequent returns to the central depot in a study where logistics is operated with a combination of a truck and a drone (Carlsson & Song, 2018). The trend in battery development has been favorable, and the drones are expected to be able to operate for more than an hour without recharging the battery (McKinsey & Company, 2017).

There is a need for robust detect-and-avoid technologies (Ky, 2020). These are systems that help drones avoid collisions and obstacles (McKinsey & Company, 2017). In the year 2017, McKinsey and Company estimated that strong solutions would emerge by 2025.

There is a need for integrating air-traffic-control systems of drones and manned aviation (McKinsey & Company, 2017). In the year 2017, McKinsey and Company estimated that integrated air-traffic-control systems would not materialize for more than a decade.

McKinsey and Company (2017) discuss that drones need to be able to identify their location in areas where GPS signals are limited and degraded. In the year 2017, McKinsey and Company estimated an alternative for GPS that could be used in navigating drones is more than 10 years in the future.

EU regulation on drones

As the geographical scope of the researched applications is Southern Finland, regulation is discussed at the EU level. EU regulation is effective from 1.1.2021 onwards (van Nieuwenhuizen, 2020). The regulation replaces existing EU member state rules (Valean, 2020). A year-long transition period to the new regulation started 1.1.2021. This EU-regulation focuses on smaller and unmanned drones flying at relatively low levels (Valean, 2020).

Regulation is needed to enable safe operations of large, remotely piloted aircraft (Valean, 2020). EU-level regulation package for package delivery, emergency services in the city, and air taxis is developed and aims to be ready in 2023 (Ky, 2020). There is strong demand for a safe, stable, and predictable regulatory environment in Europe (Valean, 2020).

U-space is an initiative of the European Commission to integrate drones safely and securely into societies (SESAR Joint Undertaking, n.d.). SESAR Joint Undertaking (n.d.) describes U-space in the following way: "U-space is a set of new services relying on a high level of digitalization and automation of functions and specific procedures designed to support safe, efficient, and secure access to airspace for large numbers of drones. As such, U-space is an enabling framework designed to facilitate any kind of routine mission, in all classes of airspace and all types of environment - even the most congested - while addressing an appropriate interface with manned aviation and air traffic control.”. In 2017, SESAR Joint Undertaking (n.d.) drafted a blueprint for U-space. The next step on the EU level is to work on the U-space regulation with the help of EASA (European Union Aviation Safety Agency) (Valean, 2020). In the U-space model, each member state is responsible for its own airspace (van Nieuwenhuizen, 2020).

A market-oriented approach to U-space will help to make the option attractive for all European companies (Valean, 2020). EU is the first region worldwide to propose a harmonized regulatory approach to unmanned traffic management (Ky, 2020). Entry to the new regulation is expected in 2022 (Ky, 2020).

Infrastructure

McKinsey & Company (2017) mentioned that most current applications have modest requirements for infrastructure. For example, drones in construction sites can land on empty land and charge from the power source in the construction site. However, some of the applications will require more infrastructure. Potentially necessary infrastructure includes vertiports for people and cargo and service centers for storing, inspecting, and maintaining the vehicles. There would also be a need for distribution hubs where goods from drones are loaded and received. In addition to distribution hubs, there is a need for receiving stations where the final delivery objects are received. Charging stations are also part of the necessary infrastructure. (McKinsey & Company, 2017).

2.2.5 Key Commercial applications of drones globally

Drone-powered solutions are applied in various industries. For example, EGNSS (2020) describes that drones are used in agriculture and environmental, inspection and maintenance, surveying and mapping, government, public safety, scientific, education, observation, communications, leisure, goods delivery, military, and other applications. Based on estimations of Goldman Sachs Research (n.d.) in figure 2, and PwC in figure 3, applications in infrastructure, construction, and agriculture have the highest market potential globally. According to PwC (2016), drones are most suitable in industries that require mobility and high-quality data. According to McKinsey & Company (2017), drones have an impact on facilitating labor-intensive or difficult tasks.

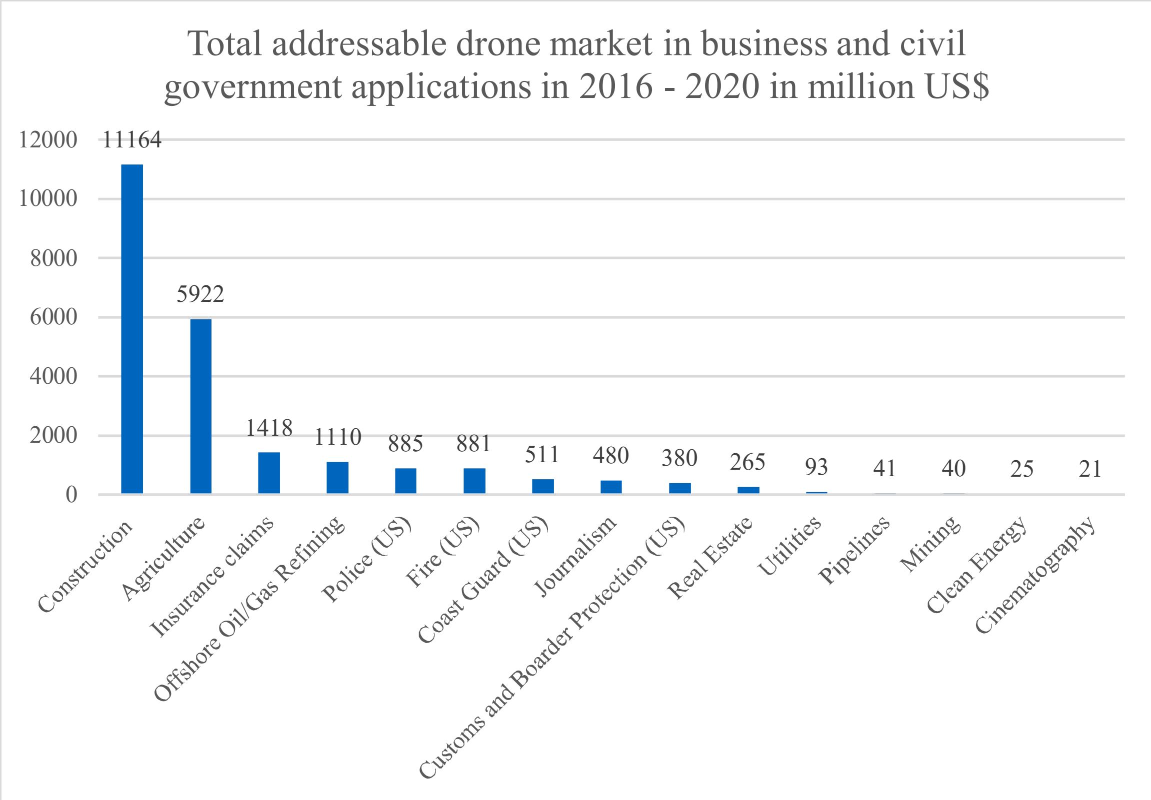

Figure 2. Total addressable drone market value by industry/function by Goldman Sachs Research (n.d.)

Source: Goldman Sachs Research (n.d.)

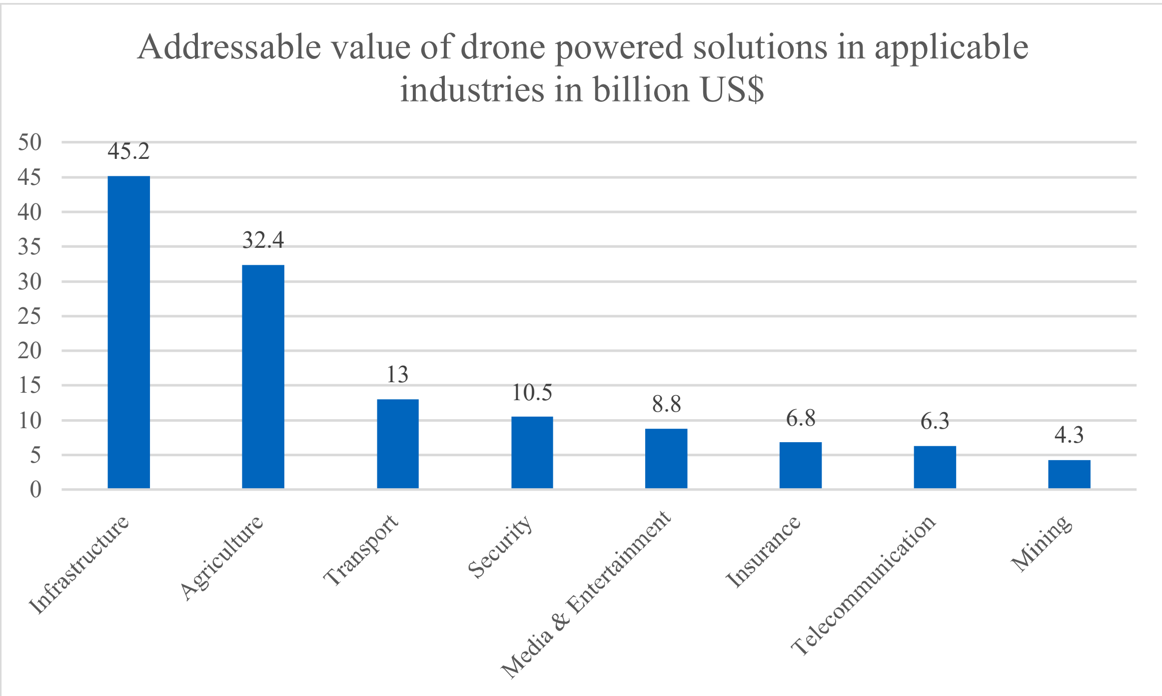

Figure 3. Total addressable drone market value by industry/function by PwC (2016)

Source: PwC (2016). Values presented in this table correspond with year 2015 value of businesses and labour in each industry that may be replaced by drone powered solutions, according to PwC research (PwC 2016).

Infrastructure
Based on the estimated value of current business services and labor that have high value for a replacement very soon by drone-powered solutions, infrastructure is the most promising field for drone-powered solutions (PwC, 2017a). This can be seen in figure 3. PwC in 2016 described that the value of businesses and labor that could be replaced by drone-powered solutions was US$45 200 000 000 (PwC, 2017a). The biggest components would be applications related to transport infrastructure (US$9 000 000 000) (PwC, 2017a) and the Power and Utilities sector (US$ 9 460 000 000) (PwC, 2017b). Furthermore, within transport infrastructure, maintenance applications would represent US$4 000 000 000 of the value (PwC, 2017a). Based on estimations from Goldman Sachs Research (n.d.) about the total addressable market in commercial/civil applications between 2016 and 2020, the biggest addressable market was Construction (US$ 11 164 000 000). This can be seen in figure 2.

Use cases of drones in infrastructure include investment monitoring, maintenance, and asset inventory (PwC, 2017a). Potential applications of drones in construction are represented in table 3. PwC (2017a) claims that drones together with 3D modeling software can be effectively applied at every stage of infrastructure investment monitoring. Precise data can be used to increase situational awareness, lower costs, and improve the safety of staff involved in maintenance or construction projects (PwC, 2017a).

Yi & Sutrisna (2021) discuss that using drones to monitor construction sites is a flexible approach with low workforce costs. Panjehpour (2019) discusses that drones have been increasingly integrated into building information modeling (BIM), where they provide highly accurate point cloud scanning and replace workforce in construction inspection. Panjehpour (2019) describes that drones with advanced technology cameras and infrared radiation have revolutionized and expedited the construction process. Panjehpour (2019) discusses that using drones in site surveys, design, volume, and elevation measurements is time-efficient and cost-saving. Yi & Sutrisna (2021) mention that the use of drones in construction is still in its infancy. The main issue has been processing the information and integration with software so that the management learns to use the information in actions (Yi & Sutrisna, 2021).

Table 3. Potential applications of drones in the field of infrastructure

The focus of the application	Reference
Pre-construction phase	
Providing precise geospatial data for the design process	(PwC, 2017a)
Helping to limit the costs of adjusting plans and designs	(PwC, 2017a)
Getting better knowledge about the construction area makes it easier to carry out engineering planning and capital budgeting	(PwC, 2017a)
Construction phase	
Monitoring work progress and quality by creating a situational view	(PwC, 2017a; Panjehpour, 2019; Yi & Sutrisna, 2021)
-Quickly surveying the construction sites and providing real-time data to project managers	(PwC, 2017a)
-Making measurements with the picture data (length, area, capacity)	(Panjehpour, 2019)
-Comparing materials allocation against project design and schedule	(PwC, 2017a; Aiforsite, 2020)
-Making decisions about the need for material replenishments	(Panjehpour 2019)
Detecting and preventing trespassing	(PwC, 2017a)
Placement of trench protection	(PwC, 2017a)
Monitoring site safety by identifying dangers to workers and supporting the prevention of accidents and injuries, identifying non-compliance of safety rules	(PwC, 2017a; PwC, 2017b; Panjehpour, 2019; Yi & Sutrisna, 2021)
Using materials as evidence in litigation	(PwC, 2017a)
Expediting data gathering during regular visits from authorities in for audit purposes	(Panjehpour, 2019)
Facilitating scheduling of further work stages and providing warnings about delays	(PwC, 2017b)
Enabling collection of construction site data for Building Information Modeling (BIM)	(Panjehpour, 2019)
Using drones to transport and lay loads in buildings and constructions. Drones would be a part of a fully or partly automated process	(Panjehpour, 2019)
Pre-commissioning phase	
Comparing the work performed to the initial design and detecting any deviations	(PwC, 2017a)
Getting imagery and documentation about the project's impact on the surrounding environment	(PwC, 2017b)
Saving data from previous phases to be used later as documentation for maintenance	(PwC, 2017a)

PwC (2017a) discusses that the information that drones provide is highly applicable in maintenance processes because it is detailed and can be compared over time. Potential applications of drones in infrastructure maintenance are represented in table 4 and potential applications of drones in asset inventorying are represented in table 5. With the use of drones, it is possible to handle the maintenance of assets spread across a vast area (PwC, 2017b) and access hard-to-reach infrastructure (PwC, 2017b). Execution of dangerous inspection procedures normally performed by humans or by expensive helicopters or planes can all be replaced by drones (PwC, 2017b). PwC (2017a) discusses that the costs of using drone-powered solutions in maintenance applications are significantly lower than the costs of conventional methods. Data acquired with drones can be used in measuring wear and predicting future deterioration (PwC, 2017b). By applying machine learning methods to regularly collected drone data, organizations can identify quality defects, malfunctions, or inventory shortages faster and at a lower cost (PwC, 2017b).

Table 4. Potential applications of drones in the field infrastructure maintenance

The focus of the application	Reference
Maintenance of roads	(PwC, 2017a)
Maintenance of railroads	(PwC, 2017a)
Maintenance of high-voltage electricity pylons	(PwC, 2017a; EGNSS, 2020)
Maintenance of wind turbines	(PwC, 2017a; EGNSS, 2020)
Maintenance of telecommunications masts	(PwC, 2017a)
Maintenance of bridges	(PwC, 2017a; EGNSS, 2020; Yi & Sutrisna, 2021)
Maintenance of solar panels	(EGNSS, 2020)
Maintenance of oil and gas pipelines	(Goldman Sachs Research, n.d.; EGNSS, 2020)
Mapping and inspecting water supply infrastructure: Pipelines, sewage, drainage channels	(PwC, 2017b)
Pollution prevention and wastewater management information	(PwC, 2017b)
Detecting overheating from power lines with thermal camera technology	(PwC, 2017b)
Improving the accuracy of energy audits by detecting building energy leaks with thermal camera technology	(Panjehpour, 2019)
A system to detect cracks in the steel components of nuclear power plants	(PwC, 2017b)
Cutting tree lines or other vegetation contacting power lines	(PwC, 2017b)
Maintenance of metropolitan transport networks and long-distance connections	(PwC, 2017a)

Table 5.Potential applications of drones in the field of asset inventorying

The focus of the application	Reference
Inventorying and keeping records of assets that are in their place of function, such as traffic signs or transformers	(PwC, 2017a)
Monitoring and stockkeeping of items in inventory, such as cars and their condition within a railyard	(PwC, 2017a)
Legal and compliance documentation of critical infrastructure	(PwC, 2017b)

Agriculture

Drones have highly potential applications for agriculture globally. The potential value of drone-powered applications is second highest when compared between different industries (figures 2 and 3). PwC (2016) estimates that in the future, agriculture is becoming a highly data-driven industry. Problems in the field of agriculture include water shortage and extensive fertilizer use (Dragic, 2020). Drones can help enable precision agriculture (EGNSS, 2020). Dragic (2020) suggests that by educating people they can start optimizing their yield. Potential applications of drones in the field of agriculture are represented in table 6.

Table 6. Potential applications of drones in the field of agriculture

The focus of the application	Reference
Monitoring crops	(Goldman Sachs Research, n.d.; PwC, 2016; EGNSS, 2020)
The health of the crops	(Dragic, 2020)
Orchard management	(Tu et *al.,* 2020)
Homogeneity assessment	(Dragic, 2020)
Size of the crops	(Dragic, 2020)
Need for replanting areas	(Dragic, 2020)
Detecting bugs	(Dragic, 2020)
Detecting diseases	(Dragic, 2020)
Monitoring field/soil	(EGNSS, 2020)
Soil moisture information	(EGNSS, 2020; Lytvyn, *et al.* 2020)
Guiding efficient use of water resources	(EGNSS, 2020)
Guiding efficient use of fertilizers	(Dragic, 2020)
Identifying objects	(Dragic, 2020)
Livestock tracking	(EGNSS, 2020)
Wildlife monitoring, counting game	(Otto *et al.*, 2018; Robots Expert Finland, 2018)
Detecting rain movements in the field	(Dragic, 2020)
Insurance for agriculture	(EGNSS, 2020)

Transportation

Applications of drones in the transportation sector have received attention. Carlsson & Song (2018) discuss that the use of drones could provide major relief for inner cities by taking off the traffic from the roads. They describe the urban first and last-mile use case of drones as probably the most tangible in the logistics industry (Carlsson & Song, 2018). According to PwC (2016), the potential value of drone-powered applications in the transportation sector is third-highest when compared between different industries (figure 3). Goldman Sachs Research's (n.d.) estimate of potential value for drone applications does not mention transportation (figure 2). According to EGNSS (2020) services such as drone package delivery are expected to have initial services kicking off and advancing the mass-market adoption of drone services. Yoo *et al.* (2018) mention that drones are not yet in commercial use in package delivery, but many companies such as Amazon and Google have done pilot tests. They mention that drones will probably become common in parcel delivery in nearby future (Yoo *et al.,* 2018).

Yoo *et al.* (2018) discuss that drones show high potential for parcel deliveries and that drone delivery can be faster, less expensive, and more eco-friendly than traditional delivery modes such as trucks. Also, the delivery time can be accurately predicted (Yoo *et al.,* 2018).

Goodchild and Toy (2017) in their study showed with a simulation that a delivery drone could be more environmentally friendly than a delivery truck. Carlsson and Song (2018) in their study show with a simulation that the efficiency is best when a truck and a drone are used as a combination in a way that the drone visits the truck to pick up the parcels. Potential applications of drones in the field of transportation are represented in table 7.

Table 7. Potential applications of drones in the field of transportation

The focus of the application	Reference
Moving objects	(McKinsey & Company, 2017; EGNSS, 2020; Robots Expert Finland, 2018)
Delivery of parcels	(PwC, 2016)
Medical logistics	(PwC, 2016)
-Blood transport	(van Nieuwenhuizen, 2020)
-Urgent medicine/medical equipment delivery	(EGNSS, 2020)
Food delivery	(PwC, 2016)
Industry applications	
-Inbound-logistics in time-critical situations	(Deloitte, 2020)
-Carrying materials from storage to factory	(Deloitte, 2020)
-Transporting directly from receiving to shipping	(Deloitte, 2020)
Moving people	
Drone taxi	(McKinsey & Company, 2017)

Surveillance

Many potential drone applications can be considered surveillance applications. Surveillance applications of drones can be found in industries such as infrastructure, agriculture, environmental research. In this section, the surveillance applications presented are mainly related to security and environmental research, as other applications are discussed in the sections related to the field in question.

Drone applications provide use cases for a variety of authorities and help them to better assess and monitor hazardous situations, gather evidence for investigations, and detect and prevent other crises (EGNSS, 2020). According to PwC (2016), the potential value of drone-powered applications in the security sector is fourth highest when compared between different industries (figure 3). In Goldman Sachs Research's (n.d.) estimate, the total addressable market was estimated only for the US market and represented separately for Police, Fire Department, Coast Guard, and Customs and Border Protection (figure 2). Potential applications of drones in the field of surveillance are represented in table 8.

Table 8. Potential applications of drones in the field of surveillance

The focus of the application	Reference
Search and rescue	(van Nieuwenhuizen, 2020; Hirsikko, 2018; EGNSS, 2020)
Police applications	(Brinkman, 2020; Hirsikko, 2018; EGNSS, 2020)
-The direction of the crowd	(van der Plaz, 2020)
-Accident overview	(van der Plaz, 2020)
-Criminal surveillance	(van der Plaz, 2020)
Firefighting	(Brinkman, 2020; EGNSS, 2020)
Emergency response and natural disaster monitoring	(Brinkman, 2020; Carlsson & Song, 2018; EGNSS, 2020)
Marine surveillance	(Brinkman, 2020; Robots Expert Finland, 2018; EGNSS, 2020)
Border control	(EGNSS, 2020)
Traffic surveillance	(Robots Expert Finland, 2018)
Area surveillance	(Robots Expert Finland, 2018; Lytvyn *et al.*, 2020)
Environmental monitoring and protection	(EGNSS, 2020; Carlsson & Song, 2018)
Observing the atmosphere	(Finnish Meteorological institute, 2018; EGNSS, 2020)

Media and entertainment

According to PwC (2016), the potential value of drone-powered applications in the media and entertainment sector is fifth highest when compared between different industries (figure 3). In Goldman Sachs Research's (n.d.) estimate about the addressable market (figure 2), Journalism and Cinematography can be considered to belong to this sector. Potential applications of drones in the field of media and entertainment are represented in table 9.

Table 9. Potential applications of drones in the field of media and entertainment

The focus of the application	Reference
Aerial photography and filming	(PwC, 2016; EGNSS, 2020)
Leveraging drones to entertain or advertise	(McKinsey & Company, 2017; EGNSS, 2020)
Providing multimedia bandwidth by emitting signal/video/sound	(McKinsey & Company, 2017).
-Extending connectivity to remote areas	
-Increasing connectivity when demand surges	

Insurance

Both Goldman Sachs Research (n.d.) and PwC (2016) recognize that there is a market for drone use in insurance applications (figure 2 and figure 3). According to PwC (2016), the potential value of drone-powered applications in the insurance sector is the sixth highest when compared between different industries (figure 3). In Goldman Sachs Research's (n.d.) estimate about the addressable market (figure 2), insurance is seen as the third highest when compared between different industries. Potential applications of drones in the field of insurance are represented in table 10.

Table 10. Potential applications of drones in the field of insurance

The focus of the application	Reference
Risk monitoring	(PwC, 2016)
Risk assessment	(PwC, 2016)
Claims management & fraud prevention	(PwC, 2016)

Telecommunication

According to PwC (2016), the potential value of drone-powered applications in the telecommunications sector is seventh highest when compared between different industries (figure 3). PwC (2017c) suggests that telecommunication operators have possibilities to generate internal efficiencies to their operations, as well as create revenue streams from infrastructure inspection and maintenance, managing and storing data from drones, setting up drone traffic control centers, and more. The reasoning why PwC (2017c) suggests telecommunications operators succeed in these market opportunities is that the telecommunication industry is seen to have unique positioning related to these opportunities. Potential applications of drones in the field of telecommunications are represented in table 11.

Table 11. Potential applications of drones in the field of telecommunications

The focus of the application	Reference
Maintenance enhancement	(PwC, 2017c)
Asset inventorying	(PwC, 2017c)
Network planning and optimization	(PwC, 2017c)
Overcoming network congestion during natural disasters or big events	(PwC, 2017c)

Mining

According to PwC (2016), the potential value of drone-powered applications in mining is eighth highest when compared between different industries (figure 3). Also, Goldman Sachs Research (n.d.) recognizes the addressable market for drone-powered solutions in mining (figure 2). Potential applications of drones in the field of mining are represented in table 12.

Table 12. Potential applications of drones in the field of mining

The focus of the application	Reference
Mining planning -Mapping the area -Optimizing hauling routes -Providing control information	(PwC, 2016; EGNSS, 2020)
Mining exploration -Enabling resource calculation through mapping -Supplying spare parts -Taking soil samples for deposit analysis -Transporting tools and lubricants required for maintenance or repair work	(PwC, 2016)
Tracking environment - Detecting erosion, tracking changes in vegetation and searching for defects in mining infrastructure that may endanger the environment	(PwC, 2016)
Reporting -Monitoring the production process in open-pit mines and for early detection of deviations and threats	(PwC, 2016)
Ore search	(Robots Expert Finland, 2018)

Forestry management

Kotivuori *et al.* (2020) describe that drones are becoming increasingly common in the areas of forest management and forest inventory management. Kentsch *et al.* (2020) discuss that drones represent an easy-to-use, inexpensive tool for remote sensing of forests. Flying close to three canopies results in high image resolution (Kentsch *et al.,* 2020). Kentsch et al. (2020) discuss that time-consuming and sometimes dangerous field surveys can become unnecessary as they can be replaced with drone surveys. In drone surveys, image processing technologies can be used (Kentsch *et al.*, 2020). Potential applications of drones in the field of forestry management are represented in table 13.

Table 13. Potential applications of drones in the field of forestry management

The focus of the application	Reference
Monitoring inventories	
Forest inventories	(Kotivuori *et al.,* 2020)
Prediction of forest attributes (i.e. height, volume, biomass)	(Kotivuori *et al.,* 2020)
Forest recovery rates	(Commercial UAV News, 2020)
Monitoring deforestation	(Lytvyn *et al.,* 2020)
Monitoring forest health	
Detection of diseases	(Commercial UAV News, 2020)
Detection of destructive species	(Kentsch *et al.*, 2020)
Diversity development of trees	(Commercial UAV New,s 2020)
Detecting plants and items	(Karjalainen, 2020)
Carbon dioxide absorption and oxygen production	(Commercial UAV News, 2020)
Monitoring incidents	
Storm destructions	(Robots Expert Finland, 2018)
Illegal tree cut down	(Commercial UAV News, 2020)
Monitoring and detecting and forecasting forest fires	(Karjalainen, 2020)
Chemical contaminations	(Commercial UAV News, 2020)

2.2.6 Use of drones in Finland

As the research focuses on applications that advance carbon neutrality in Southern Finland, information about the drone market in Finland is relevant. Previously, Traficom gathered a statistic where operators reported which is their specialization. The distribution of specializations of operators in the year 2019 can be seen in figure 4. There were 2962 registered flight operators in Finland at the beginning of 2020 (Traficom, 2020). These operators had 3815 drones in use and the average weight of these drones was 3.3 kg (Traficom, 2020). In 2019, there were 2765 registered flight operators in Finland with 3461 drones in use (Saari, 2020, p.13). In 2016 there were 1500 drones in use (Saari, 2020, p.13). Saari (2020, p.14) points out that the number of drones used has doubled within three years.

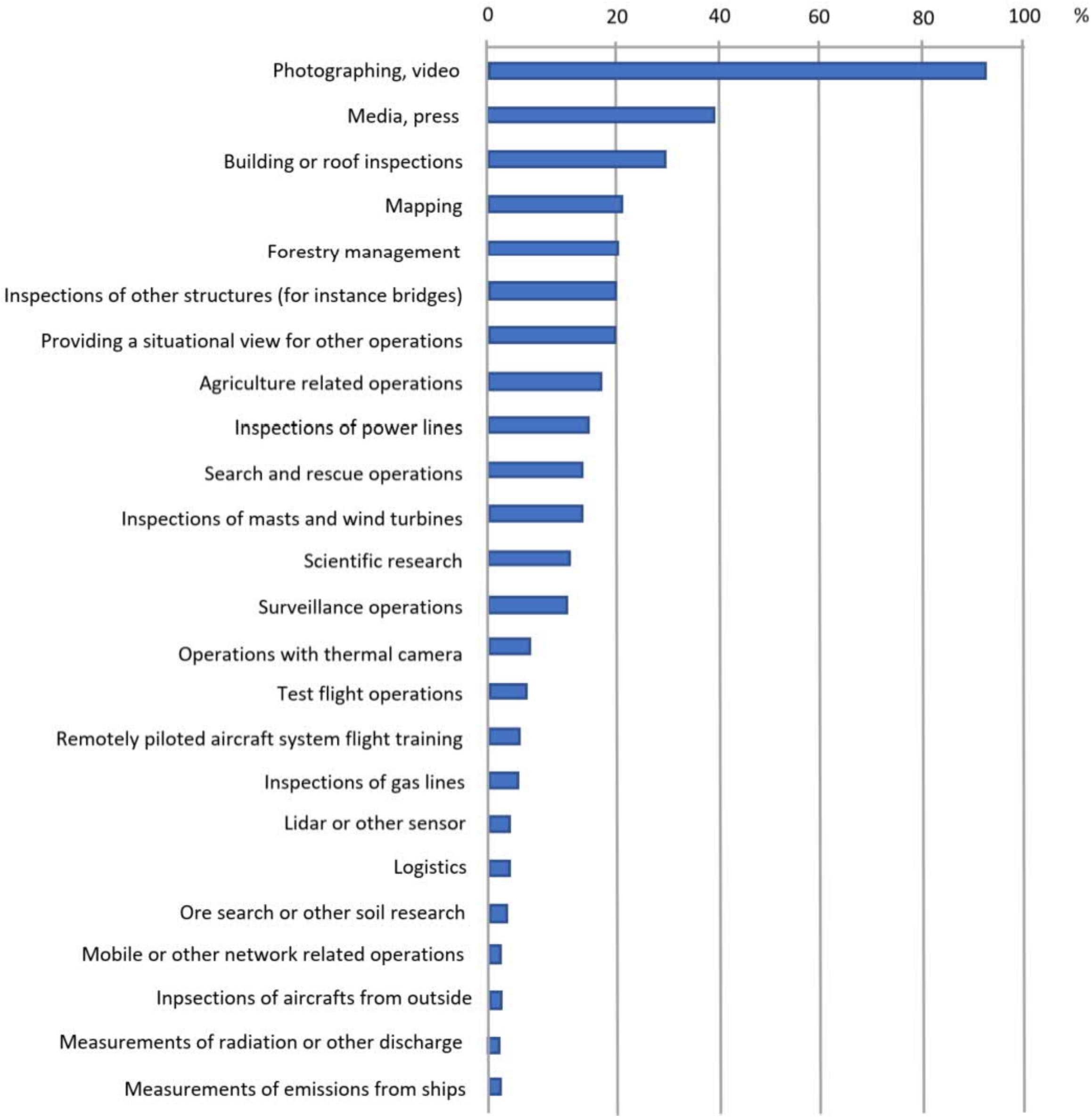

Figure 4: Specialization of remotely piloted aviation system operators in Finland in 2019 Source: Saari, 2020, p.13.

2.2.7 Implications from the review of drone powered solutions for this research

Reviewing various industries where drones are globally applied helped to develop a basic understanding of the applications that are seen to have market potential. Reviewing various industries did not provide estimations of possibilities to advance carbon neutrality with these applications. However, a key idea in this research was to identify not only applications that can advance carbon neutrality, but applications that have both the demand and/or business opportunities as well as the potential to advance carbon neutrality. The initial approach based on the review of potential applications in various industries is described below. It is worth mentioning that the interviews for the drone service providers and subject matter experts further scoped the focus of the research.

Infrastructure and construction were seen as industries where drone applications have the highest market potential. This research assumed that due to the high value of the market and high resource intensity of the market, it would be highly relevant to further research these industries for carbon-neutrality advancing applications. Agriculture was also identified as an industry where drone applications provide value. Many applications of drones in agriculture represent ways of gaining better information for decision-making. This research assumed that better decision-making in these fields could result in more efficient resource use and therefore reduced carbon emissions. Applications in the field of agriculture were included in the scope for further research.

Transportation was identified as an industry where drone applications could provide value. This research assumed that using drones to replace other transportation modes could result in reduced carbon emissions. Therefore, applications in the field of transportation were included in the scope for further research. Surveillance was another field of applications that was found potential from the carbon-neutrality point of view. This was because of the perceived possibility to gain information for better decision-making and the potential to reduce the use of other vehicles. Surveillance was included in the scope for further research.

It was assumed in this research that better information about the forests could guide better decision-making related to forest assets. It was perceived that Southern Finland has a vast amount of forest assets, which was seen as a positive potential indicator for demand. Forestry management was included in the scope of the research. Applications in the field of insurance were seen to relate to other fields of applications and therefore remained in the scope of the research. Applications in the field of media and entertainment, as well as telecommunications, were scoped outside as the potential effect to carbon neutrality was not perceived as high as the potential with other industries. Mining applications were scoped outside the scope of further research as mining activity is not focused on Southern Finland.

When narrowed scope is compared to the specialization of remotely piloted aviation system operators (figure 9), it can be seen that there are operators who have specialized in areas discussed in the literature review.

2.3 Business Model and Value Proposition Design

2.3.1 Business Models

Definition and role of business models

Osterwalder *et al.* (2005, p.10) define a business model as "a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams". According to Veit *et al.* (2014), the business model is seen as a tool for representing, innovating, and evaluating business logic in startups and existing organizations, especially in IT-enabled or digital industries. Business models can be used in management to understand and analyze the current business logic (Veit *et al.*, 2014).

Veit *et al.* (2014) describe that business models can be seen as an intermediary between a company's strategy and business processes. They describe that strategy is seen as a plan to succeed in the competition and the business model describes the logic of value creation and the effective coordination of business resources. Veit *et al.* (2014) further describe that a business process is a description of how to create a specific output from a set of inputs. Xue (2020) discussed that business model research originates from strategy research.

According to Evans *et al.* (2017) and Zott *et al.* (2011), there is no general agreement about the definition and concept of a business model. Ojala (2016) describes that the use of the term *business model* is challenging both in academic literature and in practice as there is no clear definition of the concept.

Zott *et al.* (2011) described that there has been a rapid increase in the research of business models over the last two decades. Veit *et al.* (2014) discuss that the widespread digitalization of businesses and society at large emphasizes the importance of business models in success. This is rising business model to the focus of academic inquiry (Veit *et al.*, 2014).

The existing literature of business models provides information about various components that can be included in the business model and describes how entrepreneurs develop their products based on a business model (Ojala, 2016). Ojala (2016) describes that there is no detailed information in the literature about how opportunities are created and how these opportunities lead to business models.

Business model conceptualization by Ojala (2016)

Ojala (2016) describes a business model conceptualization that builds upon the business model conceptualization by Osterwalder and Pigneur (2005, 2010) and other literature. Visualization of the conceptualization is shown in figure 5. This conceptualization describes business models as a dynamic concept that can evolve when there is a need for a change.

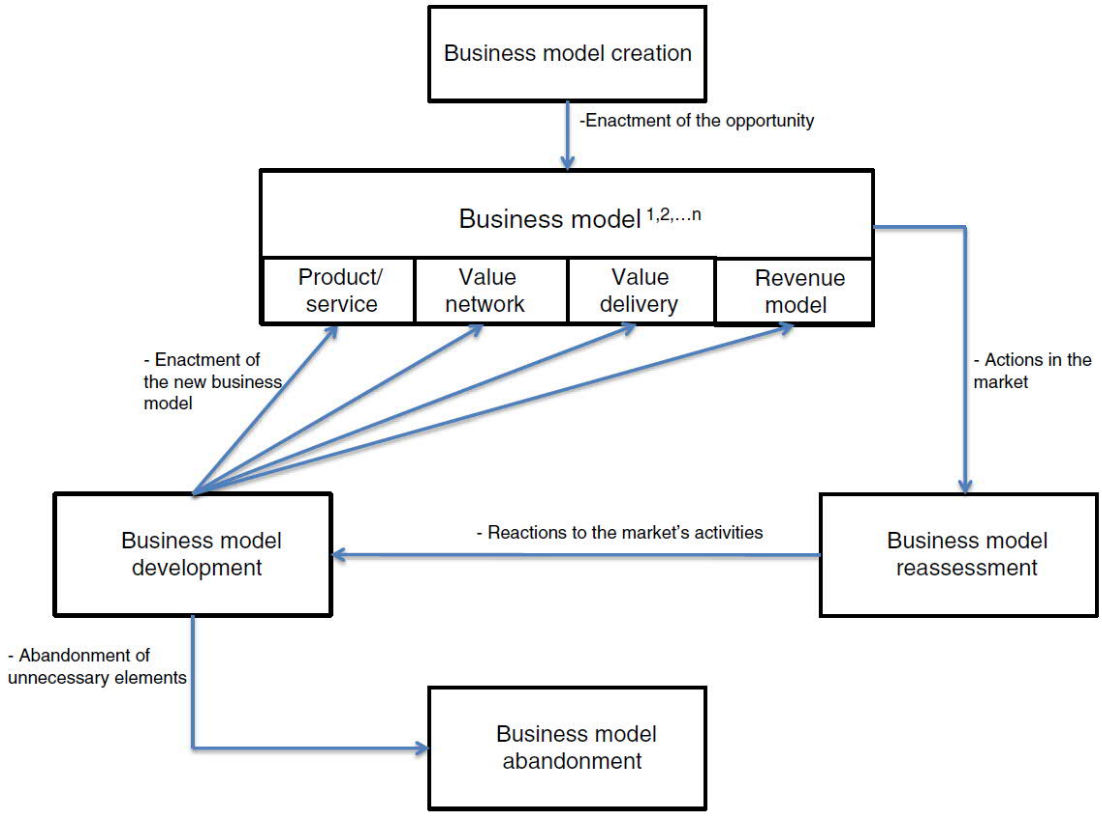

Figure 5. A preliminary theory of business model creation and evolution by Ojala (2016)

Ojala (2016) discusses that a business model is an outcome of a business model creation or a business model development phase. Ojala (2016) describes business model creation as an uncertain phase. This conceptualization follows the idea that the result of the opportunity creation process cannot often be seen or understood by the entrepreneur from the beginning, due to the need for the opportunities to interact with the market to provide more understanding. Often there is a need to develop the original idea based on the understanding gained from the test phase (Ojala, 2016).

Four components of a business model include the product/service, value network, value delivery, and revenue model (Ojala, 2016). Ojala discusses that the component *product/service* describes how the business model creates value for partners and customers included in the model. The component *value network* describes key actors, such as partners or customers, in an organization's network (Ojala, 2016). Ojala discusses that the relationships between the organization and its partners are commonly described as an important component of a business model. The component *value delivery* describes how value is delivered to the various partners in the network (Ojala, 2016). Ojala discusses that this component includes that organizations should describe how they get in touch with their customers and how value is exchanged with the organization's partners. The *component revenue model* describes how the value created to end customers or network partners creates financial revenue.

Revenue models can be one-sided or have multiple sides (Eisenmann *et al.*, 2006). In the one-sided revenue model of services, the end-user pays to use the service. In a two-sided revenue model, the end-users use the service for free and another party subsidizes the use (Eisenmann *et al.*, 2006). In more than one-sided revenue models, different actors have different roles (Eisenmann *et al.*, 2006).

Ojala (2016) describes that actions in the market can lead to a need to reassess the business model. In reassessment, entrepreneurs evaluate different possibilities to act based on technological development, market conditions, and interactions with the network of partners (Ojala, 2016). Changes could include the development of the product/service to match changes in the market strategy or segmentation, finding new partners or excluding existing ones, and considering value delivery and revenue model between partners (Ojala, 2016). Ojala (2016) mentions that the first business model rarely succeeds in the market, as there can be challenges related to the partner's assumptions or customer's needs. The organization can look for potential partners in the market, figure out how the value should be distributed within the partner network, and/or change the revenue model they are aiming for (Ojala, 2016). If the conclusion of the assessment is to develop the business model further, the business model components, product/service, value network, value delivery, and revenue model, are reassessed. Ojala (2016) mentions that from a market fit-testing point of view it is not that relevant whether the business model is completely new or just being modified, because other factors have likely changed. Starting from a point zero ensures that there is no carriage from the past within the assumptions (Ojala, 2016).

Through changes in the business model, the model can better correspond to the needs of the partners and customers (Ojala, 2016). In some cases, the organization can abandon either the whole business model or parts of it as unprofitable or unfeasible (Ojala, 2016).

Business Model Canvas by Osterwalder and Pigneur (2010)

Ojala (2016) describes that most descriptions of business models have been developed mainly for practitioners, with theoretical support remaining unformed. One of these models aimed at practitioners is Business Model Canvas by Osterwalder and Pigneur (2010) and it is represented in figure 6.

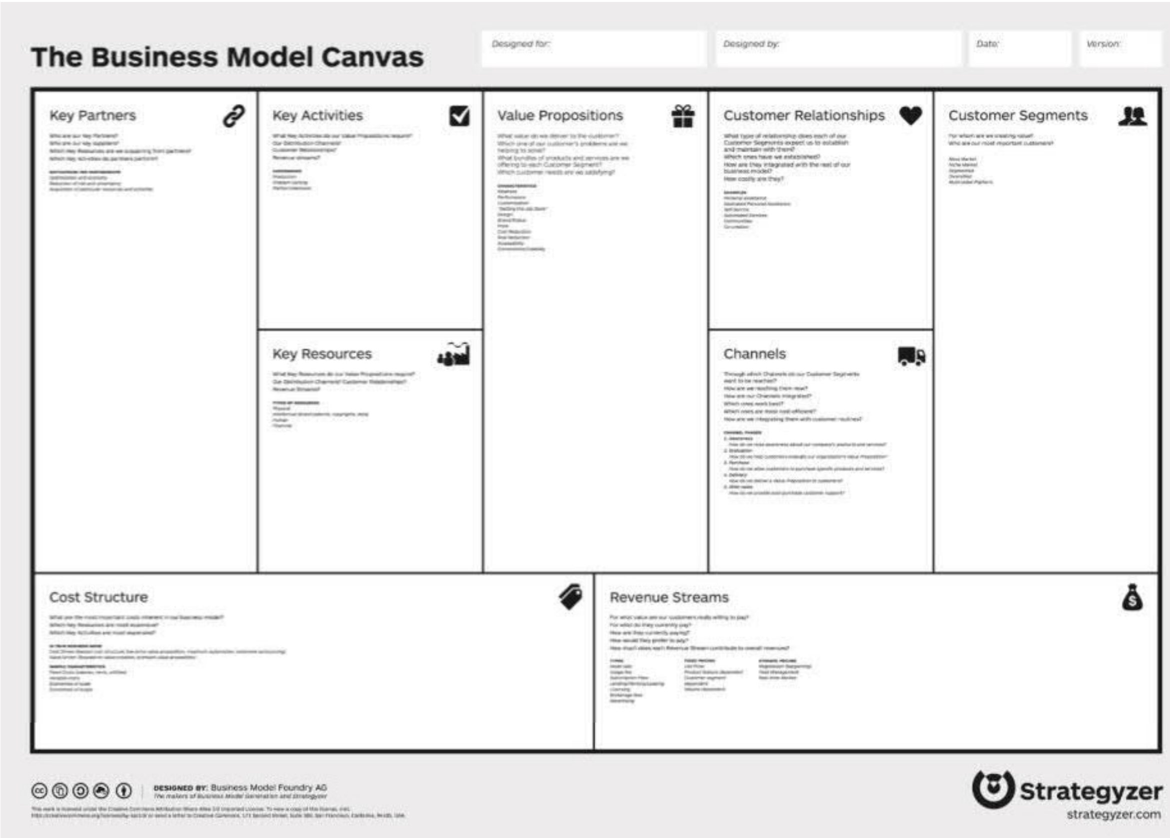

Figure 6. Business Model Canvas by Osterwalder and Pigneur (2010)

Next, the Business Model Canvas by Osterwalder and Pigneur (2010) is described in more detail. In the middle of the canvas is the *value proposition*, which refers to the value that the organization offers for a specific target customer (Dubosson-Torbay *et al.*, 2002). The value proposition describes which customer's problems the organization is aiming to solve, which customer's needs the organization is aiming to satisfy, and what bundles of products and services are offered to each customer segment. On the right-hand side, the *customer* *segments* are represented. Related to customer segments, the organization determines to whom they aim to create the value. There can be several customer segments based on the different needs of the customers.

To provide a value proposition for customer segments, the organization needs to make decisions related to *customer relationships* and *channels* that it uses to reach the customers. Related to channels, the organization determines the channels through which it aims to reach the customers. Related to customer relationships the organization determines how much it wants to deliver additional value to its customers and what support and service level it wants to provide (Dubosson-Torbay *et al.,* 2002).

On the left-hand side, the *key partners* on the supply side are represented. Related to key partners, the organization determines who are the key partners and suppliers and which key activities and resources each of these organization provide. The organization needs to define the *key activities* and *key resources* that are needed in value creation. Related to key activities the organization determines which actions are needed in the core business operations. Related to key resources, the organization determines the ones that are essential to operate the core business. Key resources can consist of physical, intellectual, human, and financial resources.

On the bottom of the canvas, *cost structure* and *revenue streams* are described. Related to cost structure, the organization determines what are the costs of creating value for the customer with the business operating model. Related to revenue streams, the organization describes the revenues coming from different revenue streams. Revenue streams can be categorized as single-time or recurring revenues.

A value co-creation view of a service business model by Chew (2016)

As Chew (2016) discusses, it can be noticed that the content of the value co-creation view of a service business model corresponds largely to the view of Business Model Canvas. The value co-creation view of a service business model is represented in figure 7. Chew (2016) maintains that the general parts of a business model are customer, organization, customer value proposition, monetization, customer-side business ecosystem, and supply-side business ecosystem.

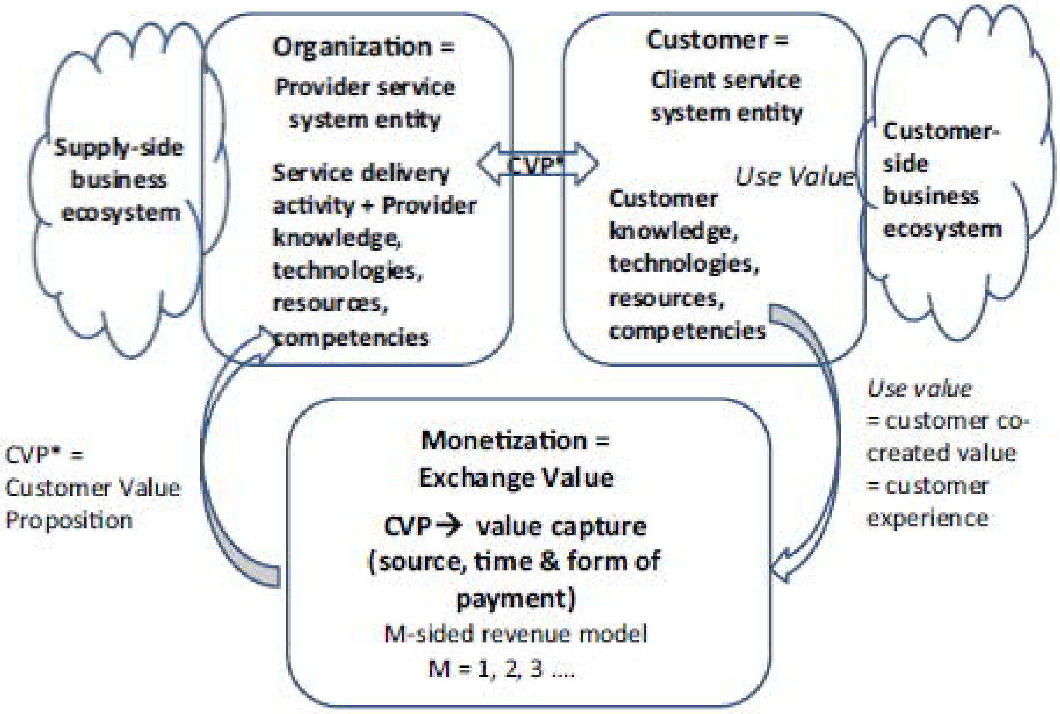

Figure 7. A value co-creation view of a service business model by Chew (2016)

The customer part describes the customer type and which of the value propositions meets their needs. The organization part describes how the organization engages the customer and gets its resources and competencies to deliver the value proposition for the customer. The value proposition is seen to be included in the service concept, which describes what the service is about and how it satisfies the customer's needs. The monetization part describes how the organization gets compensated for the service through a revenue model. (Chew, 2016)

According to Chew's view, the supply-side ecosystem of partners and suppliers widens an organization's access to complementary resources and competencies for customer value creation. The customer-side ecosystem of complementary partners makes it easier to integrate an organization's resources and competencies to reach the customer (Chew, 2016).

Building of sustainable business models

Evans *et al.* (2017) discuss that building economically, environmentally and socially sustainable business models requires an approach that differs from the traditional approach towards business models. They describe that little is known about how to successfully adopt sustainable business models. The key idea of sustainable business models is considering the sustainability aspect. The natural environment and society can be considered as primary stakeholders, as they affect or are affected by the business. Having a sustainable business model can mean that the organization cannot give priority to the stakeholder expectations of traditionally recognized stakeholders, such as owners. Not being able to prioritize the expectations of traditionally considered stakeholders requires changes in the stakeholder relationships.

Evans et al. (2017) describe the challenges that the creation of sustainable business models faces. One of these challenges is balancing the creation of profits as well as social and environmental benefits. Another challenge is that people have an existing mindset about business rules, behavioral norms, and performance metrics that they expect everyone to follow. A challenge is also that creating business model innovations and reconfiguring processes and resources for new business models needs resources, and there can be an unwillingness from organizations to allocate these resources. Challenges can also arise from integrating a technology innovation (such as clean energy technology) together with business model innovation can be complex and multi-dimensional. Another challenge for sustainable business models is a need for more extensive engagement with external stakeholders and the business environment, which is considered a challenge because of the extra effort that is needed. Another challenge is that existing business model methods and tools are few and sustainability-driven ones are rare. (Evans *et al.* 2017)

Evans *et al.* (2017) describe that a step towards sustainable business models is a *product-service system* (Evans *et al.* 2017). A Product-service system means that functionalities or outcomes are provided for the customers instead of products (Evans *et al.* 2017). The Product-service system makes the responsibility of the economic, environmental, and social issues during and after the production phase belongs to the service provider (Evans *et al.* 2017). Evans *et al.* (2017) describe that internalizing these unwanted externalities through products-service system enables innovation towards sustainable business models.

2.3.2 Value proposition design

As described earlier in the business model representations, the value proposition can be found at the core of multiple business model representations. Osterwalder *et al.* (2014) represent a *value proposition design* methodology that can be used to research what kind of products and services the customers want. Visualization of value proposition design is represented in figure 8.

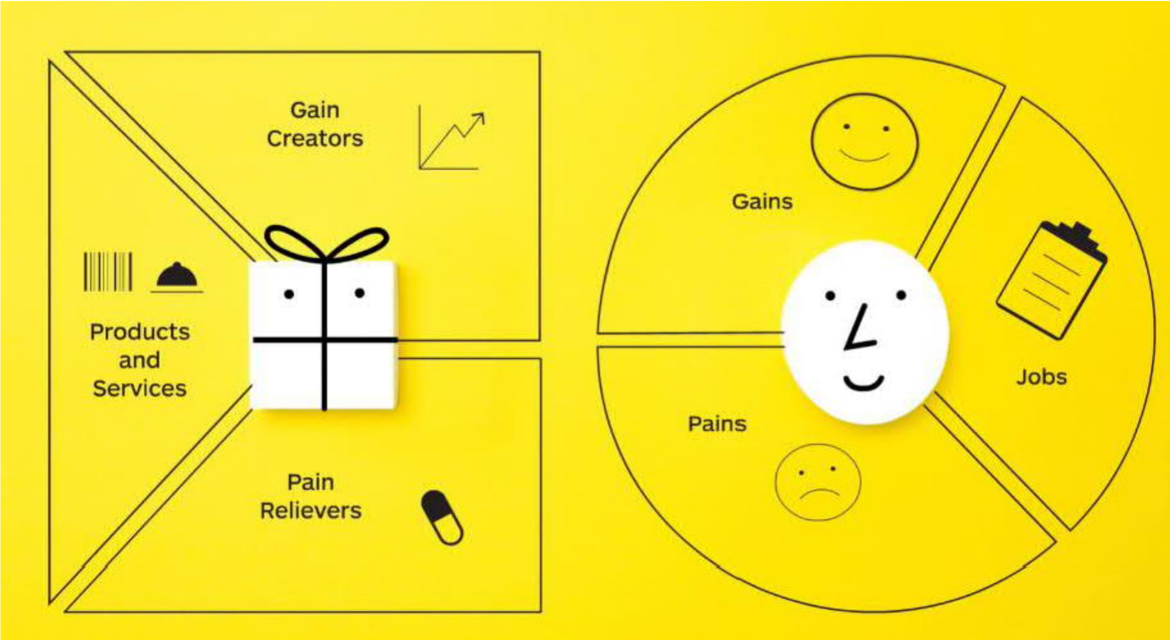

Figure 8. Value proposition design methodology by Osterwalder et al. 2014

Value proposition design consists of two parts, the customer profile, and the value map. The customer profile is created to understand better what the customers want. A value map describes the value proposition (service offering) of a company for the segment in question. The fit between the customer profile and the value proposition can be evaluated with the help of this methodology.

Customer profile consists of customer jobs, customer pains, and customer gains (Osterwalder *et al.,* 2014, p. 9). These are further mapped to understand the customer. *Customer jobs* describe what the customer is trying to achieve. These can include functional, social, emotional, and supporting jobs (Osterwalder *et al.,* 2014, p.12). To better understand the relative importance of the jobs for the customer, they should be ranked according to their importance (Osterwalder *et al.,* 2014, p.13).

Customer pains describe what challenges the customer has with completing the job and/or the things that are keeping the customer from completing the job. These can include undesired outcomes, problems, or characteristics of the job, as well as obstacles and risks related to potential undesired outcomes. As with the customer jobs, the pains should be ranked according to how extreme the customer perceives them. (Osterwalder *et al.,* 2014, p.14-15).

Customer gains describe the opportunities that the customer gets by completing the job. Gains can include different levels, such as the level that the customer requires, the level that the customer expects, the level that the customer desires, and the level that the customer is not able to expect. Similarly, to the customer jobs and pains, gains should be ranked according to how essential the customer perceives them. (Osterwalder *et al.,* 2014, p.16-17).

Value map describes an organization's products and services and how these create gain and relieve pain (Osterwalder *et al.,* 2014, p.8). *Products and services* are essentially a list of what the company offers for the segment in question. Offering includes physical, intangible, digital, and financial components (Osterwalder *et al.,* 2014, p.29). *Pain relievers* describe how the products and services aim to eliminate or reduce customers' pains related to the task that they are trying to complete (Osterwalder *et al.,* 2014, p.31). *Gain creators* describe how the products and services are intended to produce outcomes that customers require, expect, desire, and/or would be surprised by (Osterwalder *et al.,* 2014, p.31). These gain creators include utility, social gains, positive emotions, and cost savings (Osterwalder *et al.,* 2014, p.31).

As the customer profile and value proposition are mapped in a described way, a fit between these components is evaluated. A fit can be achieved if a customer gets excited about the value proposition, which can happen if the value proposition addresses important jobs, alleviates extreme pains, or creates crucial gains that customers care about. Finding and maintaining the fit is the core of value proposition design. (Osterwalder *et al.,* 2014, p.42-43)

Osterwalder *et al.* (2014, p. 88-89) describe that great value propositions can be formed from the business model environment, the business model of the organization, or the value proposition of the organization. Ways that Osterwalder *et al.* (2014, p. 88-89) described are further discussed below. Great value propositions do not always start with the customer, but they must end up in addressing jobs, pains, and gains that customers keep in high value (Osterwalder *et al.,* 2014, p.88-89).

From a business model environment, value propositions can be formed by imitating and "importing" a pioneering model from another sector, coming up with a new value proposition that cannot be copied, or by creating value based on new technology or regulation. Ways include also adapting value proposition to a new or underserved segment of designing a value proposition for a macroeconomic trend that is rising. (Osterwalder *et al.,* 2014, p.88-89)

From the organization's business model, it is possible to create a value proposition based on a new partnership. Another option is to build on existing activities and resources, such as patents, infrastructure, skills, or user base. The value proposition can also be formed by dramatically altering cost structure and lowering prices. One way is to leverage existing relationships and channels to offer customers a new value proposition. Other options include giving away the core product for free or increasing prices by a multiple. (Osterwalder *et al.,* 2014, p.88-89)

From an organization's value proposition, value propositions can be formed by creating a new gain creator for a given customer profile or by creating a new pain reliever for a given customer profile. It is also possible to imagine a new product or service, uncover a new unsatisfied job, or focusing on customers' most essential unrealized gain. (Osterwalder *et al.,* 2014, p.88-89)

2.4 Theoretical framework of this study

Value propositions are at the core of business models (Osterwalder *et al.,* 2014). Designing business models should start with designing the value proposition. This research uses the customer profile of the value proposition design methodology (Osterwalder *et al*., 2014) to gather information about the drone applications that potential customers are interested in. Visual representation of customer profile for mapping the jobs, pains, and gains is shown in figure 9. Gathering this information enables creating an overview of what kind of demand and business opportunities are enabled by discussed applications in different fields.

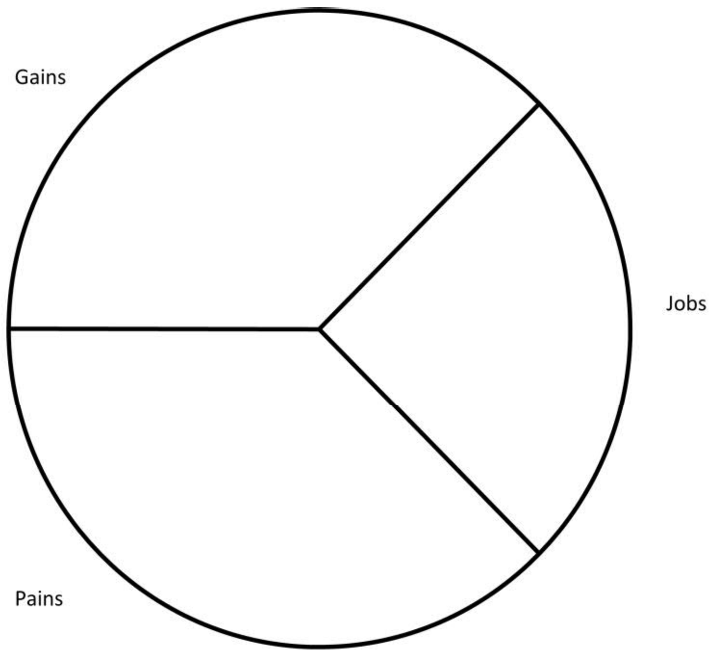

Figure 9. Canvas for creating a customer profile following the value proposition design methodology

In this research, potential customers' interest in applications is mapped at two different horizons, which are c*urrent applications* and *potential applications that raise interest*. *Current applications* refer to applications the potential customer already applies or could apply. This first horizon represents solutions that potential customers see feasible in the sense that the solutions exist in the market or can be done in-house.

Potential applications that raise interest refers to applications that the potential customers do not use, but have interest in. This second horizon also includes solutions that are not currently perceived feasible for the client. Lack of feasibility of an application can result from technological, regulatory, economic, and other aspects. In both horizons, the potential customers evaluate if an application has opportunities to reduce carbon emissions. To the best of the researcher's knowledge, no earlier research has applied part of a value proposition design methodology to research the needs of the customers for drone services. The two different time horizons are indicated with colors in the visual representations of jobs, pains, and gains in the Findings section.

In this research the customer profile is used in an adapted way. On the original representation by Osterwalder *et al.,* (2014), the solution that is used in approaching the task is not considered or included in the customer profiling part of creating value propositions. In the original representation the pains and the gains are directly related to the task. In the adaption which takes place in this thesis, the pains and gains are connected to the solution that creates them. The adaption comes from focusing only to pains and gains that are related to drone applications that are used to perform the tasks. Also, the tasks include only tasks that are related to using drones, but the options to solve these tasks are not limited to using drone applications. Pains represent pains that are related to performing the tasks with drones and gains represent gains that are related to performing the tasks with drones. From this adaption it can be seen that by alleviating some of the pains related to performing the tasks with drones, it is possible that new drone applications become feasible or that the current gains can be accomplished in a more convenient way.

3 Methodology

This chapter describes the research method and collection and analysis of empirical data.

3.1 Research method

This research was conducted as a qualitative study. In the first phase of this research, relevant literature was reviewed and the most potential industries where drone applications can be used were identified for further empirical research. As this research aimed to survey *what kind of demand and business opportunities there are in Southern Finland for drone-powered solutions that advance carbon neutrality*, interviewing was found as a suitable way to collect relevant empirical data. To gain different perspectives to the topic, three different categories of interviewees were selected. These were drone service providers, independent researchers and subject matter experts with knowledge on drone business, and industry representatives from industries where demand and business potential were further researched.

Due to the somewhat explorative nature of this research, interviews were designed to be semi-structured interviews. Wilson (2013, p.24) describes that semi-structured interview is a combination of structured and unstructured interview, as it combines predefined questions with open-ended exploration. A semi-structured interview typically has a list of topics and questions that are asked about each topic. The general goal is to gather systematic information of central topics, while having the possibility to perform exploration when new topics or issues emerge. Semi-structured interviews are used when there is some knowledge about the topic that is researched, but there is need for further details or deepened understanding.

Strengths of performing semi-structured interviews were well in line with the goal of this research as they provide a way to gather information that cannot be accessed otherwise (Wilson 2013, p.25). Also, semi-structured interviews provide a way to deepen knowledge on chosen topics and enable gathering of rich and relevant data (Wilson 2013, p.25). Wilson (2013, p. 25) describes that semi-structured interviews are suitable in situations, where the interviewer is relatively certain that the right issues have been identified. Performing semi-structured interviews was a suitable solution, as preliminary understanding of the topic and potential application areas were formed based on literature review and discussions with the project owners. Semi-structured interviews provide a possibility to raise issues that are found important by the interviewed people, and they provide a way to uncover previously unknown issues or topic areas (Wilson, 2013, p.25). This provided a possibility to test assumptions and find out whether findings from literature review were applicable in the Southern Finland.

Wilson (2013, p. 24) describes that semi-structured interviews are a way to gather facts, attitudes, and opinions. He also describes that semi-structured interviews allow gathering data that cannot be otherwise observed due timing, hazards, privacy, or other factors (Wilson, 2013). Semi-structured interviews suit well this research, as the aim is to gather information of a topic that has not been widely researched in the context of Southern Finland. The topic is hard to observe based on existing information that can be found about the drone application adoption in Southern Finland. Also, information from previous years might not be accurate as the drone technology, analytics, drone operators and market has developed. Also, information that was available rarely took a stand related to the carbon neutrality effect of the application.

Wilson describes that semi-structured interviews can be used in understanding users' goals and gathering data on complex issues where there can be a need to ask for further questions (Wilson 2013, p. 25). For the purposes of this research, semi-structured interviews allowed gathering detailed data about pains, gains, and jobs of the potential customers. By sharing information on a detailed level, it was possible to create a diverse representation of the benefits and challenges of the applications, as well as the perceived affect that applications have on advancing carbon neutrality. Diverse descriptions can help to understand the reasoning behind the findings and provide background information about the context where applications have been found to advance carbon neutrality. This understanding can help to shape actions related to drone use or drone service development.

Semi-structured interviews allow gathering information in a systematic manner, as particular points are covered with each participant (Wilson, 2013, p.25). Systematic approach to data gathering allows making board comparisons between the gathered information from multiple interviews (Wilson, 2013, p.26), which is important for the purposes of this research. Making comparisons across industries and applications makes it possible to understand how the applications can contribute in advancing carbon neutrality currently and in the nearby future.

There are weaknesses related to performing semi-structured interviews in the context of this research. Wilson (2013, p.28) discusses that it is important to ensure that the interviewer does not put words into the interviewed person's mouth or give cues that might guide the interviewed person into a particular answer. These risks can be alleviated by being mindful of them, and by having previous experience from performing semi-structured interviews. Wilson (2013, p.26) describes that the interviewer can affect the results of the research, as interviewed person can change their approach about what information they wish to share based on the trust towards the interviewer and assumptions about the understanding of the interviewer. Regarding to this weakness in this research, it can be alleviated by openly communicating about the purpose of this research and the level of understanding that has been achieved by the point where the interview takes place.

3.2 Collection of empirical data

3.2.1 Drone service provider and subject matter expert interviews

Two drone service providers and five subject matter experts were interviewed for this research. Interviewees are represented in tables 14 and 15. Interviewees were chosen in a way that they could be able to provide insights into current technological restrictions of drones and/or understanding about the current drone market and its development in Southern Finland. Professionals involved with the project *Carbon neutral drone service solutions in Southern Finland* helped in identifying some of the interviewed people and creating contacts with these people.

Table 14. Interviewed drone service providers and subject matter experts

Person	Job title	Organization	Abbreviation used
Subject matter experts			
Laura Ruotsalainen	Associate Professor, (Computer Science)	University of Helsinki	L.R.
Timo Lind	Principal Scientist	VTT	T.L.
Kari Mäenpää	Scientist	Finnish Meteorological institute	K.M.
Antti Perttula	Principal Lecturer (Systems Engineering)	Tampere University of Applied Sciences	A.P.
Risto Linturi	Executive Catalyst, Futurist, Chairman	Sovelto Oyj	R.L.

Table 15. Interviewed drone service providers

Drone service providers			
Pirkka Herpiö	Head of Training	Skydata Oy	P.H.
Markus Hohenthal	CEO	Lentola Logistics Oy	M.H.

Guiding interview questions for these interviews are represented in Appendix A. These interviews were conducted to understand which are currently used or potential drone applications in Southern Finland and which of these applications advance carbon neutrality

(Parts 1 and 2 in Appendix A). Interviews also aimed to deepen understanding about the current state of the drone service market in Southern Finland (Part 3 in Appendix A) and point of views of the near-future drone service market development in Southern Finland (Part 5 in Appendix A). The important part of the interviews was to gain a better understanding of the restrictions that drone operating and drone service providing face in Southern Finland (Part 4 in Appendix A). This helped to gain an understanding of the factors that are hindering the adoption or development of some applications.

Based on the backgrounds of interviewees, specific knowledge areas were emphasized in the interviews. In addition to the guiding questions for the subject matter experts, drone service providers were interviewed about the service that they provide to gain an understanding of the context from which the interviewed person approaches the subject.

Drone service providers and subject matter experts were interviewed between 4.1.2021 – 8.1.2021 and on 8.2.2021. Interviews were conducted as semi-structured interviews and their length varied from 60 to 80 minutes. Interviews were recorded and recordings were transcribed to notes. The thesis was sent to the interviewees so that they were able to check referenced parts.

3.2.2 Industry representative interviews

Four industry representatives from construction, one industry representative from private security, and three industry representatives from forestry management were interviewed for this study. Interviewees are represented in table 16. Guiding interview questions for these interviews are represented in Appendix B.

Table 16. Interviewed industry representatives

Person	Job title	Organization	Abbreviation used
Construction			
Ville Niemikari	Customer Relationship Manager, Digital Services	A-Insinöörit Suunnittelu Oy	V.N.
Tom Helenius	Site Manager	Bonava Suomi Oy	T.H.
Mikko Vitikainen	Discussions based on previous experience	Anonym	M.V.
Riku Laiho	Head of VDC	NCC	R.LA.
Private security			
Mika Aro	Sales Manager, RPAS Services	Securitas Oy	M.A.
Forestry management			
Interviewed person 1	Anonym	Anonym	I.1.
Kimmo Kortelainen	Head of Forest Information	Tornator Oyj	K.K.
Interviewed person 2	Anonym	Anonym	I.2.

Industry representatives were interviewed to gain an understanding of the current demand and potential business opportunities of drone applications in these industries. Industry representatives discussed also asked to discuss how they perceived that these applications contributed to reducing carbon emissions.

As described in part in the theoretical framework of this study, the customer profile component of the value proposition design methodology is used to research current applications of drones and potential applications of drones that raise interest. The first part of the interviews focused on understanding the current applications used in each industry and evaluating the perceived effect of these applications on carbon emission reductions. The second part of the interview focused on understanding what kind of potential applications raise interest among the industry representatives and evaluating what kind of effects these applications would have on carbon emissions. As interviews for the potential customers are structured in a way that the current applications and potential applications are discussed separately, the division between current applications and potential applications remains as clearer.

Further researched industries were chosen based on the literature review and drone service provider and subject matter expert interviews. Organizations that were contacted were searched based on guidelines that Osterwalder *et al.* (2014, p.118) suggest for finding trial customers. They suggest that potential trial customers should have a problem and be aware of having the problem. They should also be actively looking for a solution and preferably have tried to put together pieces of the solution. Lastly, they should have a budget or a possibility to acquire a budget for the solution. All interviewed organizations were known to have been testing with the use of drones or having current operations with drones.

Industry representatives were interviewed between 29.1. – 1.3.2021. Interviews were conducted as semi-structured interviews and their length varied from 20 to 60 minutes. Interviews were recorded and transcribed. The thesis was sent to the interviewees so that they were able to check referenced parts.

3.2.3 Panel discussion and co-creation workshop

Within the project *Carbon neutral drone service solutions in Southern Finland* and together with KiraHub, a panel discussion and a co-creation workshop *Advancing carbon neutrality with drones in constructed environment* were organized on 3.5.2021. KIRAHub is an innovation ecosystem within the constructed environment, that visions to make Finland a forerunner in sustainable digitalization in real estate and construction. The panel discussion included three experts who discussed their views using drones in the constructed environment, as well as the carbon neutrality effects which they associate with the discussed applications. Panelists are represented in table 17. The panel discussion was videoed and more detailed notes for this research were created from the recorded video.

Table 17. Panelists in event Advancing carbon neutrality with drones in constructed environment

Person	Job title	Organization	Abbreviation used
Panelists			
Marko Rajala	CEO	Tietoa Finland Oy	M.R.
Kari Hirvijärvi	CEO and Founder	Aiforsite Oy	K.H.
Lauri Hartikainen	CEO	Pointscene Oy	

The co-creation workshop that followed the panel discussion was arranged to create a discussion of how drones can be used to reduce carbon emissions in the constructed environment, what kind of challenges have been identified and what kind of solutions can be found address to these challenges. The co-creation workshop had 15 participants and the discussions took place in groups in Teams. Guiding workshop questions are represented in Appendix C. Participants used the Miro board as a tool to represent and prioritize ideas during the workshop. Miro board notes were used to review the findings from the workshop.

3.3 Analysis of empirical data

This research used thematic analysis in analyzing qualitative data. King and Brooks (2018, p.220) describe that qualitative research typically produces a large amount of detailed data, and this was applicable to this research as well. King and Brooks (2018, p.219) describe thematic analysis as a form of qualitative data analysis that focuses identifying, organizing and interpreting themes in textual data. In thematic analysis, themes are described as recurrent and distinctive features in the qualitative data that the researcher finds relevant to the research question (King and Brooks, 2018, p.219). Themes are identified, made sense of, and highlighted in a way that the important features of the research phenomena can be communicated and understood by a wider audience (King and Brooks, 2018, p.219).

As the amount of data gathered from the interviews was quite extensive, data was analyzed by grouping it on two levels. Data from the interviews with drone service providers and subject matter experts was first grouped by their main theme. These themes included factors that affect the further development of the market for drone applications, views on the challenges related to purchasing and providing drone services, as well as the different application fields: construction, agriculture, logistics, surveillance, private security, and forestry management. Data was grouped in excel in a way that a short description represented a discussion point. Within the main themes, data was reorganized to subtopics. Tables of the applications and their associated effect on advancing carbon neutrality were created, and the grouped findings were further discussed in a text form. Understanding from the drone service provider and subject matter expert interviews guided the selection of industries that were further researched or scoped outside further interviews.

Data analysis from the interviews with the industry representatives followed a similar approach. However, the main themes consisted of only the three application fields that were further researched: construction, private security, and forestry management. Discussed applications were grouped based on whether they represented a current application or a potential application that raises interest. As applications were discussed, their effect on advancing carbon neutrality was evaluated. As with the drone service providers and subject matter experts, tables of the applications and their associated effect on advancing carbon neutrality were created. The key jobs, pains, and gains related to construction, private security, and forestry management were summarized and visualized according to the theoretical framework of this research. Representation of jobs, pains, and gains of the industry representatives does not reflect whether the applications contribute to advancing carbon neutrality or not.

Findings from the panel discussion and co-creation workshop have a supplementary role in this research. Findings from the panel discussion were used to provide additional viewpoints in the field of construction. Co-creation workshop materials were reviewed, and a few relevant findings were included in the findings in the field of construction.

4 Findings

This chapter first describes how specializations of drone operators have recently been in Finland. Findings that are discussed include factors that affect further development of the market of drone applications. Also, a view related to the challenges of purchasing and providing drone applications is described. The emphasis of this chapter is on describing the applications of drones that can advance carbon neutrality. This research discusses these findings from the fields of construction, agriculture, logistics, surveillance, private security, and forestry management.

4.1 Factors that affect the further development of the market for drone applications

Factors that are seen to affect further development of the market for drone-powered solutions in Finland correspond largely to the ones that McKinsey & Company had identified in 2017. This section describes the views of drone service operators, subject matter experts, and workshop participants about public acceptance, economic drivers, technological capabilities, safety, regulation, and infrastructure.

Public acceptance

In the workshop, it was described that public acceptance is shaped by perceptions of the safety of drones, risks of potential invasions of privacy as well as the current unawareness of the potential benefits of drones. Timo Lind describes that currently, the public is likely to have a somewhat neutral approach towards drones, as drones are still a rarity and therefore the public has not had too many encounters with drones.

Similarly, like Lind, Laura Ruotsalainen mentions that drone technology is still a fairly new technology for the public. Ruotsalainen discusses the adoption of new technologies at a more general level. She describes that the acceptance of technology is related to the understanding of the technology (Ruotsalainen). Acceptance of new technology can be advanced by keeping people informed and sharing information about the technology actively (Ruotsalainen).

Antti Perttula discusses that to advance public acceptance, it is important to keep the message about the drones ongoing and help people to accept the noise level that drones cause. Perttula describes that public acceptance can be advanced by concrete actions such as including drones in the design pictures of new areas. Perttula describes that integrating drones into infrastructure should be done to new areas that are being planned or areas that are facing big renovations. Perttula sees that making changes to some of the downtown areas would cause resistance from the residents.

Economic drivers

Lind describes that there is a need for being able to remotely operate a drone fleet. This would enable the scalability of work (Lind). Lind describes that the need to have a person manually operating one drone at a time is restricting profitable business opportunities.

Similarly, Perttula describes that in many drone applications, the idea is wasted if the scalability of drone flights cannot be utilized. Perttula discusses package delivery as an example of an application where the benefits of the idea are lost. This is because there is a need for having a person at both ends of the flight, as well as people maintaining the visual line of sight throughout the whole flight (Perttula).

Closely related to what Lind and Perttula pointed out, Markus Hohenthal describes that to reach big savings related to the reduction of human resources, actions need to be highly automated. With automated drone operations, logistics can be done differently from the current way, which can lead to economical savings and have positive ecological effects (Hohenthal). Hohenthal also raises an important point related to the financing of drone service development. Not having an integrated air traffic management system and airspace can hinder getting funding for drone operators in cases, where investors see this as an uncertainty (Hohenthal).

Technological capabilities

Kari Mäenpää describes that technology can be seen as one of the biggest restrictive factors as short flight times are limiting the possibilities. Mäenpää describes that there is a need for better battery technology that would increase flight times. Lind sees that technology poses some restrictions related to flight times and loading capacity. Lind describes that battery technology development is driven by the development of electric vehicles. When the options of loading the batteries and changing the batteries between drone missions are discussed, Lind describes that charging the batteries appears to be a better option. Lind describes that if the battery recharge speed is fast enough, it is possible to fly some and recharge some.

From the carbon neutrality point of view, it is essential to consider how the electricity for electric battery drones is produced (Perttula). Some drones are not powered by electricity. It is acknowledged that combustion engine drone applications can reduce the overall carbon emissions of the task at hand. Some combustion engine drones can currently reach longer flight times than drones that are powered by electricity. However, combustion engine drones are scoped outside of this research as this research focuses on finding applications that advance carbon neutrality.

Lind describes that fuel cell technology is also a possible energy source for drones. Perttula describes that fuel cell technology drones have reached 4 hours of flight time. Solar-powered drones are used closer to the equator (Perttula). Perttula describes that there are hybrid drones that combine combustion engine and electric engine and that these drones fly up to 5 hours and a few hundred kilometers.

Similarly, as Mäenpää and Lind, Risto Linturi sees that flight times of drones are too short for many practical applications. Linturi sees that the battery development will make it possible to reach flight times of 1 to 2 hours within the next 5 to 10 years. Linturi describes that this would be possible for also other than vertical take-off and landing (VTOL) drones or by using difficult-to-manage hydrogen containers. VTOL drone is a drone that takes off and lands vertically but flies like a fixed-wing drone.

There is also a need for developing capabilities of drones for winter and rain (Lind). Lind describes that some of the potential applications would need to be delivered despite the weather. Mäenpää describes that drones that can fly in hard wind or rain are a rarity. Weather conditions such as freezing of propellers cause problems when there would be a need for continuous operations (Mäenpää).

Options for navigating drones are using optical systems on the drones or navigating based on satellite technology (Ruotsalainen). Lind describes that for the navigation of drones, there is a need for a radio connection that works in a vast area. In this kind of system, the hand-over of connection would happen between the cells in the network (Lind). Lind describes that 5G networks need to be built so that their coverage reaches up to the level of drone operations. Also, Ruotsalainen describes that a dense 5G network could be used in navigating drones. Ruotsalainen describes that currently there are no completely robust navigation technologies that could be used to fly drones between buildings in cities.

Perttula sees that drone technology is not yet at the level that would be required for safe operations. He mentions that some professional systems have double-systems to ensure that the backup will continue to work in cases where the primary system fails (Perttula). Perttula sees that the technological restrictions can be solved if testing of solutions is allowed. Lind describes that there is a need for developing capabilities that allow drones to be remotely piloted as a fleet. Hohenthal describes that there is a need for integrating drones to air traffic management control systems. He describes that situational awareness needs to be raised to the level that corresponds to the current one in manned aviation.

Safety

Lind describes the safety risks related to drones. Safety risks include the risk of misuse, such as invading privacy while photographing. There are risks of losing a delivery packet to another person (Lind). This can happen if the delivery is accidentally delivered to the wrong person due to an error or if another person picks up a delivery that was not meant for them.

Mäenpää describes that there are safety risks related to information security. He describes that the newest drones will have coded radio communication, which will require a lot of work to hijack. Mäenpää describes that there are intentional and unintentional disturbances towards radio communication.

Regulation

Mäenpää describes that the drone regulation in Finland has been flexible and that the approach to performing testing has been responsive. Mäenpää describes that small exceptions nationally are possible from the common EU's drone regulation. Mäenpää described that preparations for the common airspace are ongoing and that it is difficult to say how quickly the common airspace can be created. Mäenpää mentions that it could take up to decades. Also, Hohenthal discusses that flight control systems that connect unmanned and manned aviation have been under preparation for a long time. Using these would allow everyone involved to have a good understanding of the situation. Hohenthal mentions that there are not too many vehicles that fly at low altitudes. He sees that it is important not to let these few vehicles restrict larger transformation in the logistic sector. Hohenthal discusses that there would be a need to enable beyond visual line of sight (BVLOS) flights. He describes that it would be important to enable BVLOS flights quite soon, as these are a competitive factor for some drone applications (Hohenthal).

Enabling automated flights was discussed in the context of economic drivers. It is also discussed in the context of regulation. Perttula describes that current regulation does not allow automated flying if a person is not constantly following the flight visually. Perttula sees that regulation would need to allow automation of operations to benefit from the business opportunities that drones provide.

Currently, automated operations can be performed if a temporary danger zone is established (Perttula). It is possible to apply for temporary danger zones from Traficom and Finnish Defense Forces so that automatic flying can be performed within the temporary danger zone (Hohenthal, Perttula). Mäenpää describes that it is relatively easy to apply for a temporary danger zone permission to a single area. Applying for a temporary danger zone needs to be done 10 weeks beforehand and activated on the previous day of the flight

(Mäenpää). When asked if temporary danger zones could be used for wider business operations, Mäenpää describes that applying permissions for temporary danger zones in multiple locations for business purposes could be burdensome.

In the workshop that was arranged in the project *Carbon neutral drone service solutions in the Southern Finland*, regulation was seen as a challenge in drone operations. It was described that some operators/pilots do not obey the rules. Some of the participants perceived regulation as diverse and constantly changing.

Infrastructure

Lind describes that it is not reasonable to have a trained person operating each take-off and landing station. Instead, it would be necessary to have automated systems in the urban environments. This would include automated flights, landing, unloading, and in the best-case scenario, charging. Lind describes that building landing areas are necessary also in sparsely populated areas. Lind describes that in sparsely populated areas, some operators use winches to deliver packages. Lind describes that from the logistics perspective, multiple pieces of infrastructure are missing and need to be considered.

Perttula sees that city planning that is suitable for drone operations requires flight zones for different sized drones, not permitted flight areas, landing areas, emergency landing areas, as well as charging areas where the drones can also warm themselves. Lind describes that the use of air taxis would require building vertiports where people can board the air taxis. Lind describes that it would be optimal to connect vertiports to the network of other core stations of transportation.

4.2 View on challenges related to purchasing and providing drone services

Challenges related to purchasing drone services

Based on the workshop and the interviews for drone service providers and subject matter experts, challenges related to purchasing drone services were identified. Mäenpää discusses that clients can face challenges when they try to evaluate the services based on the websites. He describes that to improve this, the websites of service providers should provide proper information about what the operator is capable of and what kind of equipment they are using. This would be necessary especially for making decisions about if the service is to be purchased or conducted in-house (Mäenpää).

In the workshop, it was recognized one of the biggest challenges related to drone use is the lack of awareness towards drone services. In the workshop, it was mentioned that there is a rare number of service providers. Also, evaluating the knowledge of the service providers was perceived as challenging. The lack of transparency in the pricing was considered a challenge. Lastly, it was described that it can be challenging to understand which are applications that would be suitable for drones.

Pirkka Herpiö describes that clients can have difficulties understanding what they are purchasing. Herpiö describes an extreme case where salespeople were trying to sell a system that the client would not have been allowed to use. Herpiö describes that the knowledge of the different drone operators varies a lot. He describes that the skills and knowledge of drone operators need to improve. Herpiö mentions that low quality of work from one service provider can harm the perceived image of the quality of work that drone service providers offer.

Lind describes that drone services are missing a service model where the service could be ordered via an app that has multiple service providers offering their services. Similarly, Herpiö discusses the need for a platform of service providers. By purchasing through this platform, a client could rely on the quality of work and know that all requirements for the conducted work have been taken care of by the service provider (Herpiö). Online drone service procurement platforms were in the focus of a Drone as a service Hackathon arranged by Stara in Finland in fall 2020, which shows that there is interest and development towards establishing an online drone service procurement platform.

Challenges related to providing drone services

Based on the interviews with drone service providers and subject matter experts, challenges related to providing drone services were identified. Lind describes that the market is missing forward-looking clients and that the services will be provided and developed when there are clients that are willing to pay for them. Herpiö describes that all potential clients do not have a realistic view of how drones operate. He mentions that some potential clients assume that drones would operate autonomously and not need a person involved in operating, monitoring, and maintenance. Another challenge Herpiö describes is the budget that potential clients plan for the drone operations. Herpiö describes that in some cases, the drone should cost about 30-40 percent of the total budget, but some potential clients perceive that the budget consists mostly of the cost of the drone.

Deciding if a drone service should be produced in-house or purchased

Those who are interested in operating with drones need to decide if the service should be provided in-house or purchased from a service provider. Herpiö describes that organizations in Finland tend to build capabilities and run the operations in-house. Lind describes that it is still unclear for organizations when to build capacity in-house and when to buy as a service. Related to the make-or-buy decision, Lind describes that in many cases it is clever for an organization to use a service provider, at least in the beginning, as a service provider can more easily optimize the utility rates of the drones. Lind mentions that a market where the drone service provider could to a large extend optimize the utility rates of drones and use one flight for multiple tasks is not currently in place.

A challenge related to providing services in-house is that person can have only limited hours in a week to perform the drone operations (Herpiö). Herpiö describes that sometimes the time reserved is not enough to ensure a high-quality result and maintain the drones in optimal condition. Herpiö describes that there can be a challenge in developing the knowledge of the personnel as the technology develops at high speed. Lind describes that the lifecycles of the drone equipment are relatively short and that a 3-year-old piece of equipment can already be outdated from one point of view.

4.3 Applications of drones in construction

This research evaluates that construction and maintenance are among the most mature application areas of drones in Southern Finland. Among the discussed applications, several use cases that contribute to carbon emission reductions can be identified. However, evaluating the carbon emission reduction of an application is challenging when the contribution to emission reductions is created indirectly.

Applications that drone service providers and subject matter experts identified in construction and maintenance are represented in table 18. Four interviews for the construction industry representatives were conducted to gain better insight into the applications and their effect on carbon emissions. In addition, insights are combined from panel discussion and workshop. Current applications are summarized in table 19 and further described in part 4.3.1. Applications that raise interest are summarized in table 20 and discussed in more detail in part 4.3.2.

A summary of identified pains, gains, and jobs of using drones in construction industry applications is represented in figure 10. This summary consists of findings from the interviews with construction industry representatives and does not discuss views represented by the drone service providers or subject matter experts.

Table 18. Current applications of drones in construction discussed by drone service providers and subject matter experts

The focus of the application	Reference
Using drones to provide source information for earthmoving in construction sites	P.H.; K.M.
Using drones to provide a situational view to the construction site	K.M.
Using drones to support road infrastructure building	P.H.
Using drones to gather data for Building Information Modeling (BIM), creating a 3D model of a building	P.H.; A.P.
Using drones to survey humidity	K.M.
Using drones to perform inspections to infrastructure	T.L.
-Building infrastructure inspections	R.L.
-Road infrastructure inspections	T.L.; R.L.
-Wind farm propeller blade inspections	T.L.
-Power line inspections	T.L.
-Roof maintenance inspections	A.P.
-Antenna inspections	A.P.
-Crane inspections	A.P.
-Bridge inspections	T.L.
-Solar panel inspections	K.M.
-Heat leak inspections from buildings	R.L.; K.M.

(green) Application is linked to advancing carbon neutrality (based on the interviews)
(white) Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

Kari Mäenpää describes that carbon emission reductions from using drones in construction can come from detecting problems at an earlier phase, which can decrease unnecessary work or material use. Linturi describes that battery capabilities and therefore flight times are expected to grow in near future. Linturi describes that then surveying roads and infrastructure can be performed by drones, and maintenance actions can be focused better. Surveying with drones would result in reduced unnecessary physical visits (Linturi).

Lind describes that the number of operators is gradually growing in inspections to infrastructure, roads, wind farm propeller blades and power lines. Lind describes that in bridge inspections, main operators in Finland recognize drone as a tool. Drones that can be suitable for example in performing inspections under the bridge, which can be expensive by other means.

Table 19. Current applications of drones in construction discussed by industry representatives

The focus of the application	Reference
Using drones to share information about hard-to-reach places in building renovation planning	V.N.; M.V.; R.LA.
Using drones to gather better source information for projects	M.R.
Using drones in creating documentation	V.N.; M.V.; T.H.
Using drones in demolition sites	
-Sharing 3D model to potential contractors	V.N.
-Evaluating which components can be resold	V.N.
-Gaining a situational view of the area	V.N.
Using drone gathered data for earthmoving	R.LA.; T.H.; M.V.; L.H.
Using drones to detect air leakages from buildings	R.LA.
Using drone gathered data to increase visibility and reduce the need for physical visits to the site	M.V.; K.H.
Using drones to improve the situational view on sites and lead decision-making	
-Planning the movements of the vehicles on the site	T.H.
-Reducing unnecessary moving of goods on the site	T.H.
-Communicating with the project team and contractors	R.LA.
-Area planning	M.V. T.H.
-Monitoring and planning site safety	M.V.; R.LA.

Application is linked to advancing carbon neutrality (based on the interviews)
Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

Table 20. Potential applications of drones in construction discussed by industry representatives

Focus of the application	Reference
Using drones in automated site documentation	V.N.; M.V.
Using drones to guard construction sites	M.V.
Using drones to analyze building facades below surfaces	V.N.

Application is linked to advancing carbon neutrality (based on the interviews)
Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

4.3.1 Current applications of drones in construction

Using drones to share information about hard-to-reach places in building renovation planning

Based on the interviews, drone-gathered data can be used to assist in building renovation planning. According to Ville Niemikari, drones allow convenient information collection on hard-to-access spaces such as rooftops. Visual information about the damages is available and with this information, a planner can locate the damages on building facades and roofs (Niemikari). The information for facade and roof renovation planning that is collected with the use of drones and cameras is faster, safer to get, and detailed (Niemikari). This application of drones is considered extremely cost-efficient when it is compared to having people on lifts (Niemikari). Benefits of using drones in facade and roof renovation planning include that planner gets the documentation directly without having to visit the site (Niemikari). Necessary documentation can be attached directly to reporting, which makes the process faster (Niemikari). One use case for drones in documenting rooftops is that in some cases it is not necessary to do the drawings for the rooftop, as the pictures from the drones can be used directly (Niemikari). As the design engineer does not have to visit the site in person, emissions from transportation to the site can be reduced in cases where the transport would have been done by a car. In some cases, the pilots are people who are working on the site also with other tasks.

Creating a 3D model based on photogrammetric calculations provides visual and measurement information about the damages and the facade that is being renovated (Niemikari). Niemikari mentions that photogrammetry is computationally heavy, and resources and money has been invested in the capability by the organization. Maintenance costs take money and resources and therefore it is necessary also to have many sites where the use of drones can be applied (Niemikari). Niemikari sees that there have not been any specific challenges in the use of drones in this application. Regulation has been flexible enough for building renovations. and necessary notifications for authorities have not been too burdensome (Niemikari).

Also, Vitikainen discusses the use of drones in accessing hard-to-reach places, that cannot be easily inspected. With the use of drone gathered data, it is possible to for example check if eaves on the rooftops are installed correctly (Vitikainen). Drones can be used to gather data if there is a need for performing guarantee repairs that would be conducted after the building has been handed over to the client (Vitikainen). The use of drones in these kinds of tasks replaces the need for renting and bringing a lift to the location for a day (Vitikainen). When there is no need to bring a lift to a building site, carbon emissions from transportation can be reduced. In some cases, the lifts can already be located and used on the sites, and in some cases, the lift is brought to the site just for the occasion.

Tom Helenius recognizes the benefits of using drones to perform inspections. Helenius mentions that he uses drones to perform inspections that would otherwise require using a lift and personally inspecting the issue. Helenius discusses that for example facades can be inspected by using drones. He also mentions that he uses drones to cut the need for walking in the sites and within the constructed buildings. However, Helenius did not create an association between the reduced use of lifts and reduced carbon emissions.

Riku Laiho discusses that with drone-gathered material, a larger number of people can access the information that is retrieved from the hard-to-reach places, such as rooftops. Better knowledge and common understanding about the situation can help to reduce errors (Laiho). When more people have access to information, issues that need to be considered in the renovation planning are more likely to be noticed, which should lead to fewer surprises during the construction phase (Laiho). Drones can also be used to document rooftops and similar places when they are ready (Laiho). With this documentation, it is possible to show that everything has been in order when the building has been handed over to the client (Laiho).

Laiho describes that in some cases there is no need for gathering drone images if a building has been laser scanned and that material can be used (Laiho). Laiho describes that drone-gathered material improves decision-making. Laiho mentions that the use of drones does not directly reduce carbon emissions, but carbon emissions are reduced through improved decision-making and quality assurance.

Marko Rajala describes that drones can help to gather better source information for construction projects. As planning is based on building information modeling, plans are easier to construct and evaluate (Rajala). Doing things in vain, and the need for rebuilding decreases (Rajala). Rajala describes that earlier lifts were used to gain access to hard-to-reach places and that sometimes places were left undocumented. If documentation is not done, the information that the planning is based on is not as good as when documentation is available. This creates risks of having to redo some parts of the construction. In addition, when good information, models, and documentation is available, it decreases the need to visit the sites (Rajala). In a small context, this does not have a big effect but when the visits are reduced at each project, the effect becomes bigger (Rajala).

As a conclusion, when using drones to gather data from building facades and rooftops, potential carbon emission reductions would arise from the decreased need for the planners to visit the sites in person, decreased need to transport lifts to sites and use them, and from improved decision-making due to a larger group of people having the possibility to use the information.

Using drones in creating documentation

Based on the interviews, drone-gathered data can be used in documenting. Niemikari mentions that drones can be used in gathering documentation of single events such as the location of a pipeline or a construction phase (Niemikari). This kind of data does not proceed to planning but is documented for the client. The benefits of documenting single events with drones include speed and convenience (Niemikari). For example, documentation of a long pipe is fast and therefore the additional cost for the client is not high when compared to the value of information (Niemikari).

Also, Vitikainen discusses the potential of using drones in gathering documentation. As an example, he describes documenting the location of underfloor heating system pipes, which are to be covered with concrete. Documentation allows proving how the installation has been done (Vitikainen). One benefit of using drones in documenting is the ability to reach relevant perspectives from, for example, directly above (Vitikainen). Also, Helenius discusses the use of drones in documenting structures that are being covered. Helenius mentions that with the use of documentation gathered with drones, there is a knowledge of where the covered structures are situated. Laiho mentions that it can prove out to be beneficial to document things for later use even if at the moment it is not clear what the documentation can be used for.

Using drones in demolition sites

Based on the interview with Ville Niemikari, two ways to reduce carbon emissions can be identified from using drones in the planning of demolition site work. The first way relates to reducing the movement of people. 3D models can be shared with the contractors, and with this information, contractors can evaluate if they are interested in the projects without having to visit the site in person (Niemikari). Based on the information, some contractors can notice that decide that they are not interested in the project. This reduces the carbon emissions from transportation (Niemikari). Unrelated to using drones in demolition sites, Niemikari mentions that 3D modeling can be used to reduce visits also in sites where regular visits are not encouraged, such as schools and hospitals.

The second way to reducing carbon emissions is related to the recycling of materials. Drones can be used in the demolition sites to provide imagery of materials and objects that can be further sold and utilized (Niemikari). These kinds of materials and objects include for example windows, doors, stairs, panels, surface materials, and technical parts that can be used somewhere else (Niemikari).

Niemikari describes that using drones to survey demolition sites in the planning phase is a fast way to get a situational view of an area that has lots of buildings. He mentions that the use of drones in this application has not included big challenges. However, if the area is big, lightning conditions can change within the material that is being documented. In most cases, this does not affect as the material is gathered for technical use. For architecture planning, there is a preference for a consistent light within the material (Niemikari).

Laiho describes that evaluating emission reductions that can be achieved with drones in construction is not straightforward and he believes that the biggest effects to reducing carbon emission come from improved quality. He describes that drones are used to do things that were not previously possible, and therefore it cannot be directly claimed that there is a certain amount of carbon emission reduction. The possible effect of carbon reductions comes from producing less waste, fewer errors, having easier ways to assure quality, and having a better situational view (Laiho). He mentions that this can change if in the future drones conduct tasks in the construction site, such as plastering walls. In this case, the possible reduction in carbon emissions could be more easily evaluated, as drones would replace using people and lifts in tasks (Laiho). Laiho mentions that the current use of drones is about taking images and forwarding information. Laiho describes that there are a lot of new use cases emerging.

Based on the interview with Laiho, four application areas that can have an impact on carbon emissions can be identified. These include the use of drones in earthmoving, sharing information such as data gathered and shared about renovating rooftops, detecting energy leaks, and traffic arrangement planning.

Laiho describes that in their actively monitored projects, drone flights are typically performed every second week. In projects that are further away, a pilot visits and gathers the data for example at the very beginning of the construction phase and when the construction is finished.

Using drone gathered data for earthmoving

Using data gathered by drones can help to reduce the carbon emissions that result from moving trucks that transport the earth or from working with excavators that do the digging

(Laiho). Laiho describes that typically in earthmoving, the drone imagery is gathered at different phases. The first phase can be for example after the trees have been cut, the second phase can be after removing the topsoil and the last phase be after the digging has been performed (Laiho). The data is also gathered in relevant turning points during the digging phase (Laiho).

Photogrammetry can be used to gather and share up-to-date information about ground shapes. A 3D model of the ground surface is created with software from the information that is gathered with photogrammetric scanning. With the help of this information, volume calculations can be conducted. Better information about volumes of the earth's mass reduces the need for transporting it back and forth (Laiho).

Gathered data about the ground shapes can also be used in following the progress of a construction site (Laiho). Laiho describes that the surface model can be created for example every second week. The benefit of using drones in earthmoving comes from the possibility to share the information from the system also with the ground builders. As all project participants have a good situational view about what has been done and what is going to be done in the project, it is easier to avoiding doing unnecessary things, which is a good basis point for reducing carbon emissions (Laiho). Laiho describes that errors cost money, time, and resources.

Also, as information is shared with a larger group of people that includes people from outside the main contractor, more point of views and expertise can be utilized in earthmoving (Laiho). Laiho describes that often not that many people have views on how earthmoving should be conducted. One person can come up with a more lightweight solution to the matter that is being worked on (Laiho). a more lightweight solution would then reduce the energy used by excavators. (Laiho)

Laiho described challenges related to photogrammetric scanning. He discusses that to utilize photogrammetric scanning, the earth's surface must be clean, as photogrammetric scanning cannot be done through trees or vegetation (Laiho). Snow on the surface also causes an error. In addition, winter circumstance restricts the flights. In the wintertime, it is dark, which can reduce the quality of the images (Laiho). Raining and cold temperatures are also restricting the flights (Laiho).

Also, Helenius discusses the possibility to use 3D models in earthmoving, but this discussion is not related to reducing carbon emission with the use of drones. Helenius discussed the possibility to use data gathered with drones to create a view of elevations on the site. He describes how with 3D modeling it would be possible to get information related to the volumes, such as volumes of materials that are being mined. He discusses that this kind of information would be gathered in the beginning phase of the construction project. Helenius mentions that he has not had a need for this kind of work in his sites (Helenius). Vitikainen also mentions the use of 3D models in earth moving (Vitikainen).

Lauri Hartikainen describes that the future development of the use of autonomous machinery on construction sites could lead to reductions in carbon emissions. He describes that drones and other mobile surveying methods can be used to provide information to guide the work of autonomous machinery in the future. More efficient use of earthmovers and materials would then result in fewer emissions (Hartikainen).

Using drones to detect air leakages from buildings

Laiho describes that drones with thermal cameras can be used to detect air leakages from buildings. He describes that finding air leakage from buildings in the planning phase of building renovation allows these leaks to be repaired in the project. Laiho mentions that their organization does not own a drone with technology for this purpose but says that consultants could be used to provide the service (Laiho). In addition to the planning phase, thermal cameras could be used to inspect the building in the phase where the renovated building is handed over to the client (Laiho). By detecting and repairing energy leakages, the energy consumption of buildings can be reduced.

Drone-gathered imagery can be used in traffic arrangement planning. Construction companies need to consider how traffic arrangements next to the construction area are organized (Laiho). Often the construction company rents the area from a city and plans how the traffic in the environment will flow (Laiho). The current challenge is that for example, Google Maps data does not keep up with the pace of the changes within the environment (Laiho).

The benefits of using drone gathered data in traffic arrangement planning is that the plan can be based on the current situation and not based on a plan or other basic information that does not represent the area in an accurate way (Laiho). The more accurate image helps in creating new traffic arrangements (Laiho). The more flowing the traffic is, the less energy it consumes (Laiho). Laiho describes that the impact of using drone material in the planning of traffic arrangements is larger in infrastructure projects than in building construction projects because in infrastructure projects the rearrangements of traffic can be longer and change more often (Laiho). Using drones to plan traffic arrangements an application that was also recognized as beneficial in the workshop.

Using drone gathered data to increase visibility and reduce the need for physical visits to the site

Similarly, as Laiho, Vitikainen describes that there is no direct connection between using drone images and producing things with fewer carbon emissions (Vitikainen). However, by knowing the situation better it is possible to make better decisions (Vitikainen). As data collected by drones is in digital form, it can be redistributed within the organization without a limit for the times it can be distributed (Vitikainen). Vitikainen describes that if a site has 200 workers, there can be a large group of people, such as 1500 people, working as suppliers or in the planning. If more detailed information now reaches this larger number of people, it can lead to making more accurate or smarter decisions (Vitikainen). With improved decision-making, it is possible to avoid doing things in vain at the construction site, which affects the use of carbon (Vitikainen). In addition, as measured information is given to the people at the site, this may open new use cases and views that cannot be seen beforehand. (Vitikainen)

In this context, drone gathered data refers to either photogrammetric data that is turned into a 3D model or aerial photography data (Vitikainen). Vitikainen mentions that especially video material sizes are heavy, and information is, therefore, harder to distribute. He wonders that the system could become too heavy if, for example, 50 sites would share measurements, images, and video once a week (Vitikainen). Vitikainen describes that it would be important to think about how the image, video, or scanned material is distributed to those who can benefit from it. Vitikainen mentions that if the drone gathered materials are weekly distributed for the people working on the site, the effect to potential emission reductions can be completely different than what they could be in the case where the information is only used by the person who gathers the data (Vitikainen). Also, in the workshop, it was recognized that one of the biggest challenges related to drone use is the management, analysis, and distribution of the data that is gathered with drones.

Vitikainen describes that the drone gathered data can replace the physical visit on the construction in cases where the issue can be seen remotely (Vitikainen). Carbon emissions are reduced in cases where the site visit would have been done with a non-electric car. Helenius agrees with the statement that sharing drone-gathered data could reduce for example the need for engineers to visit the site in person. However, he describes that the use of drones in his site is done to support his purposes and therefore it is not used to reduce the need of visiting the site (Helenius). This mention illustrates that reducing the number of visits to sites is not an obvious gain. It is suggested that the information sharing should be planned and systematic in order to benefit from the possibility to reduce unnecessary visits to the sites.

Kari Hirvijärvi described that drones as part of a solution can enable doing work for the sites remotely. Hirvijärvi sees that as part of these kinds of solutions, drones contribute to reducing carbon emissions. Hirvijärvi describes that it is possible for example for their digital engineers to work with a construction site that is in India. He describes that in their solution, flights are conducted once a week on the sights and combined with other acquired data. Data can be used in creating and comparing situational views, as well as doing measurements about heights and capacities (Hirvijärvi). Comparing to plans allows detecting differences between plans and situations on the site (Hirvijärvi).

Findings from the workshop are in line with the interviews, as they suggest that using drones can be used to reduce carbon emissions as they reduce the need for moving and decrease unnecessary inspection visits. Findings from the workshop also stated that real-time information from the sites can reduce work that would be done in vain. Increased number of inspections on industrial equipment and buildings was seen to contribute to detect problems earlier. It was also discussed that the use of drones can result in shortened construction lead times, which reduces carbon emissions.

Using drones to improve the situational view on sites and lead decision-making

Helenius is uncertain of the link between using drones and advancing carbon neutrality but still mentions few used ways that might influence carbon emissions in decreasing way. These are related to the movements of vehicles on the site. Helenius describes that with the use of drones it is possible to perceive the construction site in a much more detailed way (Helenius). With drone images, it is easier to plan the routes for truck traffic in a way that reduces the need for extra movements (Helenius). When the cornerstones of the buildings have been marked, it is possible to determine the locations of buildings based on drone imagery (Helenius). With these images, it is possible to plan the movements of truck traffic in a way that considers the pivot pins of trucks (Helenius). Helenius describes that routes are planned in a way that there is no need for the trucks to reverse. This kind of planning helps to eliminate excess movements. Another way to limit extra movements is by guiding the suppliers to take materials directly to correct locations on the site. In this way, there is no need to relocate them after they have arrived (Helenius). In conclusion, based on the interview with Helenius, the connection between using drones and reducing carbon emissions is not seen too optimistic.

As described earlier in this chapter, Laiho discussed that drones can have an indirect influence in reducing carbon emissions through reducing errors or unnecessary work and improving quality. Also, Vitikainen discussed that improved decision-making can result in doing less unnecessary work, which has its influence on reducing carbon emissions. As possible carbon emission reductions appear to come indirectly, applications of drones related to site planning are also discussed. It is emphasized that the interviews did not connect uses in site planning to reducing carbon emissions.

Data gathered with drones can be used in site monitoring and planning in the ways that are described below. Drone-gathered imagery can be used in communicating within the project team and with contractors (Laiho). With the use of an orthographic picture instead of a plan, people can more easily understand the context, as the image corresponds to the real environment that is not yet finished (Laiho; Helenius). Having the imagery of a situation can be also used to compare with the drawings (Helenius). Planning further work phases is easier when the visual image of the site can be shown for the team and used in discussions (Vitikainen; Helenius).

Drone-gathered images can be used as a basis for area planning. Through the use of drone-gathered data, it is possible to gain a better understanding of how much space is available for materials and routings of logistics (Vitikainen). An example of area planning is utilizing a 3D model to plan where to locate a concrete truck so that the concrete can reach the building (Laiho).

Related to site safety, it is for example possible to see if routes and materials unloading places and are following safety instructions (Vitikainen). It is also possible to see for example if the storages are in order and detect other issues related to site safety (Laiho). Laiho described that occasionally some construction materials that are stored outside could become unusable due to insufficient protection (Laiho). Through drone images, people who do not make regular visits to the site can also notice these kinds of errors in the protection of materials (Laiho).

In addition to discussed applications of drones in construction, drones are also used to imagery for marketing and sales purposes (Laiho; Helenius), as well as with investor communications (Helenius). However, these two application areas are not seen to contribute to carbon emission reductions.

4.3.2 Potential applications of drones that raise interest in construction

This chapter describes applications that raise interest and that could contribute to reducing carbon emissions in construction. Three identified applications raise interest and are stated in the interviews as not currently used. These application areas include automated site documentation, autonomous site guarding, and automated building facade damage analysis.

Using drones in automated site documentation

Ville Niemikari says that an application that raises interest is automated site documentation. In this kind of application, the drone would be situated on the site and it could send pictures over the web. Niemikari sees that a documenting system that does not need a person could be sold to construction sites with a success rate, and with some construction site types it could be sold almost in all the cases. Documenting the frame-building phase would give the site supervisor a material package that would show how everything was done (Niemikari). Also, it would be possible to follow what has been the latest phase that has been conducted and when each of the construction phases has been finished (Niemikari).

Also, Vitikainen describes interest in using autonomous drones to create a situational view. He describes this application as a long shot in the future (Vitikainen). In this application, an autonomous drone would tour the construction site and scan the building from inside and outside. Based on this material, a situational view could be constructed, and it would be available for the site managers. Vitikainen describes that better knowledge about the current situation could lead to better decisions, which could reduce the amount of waste.

Helenius describes that there have been discussions about visions of drone use cases within their organization and that one of these use cases is to have an autonomous drone that would tour the site after the workday ends. The drone would compare how the construction site phase corresponds to the plans and in this way compare the progress of the construction to the schedule. Therefore, he does not see the added value of this kind of application as he can evaluate this himself based on visual inspection of the site.

Using drones to guard construction sites

An application that could potentially lead to carbon emission reductions is guarding construction sites with autonomous drones (Vitikainen). The application is visioned so that drones would fly and charge independently (Vitikainen). With a certain number of drones, the construction site could be continuously guarded, for example outside the working hours (Vitikainen). An advanced autonomous drone could detect movement and indicate if something is happening on the site that should not be happening (Vitikainen). This service would likely be outsourced to a service provider (Vitikainen). The current operating model in guarding sites is to have static cameras and for example, a guard that regularly drives to the site inspects the site and leaves (Vitikainen).

Using drones to analyze building facades below surfaces

Ville Niemikari says that they have an interest in an application that goes through the facade of the building and identifies from the surfaces where it is likely that material will fall off. This application was described as more of a curiosity (Niemikari). This kind of solution would help the organization to get rid of using lifts. The current operating model is that a person tries out the facade surface with a hammer and tries to find out from where the materials are likely to fall off. Ville Niemikari mentions that the solution should be extremely cheap as would replace a method that currently uses people with hammers on lifts. Niemikari also mentions that it is possible that this kind of application would be financially or technologically unfeasible. A summary of identified pains, gains, and jobs of using drones in construction industry applications is represented in figure 10.

Figure 10. Identified pains, gains and jobs of using drones in construction industry applications

4.4 Applications of drones in agriculture

This research suggests that when applied, drone applications in the field of agriculture would have good possibilities to reduce the produced carbon emissions. Regardless of the identified potential, customer representatives from the field of agriculture were not interviewed. This was because the interviews with the subject matter experts and drone service providers suggested that the market is currently immature. In this research, identified drone applications are classified as potential applications as they are not largely used in agriculture in Southern Finland. Identified potential drone applications in the field of agriculture are represented in table 21.

Table 21. Potential applications of drones in the field of agriculture discussed by drone service providers and subject matter experts

The focus of the application	Reference
Using drones to monitor sowing and/or detecting needs for additional sowing	P.H.; R.L.
Using drones to guide irrigation	T.L.
Using drones to guide fertilization	P.H.; R.L.; T.L.
Using drones to guide plant protection	T.L.
-Detecting pests	A.P.
-Distributing pesticides (regulation does not currently allow distribution from air)	M.H.
-Guiding the use of herbicides	R.L.
-Identifying locations of weeds	P.H.
-Detecting wild oat	A.P.
Detecting differences in growth between years and analyzing effects of taken actions	P.H.
Counting livestock or reindeers	R.L.: K.M.
Detecting underdrains and underdrain blocks	P.H.; A.P.

Application is linked to advancing carbon neutrality (based on the interviews)
Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

Herpiö discusses that when carbon footprint is considered, agriculture offers bigger opportunities for the use of drone applications than construction. Herpiö sees that the use of drone applications in the field of agriculture has not taken off.

Herpiö explains that to get the farmer to benefit from the gathered information, suggestions should be presented as practical actions that can be taken. Herpiö describes that drone service providers providing these applications should understand agriculture and that currently there are not that many service providers who have this understanding. Herpiö mentions that some farmers have had bad experiences with photographs purchased in agriculture with low prices and low value from the service.

Herpiö discusses that when drone service providers are used in agriculture, the costs get easily relatively high. Herpiö sees that it would be mainly the farmers themselves who would be using the drones to guide their operations. Herpiö mentions that starting the use of drones can be done by borrowing drone equipment from families that possess them.

Similarly, Lind discusses that drone applications in agriculture are not used widely and that the market is opening. Lind mentions that drones could be used to support automated farming, as they could guide other machines. Lind mentions that to get operations fully automized there is still a need for technological solutions for drones. Lind mentions that automation of drone operations should be relatively safe as operations would be performed above fields. Lind describes that if automation is not used, services should be provided in a way that one service provider servers many farms. In this way, it would be possible to benefit from economies of scale and reduces the cost of service to a level that could be reasonable.

Linturi sees that drone applications have excellent opportunities in surveillance, measuring, and monitoring in agriculture. He mentions that emissions in agriculture are significant due to peatland and incorrect farming practices. Linturi describes that peatland produces most of the emissions in agriculture in Finland, and that drone surveying could be used to focus attention on fields and actions that cause the emissions. Linturi visions that sowing and ploughing could be done by robots, which can be remotely guided between the fields. Legally tractors can now be remotely piloted between two fields by using public roads (Linturi). Linturi describes that by providing this kind of automated service in agriculture, the farms would not need to possess tractors and other equipment anymore, as the service provider would own the equipment and perform the operations for many fields.

Drones can be used in the autumn to see if there is a need for additional sowing (Herpiö). Data collected with drones can be used to detecting growth in the field and planning fertilization (Perttula: Herpiö; Linturi; Lind) and the use of pesticides and herbicides (Hohenthal; Linturi). Currently in Europe drones are not allowed to distribute water or any substances. However, in the drone market globally, the benefits of being able to distribute substances are noted.

Herpiö mentions that the benefit of using drones in plant protection is that it enables focusing the actions only to the areas, where they are necessary. Herpiö mentions also, that drones can be used to monitor how some specific changes have affected the fields from one year to another.

Drones can be used to monitor, count and guide animals. Mäenpää describes that drone use in counting livestock in Finland is currently rare (Mäenpää). Mäenpää describes that in Northern Finland some have used drones to count reindeers. Drone gathered data can be used in detecting underdrains (Herpiö; Perttula), which could be used also outside the context of agriculture.

4.5 Applications of drones in logistics

Parcel deliveries have received a lot of attention in applications of drones. The use of drones in logistics would reduce the carbon emissions in applications where drones are successfully used to replace other modes of transportations, such as cars. However, based on the subject matter expert and drone service provider interviews, logistics operations with drones in Southern Finland faces obstacles and are not expected to widely take place in the nearby future. According to the interviews, current obstacles are associated especially with flight distances and payloads that current batteries enable, the profitability of operating, regulatory restrictions related to automated flights, and regulatory restrictions related to flights in an urban area. Identified challenges for drone operations were discussed in more detail in part 4.1. of this chapter.

Herpiö mentions that cost structure and some solutions needed for logistics operations are not strong enough. However, he mentions that they are engaged in some niche projects. Hohenthal sees that logistics is the most challenging area of application as it requires flying close to buildings and possibly close to people. Discussions related to the workshop showed that practitioners from different fields in Finland have colliding views about the timeline of drone flights in logistics and the perceived obstacles. It is worth mentioning that Wing, a subsidiary of Alphabet, operates automated food deliveries in Vuosaari, in Helsinki (Hohenthal). In this research, identified drone applications are classified as potential applications as they are not widely used logistics in Southern Finland. Identified potential drone applications in the field of logistics are represented in table 22.

Table 22. Potential applications of drones in the field of logistics discussed by drone service providers and subject matter experts

The focus of the application	Reference
Using drone taxis to transport people	L.R.; T.L.; M.H.
Using drones in health care applications	
-Arranging logistics between hospitals	P.H.; R.L.
-Delivering medicine to hard-to-reach locations, transporting blood and first aid supplies (in Africa)	L.R.; K.M.
-Transporting first aid medicine or measurement devices or remote doctor in urban areas to the accident site	R.L.
Using drones to transport light objects that need to be transported fast	T.L.; R.L.
Distributing parcels in sparsely populated areas	M.H.; T.L.
-Distributing magazines	M.H.
-Distributing food store deliveries	M.H.

Application is linked to advancing carbon neutrality (based on the interviews)

Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

Using drones to move people

In the longer term, drone taxis are seen to be used in transporting people (Ruotsalainen; Lind; Hohtenthal). Lind sees that drone taxis could be beneficial in routes that current modes of transport do not serve well. Lind discusses that drone taxis are not dependent on traffic jams. Hohenthal mentions that some global operators, such as Volocopter and Joby Aviation, are quite far from developing the systems for drone taxis. Lind estimates that it could take around 5 to 10 years to transport people with drones.

Using drones to move objects

Herpiö and Linturi mention that there is potential in using drones in arranging logistics between hospitals. In some countries in Africa, drones are used to transport medicine to hard-to-reach locations and to transport blood and first aid medicine (Ruotsalainen; Mäenpää). Linturi mentions that it would be possible to transport first aid medicine, measurement devices, a defibrillator, or a remote doctor to the site of the accident.

Lind sees that there is potential for transporting light objects that need to be transported fast. Lind describes that transporting objects would require identifying objects that people want fast and for which they are currently willing to pay extra for the fast delivery. Lind sees that the progress towards transporting objects is happening gradually. Linturi describes that logistics that happen outside the buildings are more relevant in the context of energy use reductions than logistics that take place within buildings. Herpiö discusses that potential can be found in deliveries between port and ship.

Hohenthal mentions that potential savings in terms of cost and carbon emissions can be found on longer routes when distributing parcels in sparsely populated areas. He mentions that in cities other modes of transport, such as electric vehicles are probably more affordable to use in logistics. Hohenthal mentions that based on their tests it would be possible to organize countryside logistics with a 70 percent reduction in carbon emission by using the drone solution that they are currently developing and working with.

Hohenthal mentions that delivering packages that weigh no more than 10 kg would still be economically and ecologically feasible. Hohenthal describes that for economic and ecological reasons, in sparsely populated areas, drones will be used to distribute magazines and approximately 90 percent of package deliveries. Similarly, as Hohenthal, Lind describes that carbon emission reductions can be more relevant in sparsely populated areas if the deliveries are done with an electric vehicle instead of a van.

Point of view to organizing the movement of objects

Linturi describes that a way of organizing parcel deliveries could be by delivering parcels between entities of multiple boxes. These entities could be situated outdoors (Linturi). Linturi discusses that setting up entities of boxes in city infrastructure is a relatively fast way to build the infrastructure needed for drone deliveries.

In the cities, entities of boxes would be located within a walking distance from the end customers (Linturi). Linturi describes that for example stores within malls could place their deliveries to these entities and from there the deliveries would be taken to an entity that is close to the end customer. Linturi describes that DHL has built a prototype of this kind of solution, where the logistics occur between the entities that include multiple boxes. Linturi mentions few operators in Finland that could together be able to build a similar solution. The idea of creating the solution is based on the assumption that DHL and similar operators would not be willing to sell technologies as that is not seen as their core business.

Hohenthal describes that in China, operators such as Alibaba and JD.com send packages to villages that are in areas that are hard to reach. A person living in the village then performs the last-mile delivery. Hohenthal describes that China is approximately five years ahead of the rest of the world in drone logistics.

Point of view on building unique identifiers for object delivery

It is described above how the delivery would change from drone operator to the last mile delivery person in villages. These kinds of handovers between delivery modes occur also upstream of delivery when the mode of transportation is changed. Related to the logistics network and integrating drones into it, Linturi describes that the logistics market can become centralized or decentralized. In a centralized scenario, an operator such as Amazon can provide end-to-end logistics services and infrastructure. In a decentralized scenario, there is a multi-operator environment where for example local operators can contribute to the deliveries within the network. Linturi describes that a decentralized operating model enables optimizing which delivery modes and operators are used at which delivery routes at different times. A rich ecosystem can be more suitable for providing the overall solution, than a single operator (Linturi). Linturi describes that to create a decentralized model, it would be necessary to have a universal unique identifier for the deliveries (Linturi). This identifier could be accessible for relevant parties through a platform. Linturi describes that without a standardized platform, the transaction costs related to information sharing raise too high.

4.6 Applications of drones in surveillance

Based on the interviews, surveillance is seen as one of the areas where drone applications have the highest potential in near future. Surveillance covers multiple areas of drone applications. This research does not focus on drone applications that could advance carbon neutrality in the operations of authorities such as police, rescue services, or the Finnish Defense Forces.

Surveillance includes applications that can contribute to reducing carbon emissions. There is also a large area of applications that are not connected to reducing carbon emissions. Current applications that drone service providers and subject matter experts identified in surveillance are represented in the table 23, and further described in part 4.6.1. Potential applications that drone service providers and subject matter experts identified in surveillance are represented in table 24, and further described in part 4.6.2. Applications related to private security are discussed separately in chapter 4.7 to make representation clearer.

Table 23. Current applications of drones in the field of surveillance discussed by drone service providers and subject matter experts

The focus of the application	Reference
Using drones to gain information about traffic accidents	P.H.
Using drones to model scenes of fire	P.H.
Using drones in photographing	M.H.; T.L.
Using drones in rescue operations	P.H.
Using drones to monitor inventory levels at different industries	P.H.; K.M.
Using drones in detecting trespassing	A.P.

Application is linked to advancing carbon neutrality (based on the interviews)
Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

Table 24. Potential applications of drones in the field of surveillance discussed by drone service providers and subject matter experts

The focus of the application	Reference
Using drones in marine surveillance -Delivering life buoy or a life vest -Performing repeated surveillance operations -Detecting garbage at sea -Detecting oil spills	R.L. R.L. T.L. T.L. T.L.
Using drones in monitoring fire safety -Monitoring forest fires -Gathering information about the location of people and movement of fire in -Providing situational view for fire fighting	L.R.; K.M. L.R. L.R. L.R.
-Monitoring fire safety at factory site	I.2.
Using drones in surveillance of industrial sites	K.M; A.P.; P.H.
Using drones in event surveillance	L.R.
Using drones in traffic surveillance	R.L.
Using drones in detecting burglaries	R.L.

Application is linked to advancing carbon neutrality (based on the interviews)
Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

For example, Kari Mäenpää sees that applications in surveillance and surveying have the biggest potential in near future. Lind sees that surveying, measuring, and photographing have room to grow. Linturi mentions that tasks related to maintenance, guarding, and measuring applications offer quick and big wins.

Carbon emission reductions from surveillance applications can be found in replacing other modes of transportation with the use of drones. Carbon emission reductions can also be achieved in cases in which the drone gathered data reduces the need for a performing physical visit. Drones are currently used in inventory management, area surveillance, traffic accident sites, and scenes of fire.

When considering potential applications in surveillance, it is important to understand that applications that happen in less crowded areas and/or in private property can be easier to implement due to regulatory reasons. Some of the safety and surveillance applications would benefit significantly from the possibility to perform flights where human interventions are minimized.

An important aspect in the potential applications is targeting the work and the visit only to the locations where there is an actual need. Lind discusses opportunities to use drones in guarding and city maintenance-related regulatory and repetitive tasks. When surveillance can be done with drones, the car or the person can be sent only to those locations where it is necessary (Lind). Ruotsalainen sees that the biggest potential can be reached in monitoring or surveying targets, where the monitoring or surveying would be dangerous for a human to conduct.

4.6.1 Current applications of drones in surveillance

Using drones to gain information about traffic accidents and scenes of fire

Herpiö mentions that insurance companies have been using drones in Finland within the past years. Use cases in insurance include modeling traffic accidents and scenes of fire. Herpiö says that this kind of drone operation corresponds to the sustainable use of resources as the researchers do not have to visit the sites as the drone operator visits the site and builds the model. Herpiö mentions that models provide more detailed and accurate data than traditional ways. The operating model is less expensive when all related costs are calculated. This supports the adoption.

Herpiö mentions that drones are becoming more utilized in traffic accidents and scenes of fire. In scenes of fire, a virtual twin about the scene is created. With the use of this model, stakeholders such as researchers do not have to travel to the scene of the fire, which can decrease the carbon emissions. With the knowledge that the model provides, necessary actions about the scene can be started immediately. The documentation about the incident is done and can be used after years. A more efficient operating model offers economic benefits.

Using drones in photographing

Drones are used in photographing (Lind; Hohtenthal). For example, in real estate, drones are used for photographing real estate properties for a sales purpose (Lind). Drone photographs and video provide a better understanding of real estate, and the increased information can in some cases replace the need to visit the site in person.

Using drones in rescue operations

Herpiö mentions that in rescue operations there is a good opportunity to develop operations with drone use. Herpiö also notes that rescue operators consist of different organizations and that therefore rescue organizations have different approaches to using drones. Kari Mäenpää agrees that drones have potential in rescue operations, as the thermal camera could be utilized. Mäenpää sees flight restrictions as a restrictive factor.

Using drones in monitoring inventory levels and detecting trespassing

Herpiö and Mäenpää mention that drones can be used to monitor inventory levels in different industries. Perttula mentions that security organizations use drones to see if trespassers have entered the area that they are guarding. In area surveillance, it is beneficial to use a thermal camera and a camera for visible light (Perttula).

4.6.2 Potential applications of drones in surveillance

Using drones in marine surveillance

Linturi mentions that drones could be used in marine surveillance. Linturi mentions that drones can for example carry a lifebuoy or a life vest that they can drop where needed. Related to surveillance at sea, Lind mentions that repeating surveillance operations that are made with a boat could be potentially replaced drones. Lind considers detecting garbage at sea and detecting oil spills as use cases that could benefit from using drones.

Using drones in monitoring fire safety

Mäenpää and Ruotsalainen discuss the potential application in monitoring forest fires. Ruotsalainen mentions what kinds of use cases could prove to be beneficial. These include monitoring forest fires, gathering information about people in the risk areas, modeling the movement direction of the fire, and gathering information that helps to guide firefighting. Interviewed person 2 describes that they are using a drone in improving fire safety at a factory site. He describes that drones in fire safety use can provide a situational view from about and support guiding the situation. Interviewed person 2 describes that in their application, there is also a small capability for fire extinguishing. He mentions that a thermal camera can be used to detect risks in the area.

Using drones in surveillance of industrial sites

Remote surveillance of big industrial sites is recognized as a potential use case by Mäenpää, Perttula, and Herpiö. Surveying industrial sites is already being done (Mäenpää, Herpiö) but it is represented as a potential application in this research. This is because it is seen that the real potential for carbon reduction comes through when automation can be better utilized in drone operations. In the development of remote surveillance, the role of automated flights is significant. Mäenpää describes that an automated drone can be used to rise from its port, survey an area that has temporary danger zones, and go back to its port. Currently, due to regulatory reasons, it is necessary to have a person to follow the flight (Mäenpää). As industrial sites and ports continue to get more automated, a drone surveillance system will be beneficial in the future as it aims to replace the workforce with automated surveillance (Herpiö).

Using drones in other surveillance applications

Ruotsalainen mentions that a potential application is surveillance of events. There, the movement direction of the crowd can be detected, and they can be guided in the right direction. Linturi mentions that in the future drones could be used in traffic surveillance such as monitoring violation of rules, traffic amounts of problem situations. Linturi sees use cases also in detecting burglaries in the future.

4.7 Applications of drones in private security

An interview for a private industry representative was conducted to gain better insight into the applications and their effect on carbon emissions. Current applications of drones in private security are represented in table 25 and further described in part 4.7.1. Drone applications that raise interest in private security are summarized in table 26 and discussed in more detail in part 4.7.2. A summary of identified pains, gains, and jobs of using drones in private security applications is represented in figure 11. This summary includes findings from the interview with a private security industry representative.

Table 25. Current applications described by the private security representative

The focus of the application	Reference
Using drones in sites that have 24/7 guarding	M.A.

(green)	Application is linked to advancing carbon neutrality (based on the interviews)
(white)	Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

Table 26. Potential applications that raise interest in the private security representative

The focus of the application	Reference
Using drones in alarm situations when the guard brings the drone to the site	M.A.
Using drones in remote surveillance in the future	M.A.

Application is linked to advancing carbon neutrality (based on the interviews)
Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

4.7.1 Current applications of drones in private security

Mika Aro from Securitas discusses that they are using drones surveying areas. Aro describes that their drones are equipped with thermal cameras, visual light cameras, and possibly with remote announcement capability. They have two main types of operations where they use drones. The first type of operation is using drones in sites where they have a guard 24/7. The second type of operation is going for a site and doing inspections on the site. The second type of operation is described as a potential application.

Using drones in sites that have 24/7 guarding

Aro describes that most of their drone operations are done at sites where they have guards 24/7. In these sites, drone flights are used to replace the traditional way of going around the area with a car and by walking. The reduction to carbon emissions occurs in cases where the regular inspections at the site are performed with a drone instead of a car (Aro).

According to Aro, currently, drones are at their best in surveying large sites that have guarding 24/7. However, in Finland, the number of these kinds of industrial parks is very limited when compared to for example Germany (Aro). Benefits of surveying industrial sites include the speed of surveying the area (Aro). The benefit of using drones is that they can quickly provide live video material from any wanted angle. Aro mentions that there are areas that require high-level security, and for example entering these areas is strictly forbidden and sanctioned. Drones can be used as one tool in these situations as they can provide a live situational view with short notice. Aro describes that other benefits of surveying industrial sites include monitoring risks related to fire safety in these industrial areas. If for example more heated areas are spotted during the monitoring flights, these are further investigated.

Aro describes that they have not had bigger challenges related to drone use. Technical difficulties have not disturbed the drone flights. Aro mentions that weather conditions are restricting and that inspections are arranged in other ways in case of hard wind, icy weather, or other corresponding conditions.

4.7.2 Potential applications of drones that raise interest in private security

Using drones in alarm situations when the guard brings the drone to the site

The second type of operation is using drones in smaller sites, in which Securitas does not have a guard on-site 24/7 (Aro). In these sites, the drone would be brought with the guard that arrives at the site (Aro). Aro describes that these kinds of operations are currently not a priority, but that they will likely test the operations with for example 10 sites that are known to have events that require guarding. Aro discusses that this type of operation does not relate to reducing carbon emissions. This is because in this application, the guard would still drive to the site and the drones would be used in operations that are currently done by walking (Aro).

The benefits of using drones in inspecting smaller sites include gaining a better perspective of the situation (Aro). In the current way of working, the situational view is limited to the view that the guard perceives from the ground (Aro). Another benefit is the possibility to use a second pair of eyes in evaluating the situation (Aro). This view can be gained by streaming the view from the site to the control room (Aro).

Aro describes challenges that are related to inspecting smaller sites with drones (Aro). These include the need for performing a risk assessment for each site (Aro). Also, Aro sees that there can be a risk related to flying in alarm situations. This kind of risk would result from not observing the flying environment properly due to the situation that raises adrenalin levels (Aro).

To do inspections at smaller areas, there would be a need to train more of the guards to drone pilots (Aro). Aro sees the cost of training of guards needs to be considered and mentions that it is not necessarily reasonable to train many guards. Aro discusses that when the use of automated solutions is possible, then the guard can take the drone to the area, but the flight can be done from a remote control room. In this way, the number of trained people would reduce to a reasonable level and the drone can be used in a larger number of cases (Aro).

Using drones in remote surveillance in the future

Aro sees that when automation of drone flights proceeds in the future, drones could be used in supporting remote surveillance. Currently, remote surveillance is done by static cameras (Aro). In case of an alarm, cameras are inspected, and this information is used to determine if a guard is sent to the site (Aro). In the future, drones located in the area could provide a situational view to the site that is sending an alarm (Aro). This situational view could help to determine if there is a need to send a guard to the site or not. Better information could lead to reducing unnecessary visits and therefore decreased carbon emissions (Aro).

Aro describes that in the future, it could be possible to perform general, reoccurring inspections on the sites with drones. These inspections would be able to replace the visits where the guards inspect the outside areas and gates (Aro). This application could reduce the reoccurring visits to the sites and could therefore contribute to lowering carbon emissions (Aro). It is important to understand that there is also a level of service that includes checking that the building doors are closed and inspecting the indoor facilities of the buildings (Aro). Aro describes that drones cannot be applied in these cases. A summary of identified pains, gains, and jobs of using drones in private security applications is represented in figure 11.

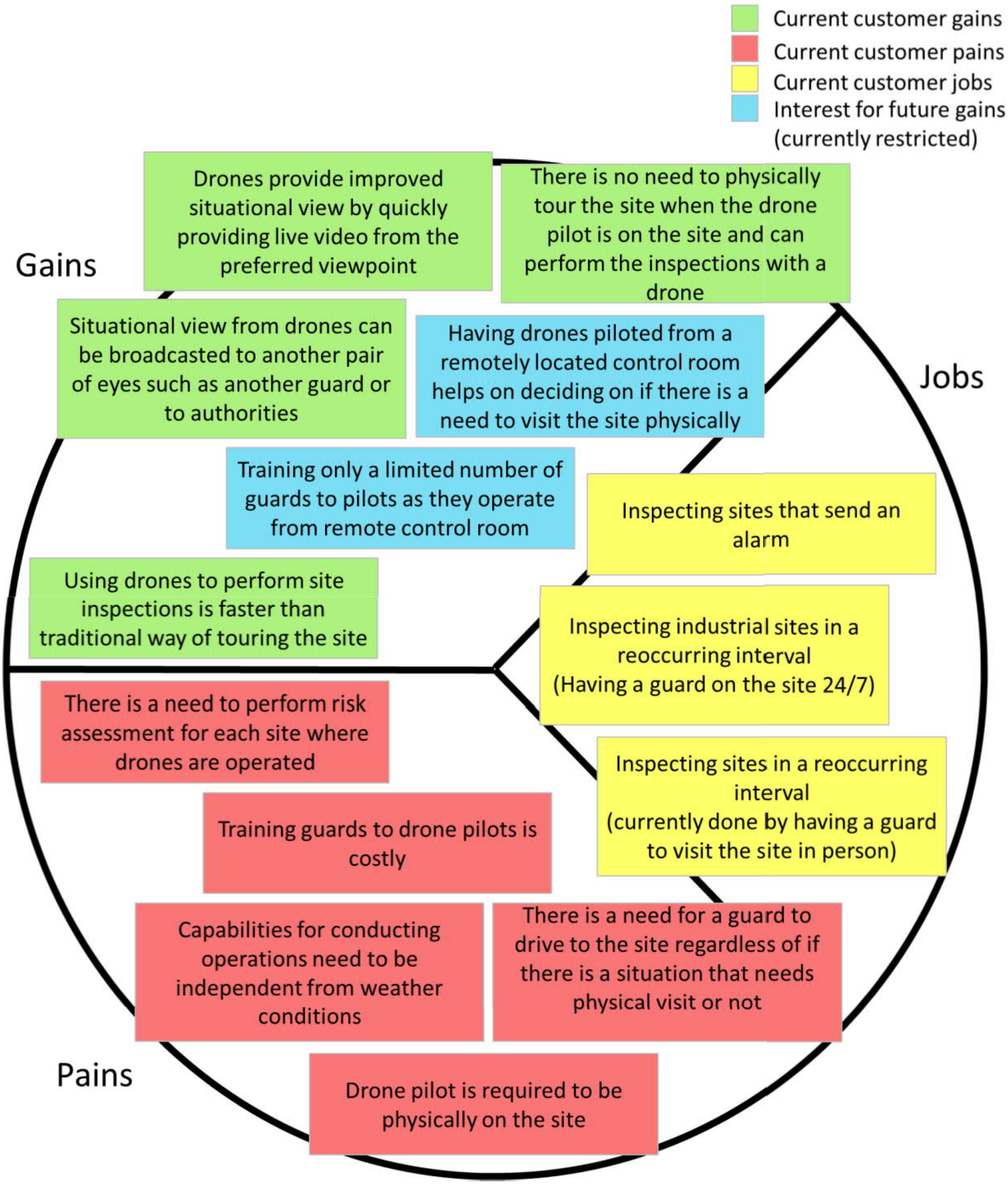

Figure 11. Identified pains, gains and jobs of using drones in private security applications

4.8 Applications of drones in forestry management

In forestry management, the impact of drone applications on carbon emission reductions was researched with three interviews. Potential demand on forest industries was found worth studying as forest represents an asset that is dispersed to a vast area also in Southern Finland. Also, large Finnish forest organizations had been running pilot programs on drone use to gain more detailed data to guide decision-making. It was assumed in research that more detailed information about the forests could guide the forest management actions in a more optimal and sustainable way. Applications that drone service providers and subject matter experts identified in forestry management are represented in table 27.

However, interviewed persons perceived that the current or future use of drones in the forest industry does not have a clear decreasing effect on carbon emissions. One of the interviewees discusses that in the future it might be possible to reduce the visits to the sites by collecting information from a vast forest area, but mostly the potential applications in the forest industry are not connected to advancing carbon-neutrality. Current applications of drones in forestry management are represented in table 28 and further described in part 4.8.1. Drone applications that raise interest in forestry management are summarized in table 29 and discussed in more detail in part 4.8.2.

A summary of identified pains, gains, and jobs of using drones in forestry management applications is represented in figure 12. This summary includes findings from the interviews with forestry management industry representatives.

Table 27. Potential applications of drones in forestry management discussed by drone service providers and subject matter experts

The focus of the application	Reference
Monitoring inventories	
Measuring forests, monitoring yearly growth	R.L.; T.L.
Planning harvests	R.L.
Flying inside the forests for gathering more detailed information (future)	R.L.
Monitoring forest health	
Detecting pests (such as engraver beetle)	P.H.; T.L.; A.P.
Monitoring incidents	
Detecting forest fires, predicting forest fires, detecting people at risk, modeling the direction of the fire, guiding the firefighting operations	L.R.; P.H.; A.P.

(green)	Application is linked to advancing carbon neutrality (based on the interviews)
(white)	Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

Table 28. Current applications of drones in the field of forestry management discussed by forest industry representatives

The focus of the application	Reference
Monitoring inventories	
Gathering materials with a drone to improve satellite data used in modeling forests	K.K.; I.2.
Measuring wood stock in a factory yard	I.2.

(green)	Application is linked to advancing carbon neutrality (based on the interviews)
(white)	Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

Table 29. Potential applications of drones in the field of forestry management that are found interesting by forest industry representatives

The focus of the application	Reference
Monitoring inventories	
Gaining information about the forest inventories	K.K.; I.2.; I.1.
Using information to forest planning and harvesting planning	K.K.; I.1.
Flying inside the forests for gathering more detailed information about the trees and tree trunks (future)	I.2.
Monitoring forest health	
Gaining information about bark beetles (including engraver beetle) (green)	K.K.; I.2.
Monitoring and planning the diversity of the forests	K.K.
Gaining information about the forest health	K.K.; I.2.
Monitoring incidents	
Gaining information about storm destructions	K.K.

(green)	Application is linked to advancing carbon neutrality (based on the interviews)
(white)	Application is not linked to advancing carbon neutrality or the relationship was not discussed (based on the interviews)

4.8.1 Current applications of drones in forestry management

Kimmo Kortelainen describes that his organization is interested in collecting and creating as detailed information about the forests as possible, in a cost-efficient way. Kortelainen describes that more detailed information is used to determine the right timing of actions in forestry management. The right timing of actions ensures that forests are handled in a sustainable way. Kortelainen describes that there is no need to collect basic information about the forests yearly as very good models are used to model the growth of the forests.

He describes that as a single method for collecting information about forests, the use of drones is not cost-efficient for an organization of its size. Kortelainen sees that drones offer possibilities for the future, but currently, he does not see drone technology as a potential solution for gathering information about vast forest areas. He describes that current drone regulation for small drones does not allow collecting information about forests in a large area at a reasonable cost. He will keep following the development of beyond visual line of sight (BVLOS) drones that have wider ranges than the currently known applications. Kortelainen discusses that automation of systems could decrease the costs for the service providers, and therefore it could lead to a situation where the data could be provided with a price that could interest the buyers.

Interviewed person 2 describes that for example taking an aerial image and analyzing forest health does not relate to advancing carbon-neutrality. Currently, a person is required to drive to the forest site, where drones are mostly used to reducing the groundwork, which is done by walking on the forest sites (Interviewed person 2). He mentions that one benefit of using drones is that it speeds up the visit to forest sites (Interviewed person 2). Also Interviewed person 1 describes that he does not recognize a connection between the use of drones and reducing carbon emissions in the forest industry.

Interviewed person 1 describes that they tried using drones to gather data about the forests, but they have backed down from the use. The purpose was to gather information to support inventorying and planning of actions related to forests (Interviewed person 1). Interviewed person 1 mentions that there were certain challenges related to the accuracy of the information related to the growing stock. The interpreted information was purchased from a service provider, who collected the data with photographing methods, not with radar-based technology (Interviewed person 1). Interviewed person 1 describes that if the drone material that they had acquired earlier would have been accurate enough, it would have been used to create forest plans for forest owners. Currently, data gathering for forest plans is done from the ground with different techniques such as photographing from the ground.

Interviewed person 2 describes that they have conducted measurements on how much wood there is in the forest site, what kind of actions should be taken within a forest pattern or a site, and what is the health condition of the forest site. He describes that data gathered with drones can be used in communicating with forest owners and updating forest resource data.

Interviewed person 2 describes that they have been testing the use of drone gathered data in forest inventorying. He mentions that the use is not in full potential and that there is room for improvement. A LIDAR (Light detection and ranging) camera could provide more detailed information about the growing stock. However, interviewed person 2 describes that LIDAR technology is currently expensive. Challenges with currently used photogrammetric technology are related to the interpretation, as thick forests can hinder detecting ground points and lower vegetation.

Using drones to collect data for improving satellite-based models of forest information

Kortelainen describes that his organization is researching if drone-gathered data can be used together with satellite data to provide improved modeling of forest information in a cost-efficient way. In addition to Kortelainen, interviewed person 2 describes that they are combining imagery gathered with drones with satellite data to gain more accurate information for interpreting the satellite imagery. Interviewed person 2 describes that with satellite data, it is possible to get the bigger picture from the area and focus the drone surveys on areas that require more detailed surveying.

4.8.2 Potential applications of drones that raise interest in forestry management

Use of drones to gather more detailed information

Interviewed person 2 describes that the effect on carbon neutrality could be completely different if drones could fly longer distances without having to be within the visual line of sight. Interviewed person 2 mentions that purchasing these kinds of services where the flights are longer would reduce the need for visiting the forest sites and therefore reduce the carbon footprint.

Interviewed person 2 describes that a service could be ordered from a larger area and it would need to be conducted relatively quickly. As the service provider could survey a larger area, also costs could be reduced (Interviewed person 2). A larger area in this context would mean multiple forest sites, a small municipality, or small municipalities. With this kind of service, there would be no need to visit each site to do the surveying.

Information that the service could provide would include quantitative forest information, aerial image, forest health information, and similar useful basis information (Interviewed person 2). Interviewed person 2 mentions that it is possible that there can be other emerging data that could be used, such as information about nutrient deficiencies or more detailed information about what actions should be done for the forest. Interviewed person 2 describes that it is difficult to estimate what this kind of service should cost to be purchased. However, he mentions that it should be cheaper than ground visits (Interviewed person 2).

Interviewed person 2 describes that legal restrictions and drone flight times are limiting the current possibilities for utilizing drones. The possibility to do automated flights without the need for having the drone within the visual line of sight would bring opportunities (Interviewed person 2). Drone technology would need to enable doing longer flights than what is currently possible (Interviewed person 2).

An application that also would raise interest is a drone that could fly within the forest (Interviewed person 2). In this way, it would be possible to get more detailed information about the trees and tree trunks (Interviewed person 2). This application is not likely to be mature in near future (Interviewed person 2).

Similarly Interviewed person 1 describes what kind of interests their organization has towards gathering more detailed data about the forests. These views are represented to enrich the views of interviewed person 2. It is important to note that Interviewed person 1 did not see a connection between the use of drones in gathering forest-related information and decreasing carbon emissions.

Interviewed person 1 describes that there would be interest for a service that is produced cost-efficiently with enough accuracy and reliability. He describes that the main interest is wood stocktaking. In addition, other information such as information about the soil, quality evaluation of harvesting, and other purposes could be collected (Interviewed person 1). Interviewed person 1 describes that if it would be cost-efficient, all the same information that is collected from the ground could be collected by drones. Interviewed person 1 estimates that the price point for a service that includes operating the flights and analyzing the data should be clearly below 10 euros per hectare. He discusses that when quality requirements are satisfied and the price point would be around 5 euros per hectare, it is likely that there would be demand for this kind of service.

Being able to include information about the health of the forests that cannot be gathered with traditional methods would add value and support the adoption of these technologies (Interviewed person 1). Interviewed person 1 sees that using laser scanning technologies with drones could bring new opportunities. He describes that it is possible that these technologies are used in the future.

Use of drones to gather information about storm destructions

Kortelainen describes that an interesting application would be gathering forest information after destruction from a storm or snow. Depending on environmental aspects such as weather, the speed of collecting the fallen trees can be important in maximizing the value of the fallen trees (Kortelainen). With the information about the locations where there have been damages, planning and harvesting actions can be focused (Kortelainen).

Kortelainen describes that satellite technology is a competing technology for drone use in storm destructions. Satellite imagery can work better for larger areas (Kortelainen). However, satellite technology cannot provide images when it is cloudy.

Kortelainen describes drone services related to locations of destructions has been offered to them previously. At least in some situations, the decision not to buy the service was related to the time and cost that it would have taken to get the information in a form that could have been used by the organization (Kortelainen). For planning and managing operations, drone data needs to be transferred for the user to the systems so that that the user can identify the location of the destructions (Kortelainen). With storm destructions, it is important to get the location data and the magnitude of destruction (Kortelainen).

The use of drones in detecting bark beetles

Interviewed person 2 describes that they have been piloting the use of drones in detecting engraver beetles, which are a specified species of bark beetles. Bark beetles are pests that can kill trees. In the pilots, trees have been classified based on if they are healthy, dead, or have health issues (Interviewed person 2). In areas where there are more damages by the engraver beetle, actions can be taken to limit the spread of the beetle to other areas (Interviewed person 2). Interviewed person 2 describes that the value of the wood product decreases remarkably if it turns into a fiber, which happens as it dies due to this pest. Detecting engraver beetles can be used to decrease the value loss.

Interviewed person 2 describes that developing a method to detect engraver beetles has required work and has not been too easy. Challenges in use include that a multispectral camera is not as easy to use as a normal camera. There are also requirements for the flying weather conditions, such as that there should be no storm, rain, or partly cloudy weather.

In addition to interviewed person 2, Kortelainen discusses the importance of detecting bark beetles in the as early phase as possible. Kortelainen describes the detecting of bark beetles with the help of drones as a wish. Kortelainen describes that the aim would be to find infected trees or areas and stop the spreading of the insect. If trees are harvested before the bark beetle changes location, the spreading of the epidemy can be stopped (Kortelainen).

Kortelainen describes that their organization does not use detecting of bark beetles, but that they would have interest in a service that provides information about the location and amount of bark beetles. Kortelainen sees that it would be more likely that they would acquire this kind of information from a service provider rather than build the capability themselves. The cost of this kind of information is an important factor in decision-making (Kortelainen). A summary of identified pains, gains, and jobs of using drones in forestry management applications is represented in figure 12.

Figure 12. Identified pains, gains and jobs of using drones in forestry management applications

5 Discussion

This chapter concludes the answer to the research question: *What kind of demand and business opportunities there are in Southern Finland for drone-powered solutions that advance carbon neutrality?*

This study approached the research question by first reviewing literature about carbon neutrality and commercial drone applications that have been found to provide value globally. Drone service providers and subject matter experts were interviewed to gain a better understanding of which drone applications in Southern Finland could contribute to advancing carbon neutrality. Construction, private security, and forestry management were further researched with interviews of industry representatives. These interviews were planned, and the results were analyzed according to the theoretical framework of this study.

When compared to the literature reviewed about scenarios for decarbonization at the EU level, this research suggested that the opportunities of drones in contributing to carbon neutrality are limited. When reflected against the presented decarbonization scenarios, this research suggests that drones could contribute to the electrification of transportation. As discussed in this study, drone gathered data can be also used in a way that reduces the need for transportation of people.

Evaluation of possibility to advance carbon neutrality with drone applications in the field of construction

Literature suggested that drone applications can provide value in the field of infrastructure and construction (Yi & Sutrisna, 2021; ENSS, 2019; Panjehpour, 2019; PwC, 2017a; Goldman Sachs Research, n.d.). Findings from this research are aligned as drones in Southern Finland have various applications that are currently utilized in operations and the popularity of use is expected to increase from the currents state. Organizations of the industry representatives performed drone operations in-house and found this way of operating suitable for them.

This research identified drone applications that can contribute to reducing carbon emissions in construction. Identified applications included *currently used applications* as well as *potential applications that raise interest*. The emphasis was on applications that are currently technologically feasible. Industry representatives describe that carbon emission reductions are not the reason why drone applications are utilized in this field. Drone applications were used as they can provide a faster way of performing tasks or provide information that cannot be obtained without using drone gathered data.

It was found that evaluating the effects on carbon emissions can be challenging as the effects can be indirect. Applications of drones in construction can result in reducing the need for physical visits to the construction sites, reducing the movement of machinery such as excavators on sites, or saving resources and energy due to improved decision-making or issue detection.

Industry representatives did not identify clear challenges related to applications of drones. Restrictions related to the current technological capabilities of drones, such as flight time, were not perceived as a challenge by the industry representatives. Neither regulation related to having to pilot the drone within the visual line of sight was identified as restricting.

However, potential applications that raise interest included guarding of sites without having personnel on sites, as well as automated site documentation. Automation of drone applications lowers the barrier to perform tasks such as documentation in a more frequent interval, as the costs of a human resource are lower.

Evaluation of possibility to advance carbon neutrality with drone applications in the field of agriculture

Globally, drone applications in agriculture are seen as a valuable market (PwC, 2016; Goldman Sachs Research, n.d.). Drone applications in agriculture include analyzing the health and growth of crops, analyzing information about the status of the soil, and detecting potential pests and weeds (Dragic, 2020; EGNSS, 2019). Improved understanding of the status of the crops and the field allows farmers to focus actions and resources on areas where they are needed. Drone applications discussed in the literature and discussed by the drone service provider and subject matter expert interviews are similar.

This study identifies that drone applications in agriculture in Southern Finland could contribute to reducing carbon emissions by improving resource use. However, currently in Southern Finland, the use of drone applications in agriculture has not widely started. Interviewed drone service providers and subject matter experts described challenges that can be affecting the adoption of drones in the field of agriculture in Southern Finland. It was described that it is important that farmers get practical suggestions that can be taken into action. Therefore, suitable applicability of data-gathering technology and analysis are crucial for providing value. Being able to provide practical suggestions also requires an understanding of agricultural practices.

The cost of the service can be found too high when the service is provided by a service provider. Therefore, the service might need to be produced by the farmers themselves. In Southern Finland, farm sizes are smaller in scale when compared to scales of farms in the

USA or in some Asian countries, which can affect the adoption of drone applications. It was described that automation of drone operations provides opportunities to advance the use of drone applications in agriculture in Southern Finland.

Evaluation of possibility to advance carbon neutrality with drone applications in the field of logistics

When comparing the findings from the literature and the drone service provider and subject matter expert interviews, mostly the same drone applications in the field of logistics are discussed. These include moving objects such as parcels, food, and medical care transportations, as well as moving people with drone taxis (EGNSS, 2019; McKinsey & Company, 2017; PwC, 2016). However, drone service providers and subject matter experts do not further discuss the use of drones in industry applications, such as logistics with drones within buildings. It is important to emphasize that this research sees discussed drone applications in the field of logistics as potential applications as the use of drone applications in logistics are rare in Southern Finland.

This research suggests that there are several challenges related to the adoption of drone applications in the field of logistics in Southern Finland. Challenges were identified related to the profitability of operations, current flight times that drones can operate with their payloads, regulation of flights in cities and over people, and regulation related to having drones within the visual line of sight. Weather can also cause a challenge, as some logistics operations would require a backup operational model that would handle operations when the weather is restricting flights. Interviews with drone service providers and subject matter experts suggested that the possibility to operate automated drone fleets would make operations economically more attractive. Currently, drone operators can operate automated drone flights if the airspace is reserved for the operator as a temporary danger zone.

Drone applications in the field of logistics can reduce carbon emissions when drone applications replace other modes of transportation that have higher emissions on the routes in question. This applies both to the delivery of objects as well as the potential transportation of people. The potential effects of carbon emissions are estimated to be different in urban and rural areas. Based on the interviews with drone service providers and subject matter experts, the largest reductions to carbon would be found on rural routes where drone transportation would replace transportation that would have otherwise been done with a combustion engine vehicle. However, it is good to emphasize that logistics was perceived as one of the most difficult fields of application due to the mentioned challenges.

Evaluation of possibility to advance carbon neutrality with drone applications in the field of surveillance

In reviewing potential drone applications in surveillance globally, applications related to the work of authorities were emphasized. These included applications in search and rescue, police operations, firefighting, emergency response, marine surveillance as well as in surveillance related to traffic and area safety (van Nieuwenhuizen, 2020; van der Plaz, 2020; Brinkman, 2020; Robots Expert Finland, 2018; EGNSS, 2019; Hirsikko, 2018). Also, applications in environmental monitoring were mentioned (EGNSS, 2019; Carlsson & Song, 2018; Finnish Meteorological institute, 2018).

From the interviews with drone service providers and subject matter experts, drone applications that could reduce carbon emissions were identified in marine surveillance, fire safety-related operations, and surveying industrial sites. Applications that can lead to carbon emission reductions are classified as potential applications in Southern Finland, as they are not currently widely in use. The current application that was seen to contribute to reducing carbon emissions was the modeling of scenes of fire.

Potential carbon emission reductions from surveillance applications would result from replacing other modes of transportation, such as combustion engine cars or boats. Another potential way to achieve carbon emission reductions is to use the drone gathered data to determine where it is necessary to send a car and a person to perform the inspection in person. Performing inspections would benefit from the possibility to perform automated, beyond visual line of sight flights and the development of battery technology that enables longer flight times.

Also related to inspections, camera and sensor technology attached to the drone is in a key position for operations, as well as the software used to analyze the gathered data. This is due to that analytics can provide insights that cannot be perceived with the human eye or that it would take excessive resources to go through the material by a human.

Evaluation of possibility to advance carbon neutrality with drone applications in the field of private security

Private security applications of drones can be categorized under surveillance applications, but this research discussed this area of applications separately to avoid making imprecise generalizations. The focus to study private security did not emerge from the reviewed literature, but instead from the scope of the project *Carbon neutral drone service solutions in Southern Finland* that this research supports. In the project, the topic of remote security was one of the areas of interest.

Current applications of drones that were identified in private security have very limited effects on reducing carbon emissions. Reductions to emissions can be gained from performing inspections with drones in sites where the inspections would have otherwise been performed by driving around the site and walking.

However, identified potential future applications could provide larger carbon emission reductions. Potential future applications could be enabled if drones could be operated from a control room, and not from the site where the drone performs the inspections. Having drones remotely piloted could reduce unnecessary visits to the sites in cases where it would be possible the evaluate the situation of the site based on what is seen in the outside areas. This would allow more optimal resource use, as the transportation times to the sites would be reduced, and pilots could perform flights remotely in sites when it is necessary.

Evaluation of possibility to advance carbon neutrality with drone applications in the field of forestry management

Findings from the interviews that focus on applications in forestry management in Southern Finland are in line with the findings from the literature. Both suggest that drones in forestry management have applications in monitoring inventories, forest health, and incidents (Kotivuori *et al.*, 2020; Commercial UAV News, 2020; Karjalainen, 2020).

This research identified few possibilities to advance carbon neutrality in forestry management with *current drone applications* or with *potential drone applications that raise interest* with industry representatives. Industry representatives recognize potential applications and benefits of drones, and their organizations are testing or have previously been testing drone applications. Drone applications are not currently largely applied in forestry management. Drones as a single source for data gathering are not seen as cost-effective for large forest organizations.

Development of flight times and the possibility to perform automated and beyond visual line of sight (BVLOS) flights would improve the use possibilities of drones in forestry management. Data gathering techniques and analysis performed on the data are key enablers in gaining wanted insights and being able to make forestry management decisions based on more detailed data.

Evaluation and main reasons of how drone applications advance carbon neutrality in discussed fields

The extent to which it is possible to advance carbon neutrality in discussed fields are evaluated in the second column of table 31. From current drone applications, drones contribute to advancing carbon neutrality to some extent in fields of construction and agriculture. From current drone applications, drones contribute to advancing carbon neutrality to a minor extent in logistics, surveillance, private security, and forest management. However, with potential applications which are discussed in this research, logistics and surveillance could become application fields in which the use of drone applications could contribute to advancing carbon neutrality to a large extent.

Main reasons behind advancing carbon neutrality with drone applications in discussed fields are summarized in the third column of table 31. Main reason for why drone applications in construction, agriculture, logistics, surveillance, and private security contribute to advancing carbon neutrality is reduced need of people to transport with combustion engine vehicles. Other reasons that can be found from multiple application fields include reduced use of machinery, which can be a reason for reducing carbon emissions in construction and in agriculture.

Table 30. Evaluation and main reasons of how drone applications advance carbon neutrality in discussed fields

	Evaluation of the possibility to advance carbon neutrality with drone applications	*Main reasons why drone applications contribute to advancing carbon neutrality*
Construction	Current applications: To some extent Potential applications: To some extent	- Reduced need of people to transport with combustion engine vehicles - Improved quality due better source information - Reduced use of machinery - Reduced energy use due detection of issues
Agriculture	Current applications: To some extent (due market immaturity) Potential applications: To some extent	- Reduced use of physical resources - Reduced use of machinery due focusing operations to areas where needed
Logistics	Current applications: To a minor extent (due market immaturity) Potential applications: To a large extent	- Reduced need of people to transport with combustion engine vehicles
Surveillance	Current applications: To a minor extent (due market immaturity) Potential applications: To a large extent	- Reduced need of people to transport with combustion engine vehicles
Private Security	Current applications: To a minor extent Potential applications: To a minor extent	- Reduced need of people to transport with combustion engine vehicles
Forestry management	Current applications: To a minor extent Potential applications: To a minor extent	- Possibility to reduce losses of trees by detecting pests and incidents

Main reasons and challenges of using drones in the discussed application fields

Main reasons for using drone applications in discussed application fields are summarized in the second column of table 30. Main reasons for using drone applications include similar characteristics across application fields. In all discussed application fields, drones provide a faster way to perform tasks and a more efficient work resource use. In all application fields except in logistics, analytics can provide information that cannot be otherwise gained. Drones are also used as they allow performing operations more often, for larger areas and for geographical areas that are hard-to-reach.

Main challenges of using drone application in discussed application fields are summarized in the third column of table 30. Cost structure, regulatory requirements, flight times with current batteries, need for common airspace that connects unmanned and manned aviation, as well as possibility to operate drones remotely can be identified as challenges or bottlenecks in multiple application fields.

Table 31. Main reasons and challenges of using drones in the discussed application fields

	Main reasons for using drone applications in the application field	*Main challenges or bottle necks of using drone applications in the application field*
Construction	- Faster way to perform tasks - Safer way to perform tasks - More efficient work resource use - Improved planning of operations - Analytics can provide information that cannot be otherwise gained - Allows gaining views from different viewpoint in a flexible way - Enables gathering documentation more regularly	- No critical challenges
Agriculture	- Analytics can provide information that cannot be otherwise gained - Faster way to perform tasks - More efficient work resource use - Improved use of physical resources	- Potentially price of service
Logistics	- Faster way to perform tasks - More efficient work resource use - Enables access to hard-to-reach geographical areas	- Need for operating drone fleets remotely - Flight times with current battery technology - Potentially cost structure in service providing - Regulatory requirements: Restrictions to flights in urban areas - Need for common airspace that connects unmanned and manned aviation - Need for drone related infrastructure - Some applications require possibility to operate regardless of the weather
Surveillance	- Faster way to perform tasks - More efficient work resource use - Analytics can provide information that cannot be otherwise gained - Enables performing operations more regularly - Enables performing analysis for a large area	- Need for operating drone remotely - Flight times with current battery technology - Regulatory requirements: Restrictions to flights in urban areas - Need for common airspace that connects unmanned and manned aviation
Private Security	- Faster way to perform tasks - More efficient work resource use - Analytics can provide information that cannot be otherwise gained - Allows gaining views from different viewpoint in a flexible way - Enables performing operations more regularly - Enables performing analysis for a large area	- Regulatory requirements: Restrictions to flights in urban areas - Possibility to operating drones remotely would allow more use cases
Forestry management	- Faster way to perform tasks - Analytics can provide information that cannot be otherwise gained - More efficient work resource use	- Potentially cost of service - Flight times with current batteries - Regulatory requirements: Restrictions to flights beyond visual line of sight - Possibility to operating drones remotely would allow more use cases

6 Conclusions

This chapter concludes the research and discusses the implications to practice and research. This chapter also discusses the limitations of this research and describes suggestions for further research.

When reflected against the scenarios related to decarbonization scenarios after 2030 at EU level, advancing carbon neutrality with drones has limited possibilities. Drones can contribute to decarbonization targets as a minor part mainly in the electrification of transportation. This research suggests that across multiple application fields, the reason why drone applications contribute to advancing carbon neutrality is that the transportation of people can be reduced with some applications. However, it is noteworthy that the interviewed organizations do not use drones with an aim to reduce carbon emissions. Reasons for using drones in all discussed application fields include having a faster way to perform tasks and a more efficient work resource use. Other reasons are also discussed in this research. In multiple application fields, analytics performed on the data gathered with drones can provide information that cannot be otherwise achieved.

Based on the findings of this research, many of the application fields in Southern Finland are still immature or currently starting to take-off. Restrictions related to potential applications are dependent on the context of each application field. At some of the application fields, development of flight times due improvements in battery technology are a crucial enabler for feasibility of applications. Multiple application fields will benefit from the development in sensor and camera technologies and analytics related to them.

6.1 Implications to practice

This research provides insights on the drone applications that can contribute to advancing carbon neutrality in Southern Finland. Categorizing the applications based on the application fields helps to create an understandable overview of the demand and business potential of the applications in the described fields. In the findings of this study, drone applications that can contribute to advancing carbon neutrality are highlighted. However, to provide a wider understanding of the subject, findings also describe the applications that are not perceived to advance carbon neutrality.

Three main groups can benefit from the findings of this research. Firstly, there are organizations that are aiming to reduce their carbon footprint by introducing new ways of working. For these organizations, this research provides an overview of what kind of drone applications are found to contribute to reducing carbon emissions in Southern Finland. Also, organizations can benefit from deepened understanding related to potential challenges that might be encountered in the use of drone applications. Based on this information, organizations can better evaluate and develop their potential approach of using drones in advancing carbon neutrality.

Secondly, this research provides insights for the drone service providers about the jobs, pains, and gains that potential customers are working with. These are summarized in figures 10, 11 and 12. This research also discusses the challenges related to purchasing and providing drone services in Southern Finland at a general level. A better understanding of the challenges that potential customers face creates a possibility to develop the service offering in a way that fits the needs of the targeted customer groups. Enabling a better fit between the customers' needs and the service provided can advance the adoption of drone applications.

Thirdly, this research provides supports the project *Carbon neutral drone service solutions in Southern Finland*. Based on this research, the project has improved understanding about which applications are currently applied and which of them contribute to advancing carbon neutrality. This research also provides information about potential applications that raise interest among the interviewed people, but which are not currently applied in a wider context. Based on the findings, the project can better evaluate which applications could be worth promoting or piloting within the scope of the project. Based on the initial findings of this research, one of the webinars and co-creation workshops arranged in the project focused on applications of drones that contribute to advancing carbon neutrality in the field of construction.

6.2 Implications to research

This research applied a customer profile part of the value proposition design methodology from Osterwalder *et al.* (2014) to analyze the interest in drone services that advance carbon neutrality. This theoretical framework was applied in the interviews of industry representatives in the fields of construction, private security, and forestry management.

Creating a customer profile based on the industry representative interviews was found as a useful approach in analyzing the current demand and future potential of identified drone applications. This theoretical framework allowed gaining an understanding of customer jobs, and the pains and gains that are related to these jobs. The main benefit of using this theoretical framework included ensuring that the right insights could be gathered from the interviews.

The interest towards application was researched with two different time horizons, named as *current applications* and *potential applications*. This approach diverges from the original representation of customer profile by Osterwalder *et al.* (2014) but was suitable for the context of this research. The gains related to *potential applications* are separated from the gains that relate to *current applications*. This separation is done by using different coloring in the visualizations of the customer profiles that are represented for fields of construction, private security, and forestry management.

In the customer profiles created for these industries, the jobs that customers are trying to accomplish appeared to remain unchanged in a concept level over time. The changes appear to happen in the way how the jobs are accomplished. It is suggested that by resolving some of the current pains, new gains can be created as reducing pains can allow some applications to become feasible. New applications can then achieve potential benefits by performing the job in a way that enables achieving the potential benefits.

Implications to practice included three main groups that can benefit from the findings of this research. In addition to these identified groups, it is possible for the academics to benefit from the findings of this survey when searching for information for further research related to these topics.

6.3 Limitations

This research has several limitations. The research was conducted as a qualitative study and the interpretation of the findings is the researcher's subjective view. Also, interviewees have a subjective view of the capabilities of drone applications and their possibilities to advance carbon neutrality. In this research, it has not been possible to verify if the views of the interviewed people correspond to reality. As an example, it is possible that there are applications that can perform tasks that are described in this study as potential applications instead of current applications. In the literature review, this research uses information from consultancy reports, panel discussions, presentations, and other pieces of work that are not peer-reviewed by other academics. Using mainly results from peer-reviewed academic work could have been seen as a more reliable approach to the literature review. Also, peer-reviewed academic literature is used.

Evaluating the possible effects of drone applications that could advance to carbon neutrality is based on the views of the interviewed people. It is possible that different people understand carbon neutrality in different ways. In many of the interviews, the discussion was extended from applications that advance carbon neutrality to applications that advance carbon emission reductions. This study therefore also discusses applications that reduce carbon emissions, and not only applications that can enable carbon neutrality. This widened view extends the original scope of the research.

Limitations of this study include a limited number of interviews, especially from the potential industry representatives. From industry representatives, this research focused on interviewing organizations that had shown interest in drone operations. In this way, it was more likely to gain an understanding of the pains and the gains that these organizations were encountering related to the use of drone applications. However, interviewing organizations that are not involved in using drones could have helped to identify different kinds of needs and understand which factors are potentially hindering the adoption of drone applications in their context.

There is a limitation related to how the customer profile section from the value proposition design methodology was used in this research. Due to the scope of the research, interviewed industry representatives were aware that this research was surveying how to advance carbon neutrality with the use of drone applications. Therefore, the jobs that were analyzed with the customer profiling were related to the tool that is used in solving them. In this case, the tool was represented by different applications of drones. In an optimal setting, the methodology should start purely from the jobs, pains, and gains of the potential customers and not discuss any potential solutions or parts of the solution.

6.4 Suggestions for further research

This research was able to identify drone applications that can contribute to reducing carbon emissions. Different applications were discussed at a high level and their effects on carbon neutrality were evaluated verbally. This research does not provide estimations of how large the potential carbon emission reductions with these applications could be. Further research could estimate these effects in more detail.

As discussed in the findings of this research, surveillance, logistics, and agriculture have potential drone applications that could contribute to advancing carbon neutrality, but which cannot be currently applied or are not currently applied in Southern Finland. Factors related to the feasibility and adoption of applications can change and therefore it could be reasonable to perform a re-evaluation of these fields of applications in the nearby future, such as in 2 – 5 years from today.

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Appendix A: Guiding interview questions for drone service providers and subject matter experts

Optional part: Value proposition of the organization.
Question in this part were asked only from drone service providers.

What kind of service offering the organization provides? What is the core business?

What are the customer needs that the organization offers services for (functional, social, emotional, supporting)?

Which are the pains or challenges that service can alleviate for the customer (unwanted end results, problems, obstacles, risks)?

Which are the gains that the customer gets from using the service (required, expected, desired and unexpected gains)?

Part 1: Potential applications of drones

What are perceived as potential drone applications?

Supporting questions: Which have been the use cases, what have the use cases aimed for, how have potential financial targets of the use cases materialized?

Part 2: Potential applications of drones that advance carbon-neutrality

Which could be potential drone applications in Southern Finland that advance carbon-neutrality?

Optional part: Asking for more details about the possible technologies when needed.

Which technology the application uses (for example data gathering technology)?

Part 3: Point of view about the current drone service market in Southern Finland

How is the current drone service market in Southern Finland perceived?

Supporting questions: How is the network of operators on the suppliers' side? How is the network of operators on the customers' side? Are there some operators that are missing from the market? Are there some parts where there is a saturation of operators?

Part 4: Point of view to restrictions for drone applications

What kind of restrictions there are for the drone applications?

Supporting topics (Weather, flight distances, payload, knowledge, regulation, information security, information flows, infrastructure, profitability, public acceptance, technological capabilities)

Optional part: Price of the services

Which are the main drivers that affect the price of providing the drone application?

Are customers willing to pay for these services?

Part 5: Point of view to the near-future development of the drone service market in the Southern Finland.

How is the development of drone services or applications seen in Southern Finland in near future?

Appendix B: Guiding interview questions for potential customers in selected industries

Part 1: Currently used drone applications.

Idea is to understand how the produced or purchased service fits the need of the organization.

Jobs: What tasks are tried to be done with using or producing the application?

Pains: What are the challenges with the application?

Gains: What goals or hopes are there for the application?

What is the meaning of low carbon emission in providing or purchasing this application? The meaning for you and the meaning for your customers?

Part 2: Needs that have not been solved but that raise interest (and are related to using drones in conducting the task)

Jobs: What tasks are tried to be done with using or producing the application?

Pains: What are the challenges with the application?

Gains: What goals or hopes are there for the application?

(What the service should include to be attractive? What would be the concept and price?)

What is the meaning of low carbon emission in providing or purchasing this application? The meaning for you and the meaning for your customers?

Optional part: Asking for more details when needed:

What technologies are used in providing the service?

Which is the way of working that the drone application replaces or modifies?

Appendix C: Guiding workshop questions

Theme 1: Drones and low-carbon emissions

In which different ways can drones reduce carbon emissions in constructed environment?

Theme 2: Challenges related to the use of drone services

What kind of challenges have you identified in using drones or drone services?

Theme 3: *Solutions to described challenges*

What kind of solutions could be found to these challenges?