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Digitalisation and Sustainability in Hospital Supply Chain Management

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Abstract

Purpose

Hospital supply chains are known to be complex entities dealing with a diversity of products, patient needs and expectations from surroundings. They remain fragmented and manual and have struggled to find an optimal structure to perform excellent patient service. Stakeholders demand rapid information, high efficiency and increased environmental awareness. There is a great potential for digitalised improvements to develop hospitals to secure both present and future needs. The purpose of this research has been to describe digitalisation and sustainability in a hospital supply chain. Our goal is to explore how digitalised unmanned aerial vehicles in hospital supply chain management can affect the three pillars of the triple bottom line principle.

Methodology

We will use the reviewed literature to design a theoretical framework which will be used as a base through this study. This theoretical framework will be applied to a case study design for Oslo University Hospital. In this case study we will use a mix of quantitative- and qualitative data, where latter is mainly obtained by semi-structured interviews.

Subject

Digitalised unmanned aerial vehicles used in a hospital supply chain to map the sustainable effects. We are comparing the differences from a current and future situation. Based on this, we have chosen our research question: ***"How can digitalisation affect sustainability in a hospital supply chain management?".***

Key findings

The main finding was how digitalised unmanned aerial vehicles is a source to predictability, which currently is absent in the hospital supply chain. Additionally, abilities of digitalisation can enhance interaction and information sharing in the hospital supply chain management. As a consequence, the flow of goods is improved causing sustainable effects in all three pillars of the triple bottom line principle.

Definitions

Throughout the research we will use Oslo University Hospital (OUH) as the designation of the hospital network of Oslo, including Rikshospitalet, Ullevål, Aker Hospital, and all laboratories, clinics and facilities related to the hospital network in Oslo.

We will also refer to Rikshospitalet several times in this research. When we refer to Rikshospitalet we mean the specific hospital located at Gaustad in Oslo. Furthermore, Ullevål Hospital (Ullevål) will be the specific hospital located in Kirkeveien.

"Biological material" refers to several types of samples; blood samples, urine, saliva, excrement, human tissue, semen, vaginal secretions, etc.
"Radioactive Isotopes (RI)" is a radioactive tracer used in Positron Emission Tomography (PET) scans.

1.0 Introduction

This chapter will explain the background and the reasoning behind our choice of topic. Our master thesis has hospital supply chain management, digitalisation and sustainability as the main topics.

1.1 Background

The Brundtland Commission has since 1987 brought global interest to the concept of sustainable development, and its application to urban and metropolitan areas (Goldman & Gorham, 2006). The most widely accepted definition of sustainable development is "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Anderson, Allen, & Browne, 2005, p. 72). Sustainable development is a combination of the growing concern about environmental issues, together with social and economic issues (Hopwood, Mellor, & O'Brien, 2005).

In an article published by the Guardian it is claimed that humans are damaging the environment and our globe faster than it can recover (Harvey, 2016). Matthews, Hendrickson, and Weber (2008) stress that large companies have a particular responsibility towards operating sustainable as they have a considerable influence on the environment, their surroundings and economy. In recent years, literature has enlightened that supply chain management (SCM) has to look for measures that can make organisations and logistics more sustainable (Carter & Rogers, 2008). To achieve a sustainable development of logistics that promotes environmental, social and economic gains, SCM has to challenge themselves to develop solutions that bring benefits in the long run (Abbasi & Nilsson, 2016). If successful, Acquaye et al. (2017) argue that strategic SCM has the knowledge to contribute to sustainable solutions in organisations.

An industry that has lacked knowledge and focus on sustainable development is the hospital industry (Gibb & Haar, 2009). Hospitals are characterised as complex and unique logistical systems with difficult demands. However, there is a growing concern that hospitals have not been able to or lacked focus on further developments to a more sustainable logistics. The hospital industry has been blinded by the focus on patient care and to some extent the costs (Moons, Waeyenbergh, & Pintelon, 2019; MTLogstikk.no, 2018). According to one study, the logistics cost in healthcare is 38% of the total expense while the same expenses are 5% for the retail industry, and 2% for the electronic industry (B. Johnson, 2015). Current logistical procedures and the overall hospital supply chain management (HSCM) has been described to be outdated and old (Gibb & Haar, 2009; McKone-Sweet, Hamilton, & Willis, 2005). With this is in mind, it is natural for the hospital sector to look for sustainable solutions in their HSCM development. A favoured solution among scholars is to evolve the logistical structure of the hospital and supply chain (SC) to become more strategic (Pinzone, Lettieri, & Masella, 2012; Shaw, Grant, & Mangan, 2010).

"*Healthcare structures are supposed to protect and improve Public Health, but in the meanwhile they are highly energy-demanding and socially impactful structures, which cause negative side effects on the people's health and on the environment"* (Capolongo et al., 2015, p. 1).

Businesses express a need to be able to deal with the trend sustainability and look to digitalisation, digital solutions and innovations for competitive answers (Bansal & Roth, 2000; Dangelico & Pujari, 2010). Multiple sources agree that the term digitalisation is a big part of the change we tend to see in businesses today (Degryse, 2016; Frederick, 2016). Isaksson, Hallstedt, and Rönnbäck (2018) claim that digitalisation and sustainability have to be considered by any business in their operations, and the hospital industry has consistently lagged behind in implementing strategic SC tools (Elmuti, Khoury, Omran, & Abou-Zaid, 2013). Isaksson et al. (2018) conclude by saying that combining the trends of sustainability and digitalisation will provide many benefits when meeting future expectations. However, they acknowledge the importance of further research on the field and stresses the fact that this is a topic yet to be looked upon, especially in HSCM.

1.2 Research Question and Case Study

Literature has pointed out that businesses in general, are not doing enough for the environment and overall sustainability. Hospitals and organisation are in need of adopting a SC-philosophy that is more strategic. Furthermore, the literature points to increasingly look for solutions from digitalisation to become more sustainable to determine the possible outlooks (Silvestre, 2015). Based on this, we have created the research question:

Research question: *How can digitalisation affect sustainability in a hospital supply chain management?*

More specifically, in our research, this was operationalised and investigated by the usage of digitalisation unmanned aerial vehicles (UAVs) in a hospital supply chain management (HSCM). We have chosen this research question because it encourages researchers to look at new ways for hospital supply chains (HSC) to benefit from digitalisation to become more sustainable. We will answer this research question through a case study, where the specific case is for Oslo University Hospital (OUH). They are looking at the opportunity of using unmanned aerial vehicles to transport biological material and Radioactive Isotopes (RI) between Ullevål and Rikshospitalet, and other clinics and facilities connected to OUH. As digitalisation includes many different measures and ventures (Khan, 2016), which are not possible to investigate as a whole, we have decided investigate the digitalised UAVs. Although this project has several angles and possible research areas, we have chosen to focus on the sustainable effects this implementation will bring to the hospital. Sustainability is a term that has received much attention the past years, and it has been suggested several definitions (Carter & Easton, 2011). We have therefore seen the need to exclude several promising theories to make it clear for our reader which part of sustainability we have focused on. Consequently, we will use Elkington (1997)'s triple bottom line (TBL) theory as our approach to sustainability. We will elaborate on this theory later in the research.

1.3 Structure of the thesis

This research is divided into eight chapters, where the first chapter is the introduction. Secondly, we give an overview of previous written and relevant theories. This part is divided into three main parts, HSCM, digitalisation, and sustainability. After the presented literature, we will give an overview of our created framework. Chapter three will present the methodology used and also the quality of the research conducted. The final part of our thesis is a case description where we present our results, before we discuss them. Lastly, we will give our conclusion, limitations, and give suggestions for further research.

2.0 Literature review

In this chapter, a discussion of previous, relevant literature and theories is presented. The discussion is based on the research question, "*How can digitalisation affect sustainability in a hospital supply chain management?*". By reviewing and discussing the literature we expect to gain knowledge and understanding of the relevant research that is conducted with respect to our research topic. Furthermore, this will indicate which topics that need further research and which areas that are not covered by theory today. Hence, the literature review will develop a basis for the analysis in our research. At the end of this chapter, a theoretical framework is applied to illustrate the findings in the reviewed literature and our further research.

2.1 Hospital Supply Chain Management

Multiple sources agree that SCM has become a significantly important part of businesses in general (Christopher, 2016; Hugos, 2018; Mangan, Lalwani, & Lalwani, 2016). Some even claim that efficient SCM is one of the core competencies in a competitive company and a key to business success (Derwik & Hellström, 2017). The statement includes how companies can allocate, facilitate, and serve resources, suppliers, customers, and accept innovations in a sufficient way (Hugos, 2018). The term of SCM can be understood and defined in multiple ways. Cooper, Lambert, and Pagh (1997) and Fahimnia, Sarkis, and Davarzani (2015) claim it is due to a continually changing term in what to include and what the objectives are. SCM in the hospital industry will be referred to as HSCM and is defined by Moons et al. (2019, p. 205) as "*the information, supplies and finances involved with the acquisition and movement of goods and services from the supplier to the end user in order to enhance clinical outcomes while controlling costs".*

The literature emphasises on the importance of a strategic SCM in any business. Strategic SCM can be described as investments and changes that make processes and activities in an SC more efficient (Seuring, 2013). Scholars claim that there is a significant gap between how the HSCM and SCM in other businesses have evolved (Chandra & Kachhal, 2004; Gibb & Haar, 2009; McKone-Sweet et al., 2005). It is argued that the HSCM has relied too much on the care delivery model and has not been able to align it with a strategic SCM (LaPointe, 2016). The care delivery model is addressing the focus on optimising the outcome of the patients at a hospital (Khatod, 2018), which means that decisions are made on behalf of the patients. However, instead of optimising the outcome for patients, over time the care delivery model has hindered the HSCM to evolve. Consequently, not being able to benefit from trends, such as digitalisation, sustainability and integration to reduce costs, that the SCM-philosophy has developed (Aronsson, Abrahamsson, & Spens, 2011). Consequently, Chong, Liu, Luo, and Keng-Boon (2015) address the need for value-adding resources in HSCM.

On the other hand, strategic SCM and the care delivery model are not mutually exclusive. Khatod (2018) argues that the two should be aligned to improve patient service and provide efficiency and value-driven care in hospitals. The SCM-philosophy has developed trends, such as lean-philosophy, integration to reduce costs and increased specialisation, which Aronsson et al. (2011) and Håkansson and Persson (2004) state can bring several benefits to HSCM. Among others, the literature finds that digitalisation can have a high impact on patient care, costs, and the environment (Godbole & Lamb, 2013).

Since digitalisation has brought improvements in other SCs, the hospital sector has begun copying implementations from other SC-sectors. Hence, there tends to be a shift in the hospital sector, where the aim is to change the industry to a more digitalised and sustainable SC (Godbole & Lamb, 2013). However, there are limited empirical findings that prove the influence of these trends in HSCM. Therefore, studies request more research on digitalisation in HSCM and how the hospital industry can become more sustainable (D. Q. Chen, Preston, & Xia, 2013; De Vries & Huijsman, 2011; G. Johnson, 2014).

There are multiple reasons for this change. The above reason is as mentioned to improve patient service. Also, by reviewing the literature, we identify five significant factors that hospitals, in general, want to optimise; *cost vs. patient service balance, patient needs, structure, environment and transportation* (AbuKhousa, Al-Jaroodi, Lazarova-Molnar, & Mohamed, 2014; Brambilla & Capolongo, 2019; Dembińska-Cyran, 2005; G. Johnson, 2014; S. M. Lee, Lee, & Schniederjans, 2011; Syed, Gerber, & Sharp, 2013). These factors are important for the patients and for the hospital to operate efficiently. Typical for them all, digitalisation is suggested as a solution to optimise these factors. On the other hand, research is needed to prove the actual benefits of implementing digitalisation (Brambilla & Capolongo, 2019).

2.1.1 Cost vs. patient service balance

The overall goal of the hospital industry is to provide excellent and superior patient care and treatment (G. Johnson, 2014). At the same time, the hospitals have a responsibility to be a well-run business to stay competitive. According to Kowalski (2009), total supply expenses have historically accounted for over 45% of the operating budget for hospitals on a general basis. Furthermore, the article states that strategic SCM can reduce the supply expenses without degrading the patient service. Therefore, the balance between cost and patient service has become increasingly important (D. Q. Chen et al., 2013).

Multiple sources agree that the current HSCM has not been able to optimise the balance between costs and patients service (Chong et al., 2015; S. M. Lee et al., 2011). Scholars highlight that the major problem stems from a highly complex and challenging SCM (Chong et al., 2015). Additionally, McKone-Sweet et al. (2005) point to multiple barriers as to why hospitals find it increasingly difficult to optimise the balance. They mention, among other things, short product life cycles making the products costly, inadequate SCM education among employees and difficulties in frequency, patient visits, and the associated product requirements.

Consequently, scholars acknowledge that the hospital industry has lacked behind in taking advantage of evolving a mastered SCM (McKone-Sweet et al., 2005). Gibb and Haar (2009) state that on an international level, the health sector falls behind other industries by nearly 10 to 15 years when it comes to the adoption of information technology. As a result, hospitals experience medicine shortage and improper pharmaceuticals, which Uthayakumar and Priyan (2013) argue affect the patient service, and leads to financial losses.

According to several types of research, digitalisation has emerged in SCM as a way to keep up with competition and has brought several advantages to SCs in general (Bechtsis, Tsolakis, Vlachos, & Iakovou, 2017; Sendlhofer & Lernborg, 2018). Therefore, it is suggested to implement digitalisation and strategic SCM in the HSCM to optimise the balance between costs and patient service (Bechtsis et al., 2017).

2.1.2 Patient needs

The hospital sector has the patient needs as a primary focus. The HSC requires an accurate and adequate medical supply based on patient needs (Chong et al., 2015). The management of logistics activities in the hospital industry does not only concern the flow of materials, but also the flow of patients and securing the patient needs. HSCM, "'*enables' patient care through supplying the diverse medical professionals with products and services they need to deliver prompt and best quality medical care"* (AbuKhousa et al., 2014, p. 3). There are several complicated issues to manage with respect to patient needs, such as crucial waiting times, the urgency of the matter and also misuse of medical resources (Ageron, Benzidia, & Bourlakis, 2018). Hence, safety and efficient treatments are recognised to be essential factors for patient needs (de Vasconcelos et al., 2019).

A significant difference between the HSC and the SC of other industries is the handling of a diversity of items for a high amount of diagnosis types and procedures and methods with an overall goal of rapidly responding to patient needs (AbuKhousa et al., 2014). An item that needs special handling is the handling of biological material, which is present in every HSCM and crucial for the patient needs (de la Torre-Bueno, 2014). However, the article claims these samples lose much of their beneficial qualities if not handled right, which may occur from poorly tracking, mix-ups, or human errors. Meslin and Quaid (2004) also points out that hospitals have to comply with patients' right to have their genetic data handled in a way that secures their individual privacy and confidentiality and prevents misuse. Furthermore, Meslin and Quaid (2004) state that currently, there is a widespread perception that the handing is inadequate.

Commonly, to serve patient needs, is that they require a controlled interconnection and synchronisation between the administrative- and medical steps to avoid any potential problems (Ageron et al., 2018). De Vries and Huijsman (2011) states that due to a growing focus on patient needs, hospitals are urged to deliver health service in a more efficient, effective and economical way and point to logistics and digitalisation as a solution. According to D. Q. Chen et al. (2013), the hospital sector has an unprecedented opportunity to benefit from information technology (IT) and technology to improve patient safety and their quality of care.

2.1.3 Structure

The hospital structure is an essential factor in maintaining and improving public health in HSCM (Capolongo et al., 2015). There are a number of operations and information within the HSCM that are necessary for the care of patients. As a result, the hospital sector is in deep need of structuring the operations and information in an efficient way (Kong, 2019). A recognised barrier in HSCM is the bottlenecks that occur due to the poor connection between departments and slow processes (Rechel, Wright, Barlow, & McKee, 2010). The article argues that the bottlenecks result in long delays for patients.

However, G. Johnson (2014) state that many operations remain highly manual and fragmented, which leads to slow processes and unstructured systems. Duffield, Kearin, Johnston, and Leonard (2007) claims that hospitals have strategically tried to renew their structure, but uncertainty and defining the exact organisational structure necessary is difficult. Capolongo et al. (2015) agree and claim that healthcare structures are energy demanding and socially impactful structures, causing negative effects for the environment and peoples' health. As a result, the poor structure in HSCM influences the sustainability of the hospitals negatively. However, De Vries and Huijsman (2011) have recognised a change in HSCM. They claim that there is a digital shift happening, where operations regarding structuring patient logistics and physical goods in a more sustainable way, gain attention. It is stated that "*hospitals able to cope with the definition of health as complete well-being and which can fit the future means therefore constructing sustainable structures"* (Capolongo et al., 2015, p. 1).

As HSCM remains manual and fragmented, the literature has identified innovation as a critical success factor for structure in HSCs (Y.-C. Lee, Li, Yen, & Huang, 2011). Y.-C. Lee et al. (2011) states that SC-innovations are those tools that can improve the organisational structure needed for seamless interactions with suppliers, manufacturers, distributors, customers, and patients. Hence, innovations can enhance the structure in the HSCM. Furthermore, Y.-C. Lee et al. (2011)

figure that three primary forms of innovation are important for healthcare, namely customer faced-, technology-, and integrator innovation. Customer faced innovations focus on reducing patient waiting time. Technological innovations focus on improving delivery systems. Integrator innovations focus on improving the efficiency of healthcare services and IT-applications that can improve all three types of innovations. However, innovative developments are evolving at a rapid pace, making an HSC knowledge and information intensive (D. Q. Chen et al., 2013). Before adopting a piece of new equipment or other innovative initiatives, HSCM needs to understand the exact specifications before looking at a possible implementation. Hospitals need to know every detail of the equipment, as it is a part of life-saving operations. Consequently, innovations in HSCM develop slower than innovations in other SCMs (D. Q. Chen et al., 2013).

2.1.4 Environment

Hospitals, in general, have given little thoughts on how their operations affect the surroundings and the environment (Brambilla & Capolongo, 2019). At the same time, it becomes clear that HSCM is highly polluting, and hospital operations stand for a considerable share of the emissions in the world. WHO estimated that the healthcare sector stands for 2,8% of the total contribution to greenhouse gas emissions in the world (Savage & Vernon-Mazetti, 2017). With this in mind, Buffalo et al. (2014) argues that on a general level, new hospitals have to be built with environmentally friendly solutions and existing hospitals must improve their standards, as the current solutions are not sustainable with respect to the environment.

It is argued that the HSCM has acknowledged that their operations are not environmentally friendly, which is why Setyowati, Harani, and Falah (2013, p. 189) claim that "*hospitals must be environmental oriented*". They have to establish an environmentally friendly concept. It has been claimed that digitalisation is one emerging trend in SCM, but another is the focus on the environment. Fahimnia et al. (2015) claim that SCM has developed and matured from a field that solely addressed operational and economic matters, to comprehensively consider the broader environmental and social issues. Unfortunately, Brambilla and Capolongo (2019) claim that there are limited or no research on environmental hospitals and even less on how hospitals can operate environmentally friendly. The researchers conclude by acknowledging a need for more profound studies concerning the focus on the environment in hospital structure.

2.1.5 Transportation

According to Syed et al. (2013), transportation is highly necessary for ongoing health care and HSCM in general. Transportation is incorporated in several vital processes in the daily management of a hospital. Consequently, transportation affects the hospital economy and patient service and their overall treatment. A hospital consists of a complex network of multiple small entities that are dependent on rapid deliveries of medical supplies (Landry & Beaulieu, 2013). Therefore, the transportation of these supplies has to be efficient and operational.

Syed et al. (2013) argue that transportation is often found as a barrier for HSCM. They found multiple barriers such as lack of transportation methods, expensive transportations, complexity and time. The barriers lead to delayed care and expenses for HSCM. In addition, multiple scholars address that transportation processes in SCs is one of the most significant contributors to a severe amount of environmental threats and problems (Azadi, Shabani, Khodakarami, & Saen, 2015; Björklund, 2011). As Eliasson and Proost (2015) enlighten, there is consensus in the sense that policies must respect the living conditions of both present and future generations. It comes clear that the transportation methods today have to change in every sector.

It has been highlighted that innovations and digitalisation enhance today's transportation methods to more sustainable solutions (Björklund, 2011; Brambilla & Capolongo, 2019). Nevertheless, there are mostly provisional theories that claim the effect of innovative transportation methods on sustainability, and even fewer findings regarding innovative transportation methods effect on sustainability in HSCM (Borén et al., 2017).
Azadi et al. (2015) argues that SC managers have to look at new solutions in their SC. These aspects are highly concerned for the hospital sector, which is an argument that favours the change to a sustainable HSCM. However, it has been enlightened that transportation in HSCM is not concerned with sustainability (Azadi et al., 2015).

In sum, the reviewed literature on HSCM highlights that the hospital sector needs a strategic SCM to make the five factors mentioned above more sustainable. Several articles see the emerging trend of digitalisation improving SCs in other businesses and making them more sustainable (Borén et al., 2017; D. Q. Chen et al., 2013). Digitalisation can affect the balance between costs and patient service, patient needs, structure, environment, and transportation in HSCM (Amukele, Ness, Tobian, Boyd, & Street, 2017; Bechtsis et al., 2017; Brambilla & Capolongo, 2019; Buffalo et al., 2014; D. Q. Chen et al., 2013; Sendlhofer & Lernborg, 2018). However, these articles find that there is a lack of research and limited evidence, which make the literature request studies to investigate the affection of digitalisation on sustainability in HSCM further

2.2 Digitalisation

Digitalisation is a complex term that incorporates many factors and concepts which makes it hard to define (Khan, 2016). Consequently, this research will define and use the term with HSCM in mind. Brennen and Kreiss (2016, p. 1) state that according to The Oxford English Dictionary digitalisation is defined as "*the adoption or increase in use of digital or computer technology by an organization, industry, country etc.*". They refer to digitalisation as the way many domains of social life are being restructured around digital communication and media infrastructures (Brennen & Kreiss, 2016). Harteis (2018) supports these claims, and that regardless of profession or occupation, everyone is potentially a subject of the changes that come along with digitalisation. Leviäkangas (2016) argues that digitalisation is the most significant technological trend faced globally and that it will affect individuals, communities, and entire nations. Furthermore, digitalisation offers a paramount of opportunities but does also challenge existing solutions and sectors. For example, the transportation industry might experience digitalisation in an unprecedented manner (Leviäkangas, 2016).

As digitalisation is making its impact, especially in SCM, MHI Annual Industry Report claimed in 2017 that the timeframe for the next-generation SC is just five years away (Michel, 2017). Multiple sources describe this next-generation with an umbrella term, called 'Industry 4.0' or the fourth industrial revolution (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014; Michel, 2017). In respect to Industry 4.0, Michel (2017) states possible trends that have and will emerge in SCM from digitalisation. Among them are robotics, broader connectivity through Internet of

Things (IoT), and scenario-based planning. It is claimed that digitalisation will contribute to "*that supply chains are evolving from often poorly synchronized links in a chain into a connected, harmonized network of trading partners who can instantly share information around a `digital core´ or foundation*" (Michel, 2017, p. 26). Moreover, SCs are evolving due to digitalisation and are becoming "smart". Smart in the meaning of denoting the effective integration of physical-, digital- and human systems to deliver a sustainable, prosperous, and inclusive future (Cavada, Hunt, & Rogers, 2014).

It has become clear that the logistics industry, can benefit from digitalisation, where stakeholders demand more information, faster deliveries, environmental awareness, and high efficiency (Gomez, Grand, & Gatziu Grivas, 2015). Several different technologies and digitalised solutions have been evaluated as a possible means to improve the hospital sector (Carrillo-Larco, Moscoso-Porras, Taype-Rondan, Ruiz-Alejos, & Bernabe-Ortiz, 2018). Based on this, several studies state that digitalisation has brought forward digitalised advancements and among them the possible usage of UAVs to create an entirely new way of dealing with transportation (Gomez et al., 2015; Scott & Scott, 2017). However, they acknowledge that this area needs further exploration and is yet to be looked upon.

2.2.1 Unmanned Aerial Vehicles

In the past decade, technological and digitalised developments have been growing at a massive pace, changing the way we communicate and how we deal with transportation (Holdgaard, 2018). A specific area in transportation that has seen much development and gained interest is *unmanned aircrafts*, also known as *drones*, *UAVs*, or *remotely piloted aircrafts* (Murray & Chu, 2015). Yoo, Yu, and Jung (2018) state that UAVs have a high potential for parcel delivery, making transportation faster, less expensive and more eco-friendly than traditional delivery methods such as trucks and cars. Lohn (2017) also states that UAVs may be widespread within the next five to ten years in parcel delivery, especially for what is called "last mile"-delivery. Lohn (2017) argues that UAVs possess potential benefits in the way that they can influence public safety, air pollution, city noise, air traffic management, urban planning, and road congestion.

Based on Thiels, Aho, Zietlow, and Jenkins (2015, p. 104) argument that "*UAVs may soon be used to transport goods quickly, safely and inexpensively…*". Carrillo-Larco et al. (2018) claim that digitalised UAVs can be implemented in HSCM for commercial transport, medical transport, and also disaster relief. Multiple studies show the possibilities and benefits an implementation would give commercial- and civil purposes (Carrillo-Larco et al., 2018; Haidari et al., 2016; Pappot & de Boer, 2015; Thiels et al., 2015). However, several articles confirm the fact that there is limited literature on the feasibility and potential application of UAVs in the medical field and Haidari et al. (2016, p. 2) state "*limited evidence is available regarding the impact of UAVs for routine delivery of medical supplies"*.

Kaya, Turan, Midilli, and Karakoc (2016) have studied UAVs in general and find numerous advantages over manned aircrafts concerning sustainability. To mention some, UAVs are more operable in adverse conditions, have better design flexibility, environmentally friendly, and multiple economic advantages. In the last three to five years, researchers have made studies and begun experiencing with the UAV technology in SCM and some also in HSCM (Carrillo-Larco et al., 2018; Haidari et al., 2016). The primary goal of these studies has been to discover the effect of UAVs as a transportation method on SC bottlenecks and inefficiencies. Nevertheless, as UAVs are recently acknowledged for commercial- and civil purposes, there is limited research on how to allocate and benefit from the abilities of UAVs in HSCM.

2.2.1.1 UAV as a part of digitalisation

UAVs were first defined in the 1980s to describe autonomous, remotely controlled, multi-use aerial vehicles that are driven by aerodynamic forces (Rosser Jr, Vignesh, Terwilliger, & Parker, 2018). As the name suggests, the vehicle is unmanned and remoted based on a conjunction with a data terminal, with a sensor array and an electronic data link. UAVs typically consist of an airframe, a propulsion system and a navigation system, which makes it facilitate various applications. Examples of UAVs are octocopters, fixed wings, multi-rotor, single-rotor helicopter, fixed-wing hybrid, and heli-wing (Chapman, 2016; Hassanalian & Abdelkefi, 2017). Commonly, they are based on batteries produced for smart devices, and therefore, it is claimed that UAVs have become more capable, affordable, and accessible in general (Rosser Jr et al., 2018).

Over time, the technology of UAVs has developed, and different designs of UAVs have emerged (Rosser Jr et al., 2018). Some are rather simple and small, and not based on digitalised technology. However, more complex and modern UAVs used in the army, and more extensive operations in the civil sector, are coherent with the term of digitalisation. It is stated that digitalisation is the use of digital technologies to improve the existing business model (Heberle, Löwe, Gustafsson, & Vorrei, 2017). Furthermore, digitalisation is used to create new revenue and add value to the organisation or the SCM. An important factor in digitalisation is that the improved business model is based on highly automated processes, managing large user groups at low transaction costs (Heberle et al., 2017). As stated, the more developed and complex UAVs are highly automated and additionally use smart technology, to learn, predict, and estimate future situations. Smart technology or artificial intelligence is used in UAVs due to a common need for navigation, safety, communication, and airspace management (Gharibi, Boutaba, & Waslander, 2016) and can be defined as robotics. Robotics was defined as a part of digitalisation above. Therefore, it is argued that digitalised UAVs are coherent with the definition of digitalisation that is presented in the introduction of this part.

2.2.1.2 Economic perspective of UAVs

The literature finds UAVs to be a cost-saving solution in SCM in general (Haidari et al., 2016; Kaya et al., 2016). It is proved that UAVs can traverse difficult terrains, reduce labour, and replace vehicles that require expensive maintenance (Haidari et al., 2016). Since UAVs use smart technology to operate unmanned, the SCM will be able to diminish the existing cost regarding human labour (Haidari et al., 2016). UAVs will additionally be able to operate 24/7 with no additional costs or in need of upholding law regulations regarding needed hours of rest that for instance, truck drivers have to follow (Vegvesen, 2019a). Furthermore, when the UAVs are purchased, and the infrastructure is fully implemented in the SC, the expenses in respect to gasoline will be heavily decreased (Kaya et al., 2016).

On the other hand, there are acknowledged some expenses towards UAV based transportation in SCM. Common for any new technology, there is a high cost of purchasing and operating in the implementation phase regarding the infrastructure (Haidari et al., 2016).

Moreover, as the energy source used in UAVs is mainly small batteries, the range and carrying capacity of deliveries are limited. The limitations are based on the lack of technology, and Haidari et. al, 2016, claims that the UAV-technology will evolve. A current fuel-based engine can cover over 600 km on one tank and carry a higher payload than what a UAV can (Rawa & Townsend, 2016). In situations where companies have to deliver almost a container worth of items in a single direction, the cost per delivered package would be considerably lower with a truck. However, UAVs can take advantage of their abilities when it comes to 'last-mile'-deliveries with short distances, for instance, in an HSCM. In a HSCM, UAVs can deliver the goods fast in a circular area surrounding a UAV centre with a direct route to their destination, reducing the *energy used per drone-delivery package* (Lohn, 2017). Although the usage of UAVs brings exciting cost opportunities, the subject has yet to see testing and is lacking data to determine future prospects and financial impact, especially in HSCM (Haidari et al., 2016; Regjeringen, 2018).

2.2.1.3 UAVs and safety

Several articles highlight the safety aspects of implementing UAV based transportation in SCM (Haidari et al., 2016; Kaya et al., 2016). They state UAVs may be a source for creating safety or reducing threats of accidents that can arise with ground-based transportation. By moving the transportation from the road to the air, the possibility of derailing the road is removed, and it reduces the risk of hitting objects or people at or near the roadway. Maza, Kondak, Bernard, and Ollero (2009) argue that sensoring and smart technology have the ability to make digitalised UAVs transport goods in the air instead of on the ground.
Afman et al. (2018) argue that digitalisation make the UAVs autonomous and therefore there is no need for a person physically driving. Hence, there is a total reduction of potential casualties for the pilot, driver, or passengers. The only possible causality will be if a UAV crashes into a person or falls down. UAVs will though have special programs implemented to reduce many of these risks and

safety measures such as sensors, parachutes, and high-tech GPS-systems (Afman et al., 2018). Consequently, the UAVs used in transportation are highly regulated, and there are multiple legislation and tests to approve the vehicles before they can be used (Afman et al., 2018).

Based on the reviewed literature, different sources do also point at threats related to the usage of UAVs (Maddox & Stuckenberg, 2015; Regjeringen, 2018). The main threat is if the UAVs are to fall down due to system malfunctions (Zhang, Tang, & Roemer, 2013). According to Zhang et al. (2013), the weather and temperature fluctuations are profoundly affecting the safety aspect of UAVs. The authors state that there are technological developments that are used to make the UAVs safer in difficult weather conditions. Besides, they do acknowledge that there is a need for more research on UAV-technology to make UAVs more or less independent of weather conditions.

Moreover, Regjeringen (2018) addresses the safety issue of drones being used for criminal activities, such as espionage, sabotage, cyber-attacks, and terror. They mention that even though drones might not be the obvious choice for a terror attack, terrorists take advantage of UAVs being airborne, as security measures that are around buildings and structures tend to be less in the air than on the ground. To reduce the possibility of being hacked or hijacked by terrorists, security measurements like firewalls and advanced virus programs are made for UAVs (Regjeringen, 2018). In addition, terrorists or hijackers can as easily take over a car, a plane or truck as a UAV. In other words, the threat of being hijacked is there today, but UAVs are a new phenomenon which makes people naturally doubt its safety. According to Regjeringen (2018), there are several ways of dealing with the safety aspect of UAVs, but each measure needs to be modified for a given situation or city.

2.2.1.4 Eco-friendly perspective of UAVs

As HSCM is changing, hospitals impact on the environment is an important factor in how to make decisions regarding resources and infrastructure. Due to UAVs vast amounts of information sharing it is expected that UAVs will become an integral part of the next generations intelligent transport systems (Garg, Singh, Batra, Kumar, & Yang, 2018). Different sources are claiming that UAVs as a transportation method positively affect the environment (Lohn, 2017; Yoo et al., 2018). It becomes evident that most UAVs are driven by an electronic energy source, which provides a much more eco-friendlier solution than gasoline-driven transport methods or other high polluting transportation methods (Rosser Jr et al., 2018). A study made by Figliozzi (2018) aimed to compare UAVs to gasoline driven vans in 'last-mile' deliveries. He acknowledged that the vans were capable of delivering more cargo as vans are bigger. The vans are eight times more efficient in terms of energy consumption. Despite this, the findings showed that per-unit distance, the UAVs were 1050 times cleaner than the vans (Figliozzi, 2018). Therefore, he concluded that "*UAVs are very CO2e efficient*" (Figliozzi, 2018, p. 23).

In a previous study, Figliozzi (2018) found that transportation in most developed countries accounts for a large share of total greenhouse gas emissions. He states that UAVs have already shown a significant impact on delivery costs, but their potential effect on energy consumption and greenhouse gasses is somewhat understudied. He acknowledges that some previous studies enlighten the potential benefits of UAVs regarding the environment. Primarily when customers are located close to the depot and trucks emit fewer for faraway customers, UAVs produces less emissions (Figliozzi, 2018). Consequently, implementation of UAV based transportation should be taken into account, but it needs more research and tests to determine the impact on the environment.

Implementing UAVs in SCM will result in a new source to noise. According to Sinibaldi and Marino (2013), the propellers that enable the UAVs to fly produce a specific noise. It is claimed that noise from UAVs has a potentially negative effect on the surroundings (Christiansen, Rojano-Doñate, Madsen, & Bejder, 2016). However, the article claims that the degree of influence on surroundings is highly affected by the distance of the UAV, the number of UAVs flying in the same area, where the UAVs fly and the size of the UAVs. Consequently, the authors highlight the importance of regulations and legislation concerning the usage of UAVs to minimise the potential damage the noise brings on the environment. With this in mind, Sinibaldi and Marino (2013) argue that there are limited empirical findings to what extent UAVs are sustainable in regards to disturbing noise, which makes the authors request further research on the topic.

2.3 Sustainability

It is a known fact that environmental matters are important to the survival of companies (Beekaroo, Callychurn, & Hurreeram, 2019). Furthermore, Beekaroo et al. (2019) claim that companies, in general, tend to degrade the environment by exploiting natural resources, generate an unmanageable amount of waste and pollution. To survive, companies cannot solely focus on financial returns, but have to be aware of, and acknowledge the long-term impacts on living standards on both present and future generations of their business. Companies have a responsibility of operating sustainable with respect to the environment, people and in addition to provide financial returns (Yi-Chan & Tsai, 2007).

Sustainability as a term was first acknowledged at "The World Commission on Environment and Development" in 1987 based on the report "Our common future" (TheWorldCommission, 1987). The report acknowledged two major global concerns, namely development and the environment. These concerns became the basis for the concept of sustainability, where the main concept is not to harvest more than you can bare. In the wake of The World Commission in 1987, the importance of environmental protection, research in green innovations and sustainability, in general, has grown in interest (C. Chen, 2001; Pujari, Wright, & Peattie, 2003; Yi-Chan & Tsai, 2007). As a result, the fundamental interest is in how SCM can enhance environmental, social, and economic issues. Acquaye et al. (2017, p. 572) argues that "*supply chain management can contribute to solving the global sustainability challenge*". Further, Carter and Easton (2011) claim that environmentally friendly SCM will generate competitive advantages, which may result in economic growth. They argue that such an advantage is due to the transformation of resources. Also, there is a growing importance of social innovations as the traditional solutions are not enough to address the deep-rooted social problems (Dainienė & Dagilienė, 2015). This includes the company's responsibility in terms of education, social mobility, trust, labour, customer service, and community safety, and more.

The term sustainability has later expanded to three major concerns, which are economic-, social- and environmental issues (Helming et al., 2008; Kates, Parris, & Leiserowitz, 2005). The three mentioned concerns of sustainability are also referred to as the *Triple Bottom Line* (TBL), which was developed by (Elkington, 1997). TBL consists of three "P's": Profit People and Planet. The TBL is a principle of sustainable business. The theory enlightens the fact that businesses have a responsibility beyond making profit. In addition, to generate profit, companies have an impact on people and the planet, and therefore, responsibilities for operating sustainably in respect to these terms as well.

2.3.1 Planet

The term planet refers to the environmental aspect of the TBL-principle. This term seeks to enlighten the focus on the sustainability of our planet and environment in decision makings. As the literature tends to talk about the environmental aspect of TBL as environmentally sustainable, we use Acquaye et al. (2017) definition of the term. They define environmentally sustainable as "*the integration of environmental thinking into the entire lifecycle process of supply chain activities*" (Acquaye et al., 2017, p. 572). Based on this definition, the HSCM has to favour and develop solutions that make the activities in SC environmentally sustainable.

Van Fan, Perry, Klemeš, and Lee (2018) stress the importance of reduction in air emissions that stem from SC-operations. They identify multiple different greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), with more that are contributing to the change of climate and come from various SC-activities. Globally, governments and policies have been focusing on greenhouse gases and air pollution and what effects they have on the environment, the planet and human health (Van Fan et al., 2018), as it is a growing concern. Consequently, it is acknowledged that the pollution of the planet is a problem, and research is needed to suggest solutions on how HSCM can overcome the problem (Brambilla & Capolongo, 2019).

Transportation is for many companies of significant importance, but also one of the greatest contributors to greenhouse gasses and air pollution (Paksoy, Bektaş, & Özceylan, 2011). In fact, transportation stands for nearly a third of all greenhouse gas emissions (Barth, Wu, & Boriboonsomsin, 2015).

Moreover, transportation is a source of noise. Noise can be defined as "*an unwanted sound and an environmental noise is all unwanted sounds in an area except those that originate from the workplace*" (Goines & Hagler, 2007, p. 287).

Although noise cannot be measured in the same way as CO_2 emissions, it is still regarded as environmental noise and therefore defined as harmful to the environment. Goines and Hagler (2007) stress the fact that environmental noise is more severe and widespread than ever before. Due to urbanisation and growth of population (Goines & Hagler, 2007), transportation by highway, rail, and traffic, in general, is increasing. As a result, the environmental noise will continue to increase in magnitude and severity (Goines & Hagler, 2007).

The literature acknowledges suggestions in how SCM can deal with the growing environmental issue, and one of the most considered and attractive suggestions is the use of digitalisation (Berger, Cunningham, & Drumwright, 2007; Isaksson et al., 2018). Innovations are continually changing our way of life, and Silvestre (2015) claims that innovation is a key element for how organisations, SCs, institutions, and countries can implement environmental sustainability. For example, intelligent transportation systems (ITSs) have been pointed out as a promising factor, having shown a potential to reduce emissions with 5-15% in the transportation sector (Barth et al., 2015). However, they see the relevance for further research and Clark and Dickson (2003, p. 8059) say that "*much remains to be done*", which is supported by Isaksson et al. (2018, p. 1) who states that *"support for design and development work is needed that takes into account the mega-trends digitalisation and sustainability…".*

2.3.2 People

The second term of TBL is people, which refers to the companies' decision makings in respect to fair business practices, labour, human capital, customers, and the affected community (Elkington, 1997). The idea of this term is to create value for society and give back to the stakeholders. Examples of such practices are fair wages, providing job opportunities, patient and customer service, and acts that are good to the community in general. In other words, the term people concerns both the people who carry out the work for a company and the people who are impacted by the company's decisions and activities.

In other words, the term people is often referred to as the social perspective or social sustainability and is defined by McKenzie (2004, p. 23) as "*a positive condition within communities, and a process within communities that can achieve* *that condition*". Additionally, Labuschagne, Brent, and Van Erck (2005) argue that the stakeholders, like customers, employees, patients, suppliers, and more, are to be considered in decision makings. According to Giunipero, Hooker, and Denslow (2012), stakeholders have played a major role in increasing corporations' responsiveness towards sustainable solutions. However, according to Staniškienė and Stankevičiūtė (2018), the term people is the "pillar" that often gets less attention and focus due to lack of clarity and maturity in terms of definition, content and measurement tools.

In respect to HSCM, the people term is highly related to the internal focus on hospital storage and patient needs and how to improve their overall treatment (S. M. Lee et al., 2011). This focus has become increasingly important due to patients'- and customers' demand for higher overall service. Jin, Nicely, Fan, and Adler (2019), claim that customer service and customer satisfaction is the cornerstone of any successful business. Quality of service is a key ingredient to success for typical service organisations (Sohail, 2003). Sohail (2003) uses health care as an example and claims that they are measured on their technical accuracy of the diagnosis and procedures. In this context, patients can be seen as customers. However, in contrast to other industries Sohail (2003) claims that within health care, patients have a distorted view of the perception of quality due to an inability of being able to judge the competence of the medical practitioner. However, based on the conclusion argument of Larson, Nelson, Gustafson, and Batalden (1996), providers of care should focus on delivering and meeting the information needs that patients require, because their perception of a hospital is their ability to transfer vital information to their patients.

Human capital is known to be a highly competitive strategic resource in SCM and is positively related to the performance of a company (Hitt et al., 2017). However, having possession of a strategic resource such as human capital will not give any advantages unless they are facilitated well. By resources, we refer to their skills, knowledge, and other capabilities that can be beneficiary for the company to exploit and help enhance performance (Hitt et al., 2017). Human capital has been necessary for companies for decades and Barney (1991) claimed as early as in 1991 that companies are in deep need of capabilities that are value-enhancing, limited in supply, or hard to duplicate, to outperform competitors.

In a time where digitalisation is evolving rapidly and is implemented in a high scale, empirical findings find digitalisation to affect social sustainability in a positive direction (Bechtsis et al., 2017). Technical developments can improve safety and reduce the time, which is essential to the end user (Barth et al., 2015; Bechtsis et al., 2017). At the same time, there is a fear for digitalisation and robotics to take over for human capital in business after business (Hanifan & Timmermans, 2018). However, the article claims this is a misinterpreted understanding. SC-managers need to rethink and redevelop the whole SC, where human and robots are interacting with each other to create a superior service to the end user (Merlino & Sproģe, 2017). Consequently, an interaction between human and digital solutions in SCs will create new value for the company, the stakeholders, and to the customers or patients. Therefore, the literature is now searching for opportunities to merge human capital and machines in SCM (Hanifan & Timmermans, 2018). However, it comes clear that this field is rather unstudied, and research is needed to look upon this in practice (Hanifan & Timmermans, 2018).

2.3.3 Profit

According to Elkington (1997), the profit line of the TBL principle refers to a company's ability to generate economic value. It determines how a company operates to secure financial returns in the current situation and evolve into the future in order to support future generations. Consequently, every company that wants to sustain over time needs to consider its financial returns in decision makings (Carroll, 1991; Sneirson, 2008). A company's ability to stay competitive in a market will determine their income (Hussain, Rigoni, & Orij, 2018; Porter, 1991), and no company is willing to make a change if there is no financial winning to be made by changing (Sneirson, 2008).

The financial perspective of sustainability is connected to how an organisation can develop its economy by higher performances (Cho, Lee, Ahn, & Hwang, 2012). Cho et al. (2012) argue that SCM is developing economic aspects in organisations. SC can efficiently and effectively lower the total amount of expensive resources required to provide the necessary level of customer service. It is also emphasised in the literature that strategic SCM can increase economic development by increased product availability and reduced order cycle time (Cho et al., 2012).

To develop a sustainable economy and stay competitive, the SCM will have to invest in new methods and solutions (Feige, Wallbaum, Janser, & Windlinger, 2013). As stated, innovations are often expensive in the implementation phase (Haidari et al., 2016). However, Feige et al. (2013) argue that businesses have to focus on the break-even point. Gutierrez and Dalsted (1990, p. 1) defines a break-even point as "*...when an investment will generate a positive return and can be determined graphically or with simple mathematics*". Based on this definition, an investment will be sustainable for the profit pillar when the investment generates a more favourable return than a previous operation (Feige et al., 2013).

Croucher (2018) argue that companies have to follow the market and adapt to changes to stay competitive. In the hospital market, there has been a change to implement SC-philosophy (Uthayakumar & Priyan, 2013). The main change is to balance patient care and minimise the costs. Therefore, it becomes clear that SC-managers are today in greater need of evolving and keeping their strategies up to date with new innovations and trends to cut costs, maintain market share and earn a profit (Molle, 2015).

Digitalised innovations have been favoured in SCM to bring sustainable economical advantages (Rogetzer, Nowak, Jammernegg, & Wakolbinger, 2019). Furthermore, the usage of digitalisation in SC is described in terms of additive manufacturing, blockchain, UAVs, big data, and IoT. These solutions have the ability of create flexibility, mobility and fast deliveries in SCM, which is important to generate sustainable profit (Barth et al., 2015; Bechtsis et al., 2017). However, there is no guarantee that the increased use of digitalisation will make the project yield positive results (Bechtsis et al., 2017). Consequently, evidence of digitalisation's influence on the sustainable economy in SCM and HSCM is needed (Reddy & Sharma, 2016).

2.3.4 TBL-principle as one

As the field of sustainability grows, it is crucial for any SC to acknowledge all the three pillars and link them together to create a sustainable business (Ding, Wang, & Zheng, 2018). More recently an article was published that aimed to encompass the importance of knowledge and understanding of the balance between the three pillars and how industrial activities affect the current and future environment, economy, and people (Ding et al., 2018). The findings revealed that existing literature has not yet given enough attention to the interactive effects between interests regarding the three pillars. The authors state that SCM in terms of reducing environmental- and social externalities is a rather complex task in reality and expects the transformation to take a relatively long time. Furthermore, they highlight that the trade-off between the profit-, people- and planet pilar is a crucial issue (Schiebel & Pöchtrager, 2003).

2.4 Summary of the literature review

Based on a review of the literature regarding HSCM, digitalisation, and sustainability, we recognise a shift in the HSCM (Godbole & Lamb, 2013). There are identified five factors; *cost vs. patient service balance, structure, patient needs, environment, and transportation*, that literature claims have to improve in HSCM (AbuKhousa et al., 2014; Bechtsis et al., 2017; Brambilla & Capolongo, 2019; Buffalo et al., 2014; D. Q. Chen et al., 2013; Dembińska-Cyran, 2005; G. Johnson, 2014; S. M. Lee et al., 2011; Sendlhofer & Lernborg, 2018). The literature has highlighted that digitalisation brings abilities that can enhance sustainability in SCM in general (Cavada et al., 2014; Gomez et al., 2015). Based on this, researches find digitalisation to be a solution to cope with unsustainable issues in the hospital sector, but there is a need for more empirical evidence. As we found digitalisation to be a big term, this research has looked at digitalised UAVs, which can transport products in 'last-mile' delivery in a more sustainable way than traditional vehicles (Yoo et al., 2018). We identify five variables that come from digitalised UAVs: "delivery", "safety", "eco-friendly", "cost-efficient" and "smart technology". To be able to verify the sustainable effect of digitalisation on HSCM, the TBL-principle is applied. The TBL-principle is divided into the three Ps; planet, people, and profit. Scholars claim that it is important to look at all Ps at the same time in decision making to determine the sustainable influence (Ding et al., 2018; Schiebel & Pöchtrager, 2003). From the reviewed literature, it is recognised that digitalisation and strategic SCM affect all of the three Ps in an organisation.

2.5 Theoretical Framework

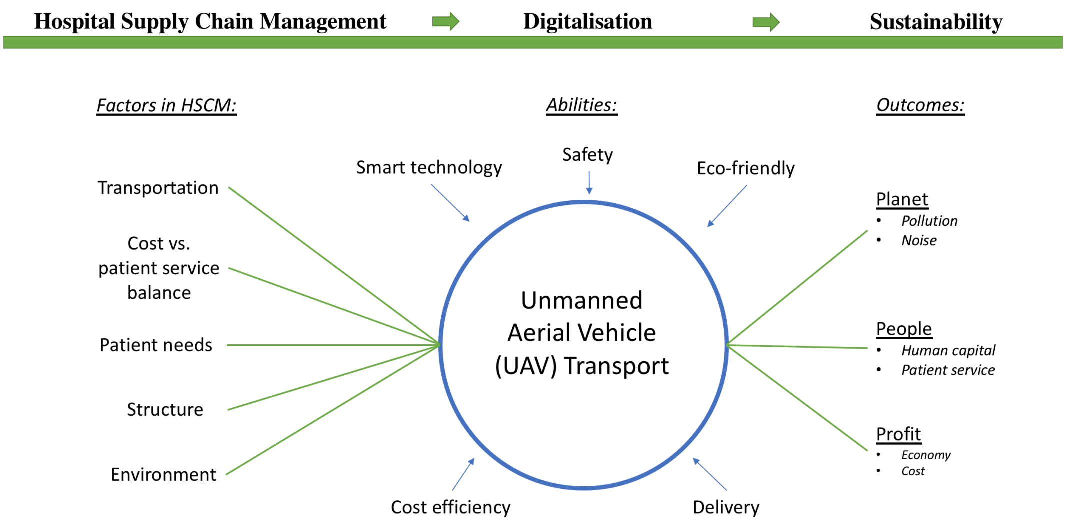

Figure 1 - Theoretical framework

In order to structure our findings from the literature review and apply them to our further research, a theoretical framework (framework) is applied (Figure 1). According to Malterud (2001), a framework can be equated with the reading glasses worn by the researcher, when the researcher is asking questions about the material. To address and share the type and role of the framework correctly, the researchers can maintain communicative validity. This framework illustrates the main findings from the reviewed literature with respect to HSCM, digitalisation, and sustainability.

3.0 Methodology

This chapter will illustrate what methodological choices we have made to answer our research question, "*How can digitalisation affect sustainability in a hospital supply chain management?"* based on our framework. We will describe the research design and research strategy applied. Furthermore, we give a description of what data we have collected, including why and how. We then describe how we analysed the data. Lastly, we will go through the quality of the data.

3.1 Research Design

A research design is defined by Bryman and Bell (2015) as a framework that provides guidelines to the collection and analysis of data. Hence, the research design aims to explain how the empirical study will be led in detail. The choice of research design is of great importance as the design will affect and influence the outcome of the study (Lewis, 2015; Miller & Salkind, 2002). In order to examine and study the possible effects of digitalisation may have on sustainability in HSCM, we chose to study a specific project. OUH has an ongoing project where digitalised UAVs are to transport biological materials and RI for PET-scans. The transportation will be between Ullevål and Rikshospitalet, clinics and stations in the Oslo-area. Based on this, we chose a case study research design.

3.1.1 Case Study

Case studies are suited when research will answer "how-" and "why" questions (Yin, 2003). Our research wants to describe how digitalised UAVs can influence an HSCM, and why, or why not, these UAVs can bring sustainable effects in the HSCM. The case study design is a preferred method to map the effects of a new phenomenon (Yin, 2003), which UAVs in HSCM arguably are. In order to answer our research question, we have applied our framework to a specific company within the hospital industry, OUH. Such a single case study is defined as an intrinsic case study where we try to gain insight into the particularities of a specific case to discover the relationship between theory and research (Bryman & Bell, 2015; Stake, 1995; Zikmund, Babin, Carr, & Griffin, 2010). Moreover, intrinsic case studies are often used to process evaluation, but can also be used to document and analyse outcomes of interventions (Yin, 2011), which our research wants to analyse when UAVs are used as a transportation method in OUH's SC.

Based on OUH's project and their interest in digitalisation, we chose to apply a case study on their organisation. Our research will have a focus on discovering OUH's organisation in a before-after approach and compare today's transportation methods to a future situation with UAV based transportation. We seek to map any sustainable effects when comparing the situations, which is described as an exploring case study design.

3.1.2 Empirical setting

The basis for our case is OUH's developing UAV-project. OUH is planning to implement a fully operational, digitalised UAV park to transport biological materials and RI within the Oslo-area. The digitalised UAVs will replace the current transportation methods of these products, which currently consists of their own vehicles and taxi-services. OUH is a large and complex network of operations and clinics. To enhance the overall patient service in an economical way, the hospital wants to restructure their transportation methods to a digitalised platform. In appendix 10.2, we add OUH's project description if further investigation is of interest.

Our case and research objective is to investigate whether digitalised UAVs are a more sustainable transportation method than OUH's current transportation methods with respect to the TBL-principle. From the literature, we identified abilities that digitalisation and UAVs have, which can enhance sustainability in SCM. By comparing the current situation at OUH to a UAV based situation in the same network, we will be able to map whether the abilities enhance sustainability in OUH's HSCM.

3.2 Research Strategy

Bryman and Bell (2015) claim that a research strategy is merely the distinction between two clusters, namely, quantitative- and qualitative research. In order to triangulate approaches, we have decided to use a combination of these two. This is referred to as a mixed approach (Bryman & Bell, 2015). A mixed approach is defined as "*the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study*" (R. B. Johnson & Onwuegbuzie, 2004, p. 17). As Malterud (2001) claims that quantitative- and qualitative strategies are not incompatible, but rather complementary, we have used both approaches.

Our research has been interested in comparing two situations. By applying quantitative data, we can find differences in the two situations. However, digitalised UAVs are a new phenomenon in HSCM. As a result, we found limited quantified data regarding their effect on OUH's SC. Consequently, we needed additional data. The qualitative data was used for this purpose. Also, the qualitative data enabled us to have an explorative approach to our case. The distinction between quantitative- and qualitative research will be discussed below.

3.2.1 Quantitative research

As our study is a comparative research, where the phenomenon of this research in HSCM is understudied, quantitative data is a key factor in our research. Quantitative research conceptualises reality in terms of variables and measures the variables to establish a relationship between them (Bavelas, 1995; Punch, 2013). Moreover, quantitative research uses numbers as data (Bryman & Bell, 2015). The quantitative data has been applied to this research in order to emphasise the differences between today and a future situation. Some of the factors that our quantitative research will pick up on concerning our framework are transportation, patient needs, deliveries, noise, and more. These will be further highlighted in our results and discussion. The quantitative will also be used to cross-check with findings from the qualitative data and help to determine the importance of findings. Hence, our research will be able to claim findings and results in a more reliable matter by using quantitative data.

3.2.2 Qualitative research

A research strategy that emphasises words rather than quantification is defined as a qualitative research strategy, where quantitative data is neither collected nor generated (Bryman & Bell, 2015). Since this research is looking at a rather new transportation method and especially new in an HSCM, it is of importance to gain knowledge in peoples' experience, ideas, plans and beliefs of a not fully discovered topic. The qualitative data will be used as a source to support findings in regard to the current and future situation. The qualitative research approach makes it possible to answer different scientific questions that cannot be answered with a quantitative approach (Sale & Thielke, 2018).

3.3 Data Collection

Bryman and Bell (2015) claim that data collection is the key point of any research project. To obtain triangulation in the data collection, Bryman and Bell (2015) suggest the usage of both primary- and secondary data. Secondary data are collected by someone other than the researchers and provides an overview of the situation and topics (Bryman & Bell, 2015). Hence, the data are not directly collected or developed toward our specific case, but we use it as supplementary and explaining data. Secondary data may be relevant examples, articles on the subject, or previous research if there exists any. Primary data are data that are collected specifically for the representative business analysis research (Zikmund et al., 2010). Typical collecting methods of primary data are observation, surveys, and interviews (Zikmund et al., 2010). This will depend on whether the data is quantitative- or qualitative data.

3.3.1 Secondary Data

First of all, our secondary data consist of a document from OUH, written as an application to the Norwegian Government that contains information about their project (Appendix 10.2). The document has been used as a base. Additionally, OUH has made an internal report regarding the UAV project (Appendix 10.3). This report was based on a Microsoft Excel (Excel) file, which we received excerpts from. The file contained numbers and calculations on budgets, estimates, patient flows, personnel costs, volumes of blood samples with other analyses. Furthermore, we have used previous reports and studies directly or as a base for our calculations. These will be referred to when used.

3.3.2 Primary Data

Our main goal for the primary data was to collect information on digitalisation and how it can impact sustainability in HSCM. Based on this, semi-structured interviews have been our main research method and source for collecting qualitative primary data for this research. Semi-structured interviews let us have an explorative approach to our theme. According to Bryman and Bell (2015) it can provide researchers with a rich and broad knowledge of the research topic. Gillham (2005) claims that this method facilitates a strong element of discovery, but at the same time keeps a structured focus, which is important in the analysis. It was essential to our research that we had topics we wanted to explore but let those interviewed provide us with information beyond this as well. It can be argued that this form of interviews is the best way of conducting research due to flexibility balanced by structure and quality (Gillham, 2005). Also, by using semi-structured interviews, we can add questions to get clarification during the interviews (Berg, 2009).

Moreover, as the primary goal was to gain an in-depth understanding and have an explorative view of the research, we wanted to gain knowledge of consequences that included multiple perspectives. We interviewed people in different sectors, with different experience and various relationships to UAVs and digitalisation. Consequently, we wanted to study complementary viewpoints. An overview of the interview objects is presented below, where we have rated their "involvement in the project", "knowledge of the hospital structure" and "knowledge of UAVs" from "low" to "high". We have included this categorisation to illustrate that not all interview objects have a direct relationship to OUH, but emphasise that they are still relevant to this research. We base this on the fact that they either have knowledge of UAVs, are involved in the project and/or have knowledge of the hospital structure.

Object	Company	Knowledge of UAVs	Involvement in OUH's project	Knowledge of hospital structure	Interview type and length
Object 1	Oslo University Hospital	High	High	High	Face-to-face Approx. 75 min
Object 2	Posten Norge	Medium	Medium	High	Skype Approx. 60 min
Object 3	Posten Norge	High	Medium	Medium	Skype Approx. 60 min
Object 4	IoTix	High	Low	Medium	Face-to-face Approx. 60 min
Object 5	Oslo University Hospital	High	High	High	Face-to-face Approx. 70 min
Object 6	«Luftfartstilsynet»	High	Medium	Low	Phone Approx. 40 min
Object 7	«Samferdselsdepartementet»	High	Medium	Medium	E-mail

Table 1 - Overview of interview objects

The interview objects have been selected based on their relevant connection towards our research question, framework and case. These persons were picked with a purpose to gain rich information (Sandelowski, 2000), and are not randomly picked, which Malterud (2001) argue is of importance to gain validity. To get in contact with these persons we have used our own network and Internet searches. Additionally, we have been directed to some of the objects by previous interview objects, due to their knowledge and experience within the field. Most of the requested objects were happy to help and agreed to attend an interview. However, some had to decline based on limited time, but we have been met with a positive attitude by all.

We conducted seven interviews (Table 1). In addition to the interview objects at OUH, we interviewed two objects from Posten. Posten's role was related to how they could benefit from a potential UAV-park and infrastructure created by the project at OUH. To obtain a naive-eye during and after the interviews we did interview one person with high knowledge about digitalisation and UAV. In addition, "Samferdselsdepartementet" and "Luftfartstilsynet" were interviewed as they have information about the project and regulation of UAVs.

Our preparation part for this interview technique started by developing a "naïve eye", which Gillham (2005) states is of importance to not have a subjective view in the interviews. We asked questions about the current situation and future situation in regards to the three main themes in our framework. This particular structure was chosen to give us as interviewers a natural flow. Also, it was chosen so that those interviewed could follow our reasoning with a separation between the two scenarios. The interview guide can be found in the appendix (Appendix 10.1).

Since this is an area lacking research and knowledge, we found interviews more explorative than, for instance, questionnaires, which can be used as a quantitative data collection method. Questionnaires are often more restricted and will limit our detailed explorative research. Answers given in questionnaires tend to be influenced by the presuppositions underlying the questionnaire.

3.4 Data analysis

This part of the research will describe how we analysed the collected data. Moreover, a description of how we transformed it into valuable and reliable information to answer our research question is given (Bryman & Bell, 2015).

Bryman and Bell (2015) stress the importance of eliminating flaws and unnecessary information that come from data collection. Thereby, we have use both primary- and secondary data.

3.4.1 Quantitative data

The quantitative data given by OUH was, to some extent, measured in a perspective that allowed us to use their calculations directly. Meaning that OUH had gathered a severe amount of data in advance concerning their project, and several were directly applicable to our case study. An example is OUH's analysis of the experienced 'peaks' related to biological materials which we have used in our results. However, we had to transform variables and add other sources and parts to be able to measure the variables we needed in our case study. We started by familiarising with the data, which Bryman and Bell (2015) claim is of importance. Some of the calculations sent to us were confusing and lacking information. Also, some variables were not provided which we wanted information about. Therefore, we contacted OUH to get clarification in the missing data and variables. For instance, we needed clarification of the production of RI. Therefore, we had a meeting with OUH to gain a deeper understanding of RI.

In order to manage and analyse the quantitative data provided, the software Excel was used. By using Excel, we were able to clean the data and target it towards our case. We chose Excel, instead of more complex software programs like R-studio as the data given by OUH were to some extent treated. In fear of complicating the existing data by using softwares that we did not have experience with, Excel was suitable. In addition, Excel had more than enough computational power to conduct our analysis, and we did not see the need for more complex software systems.

When we were familiarised with the data, we recognised some minor errors. Consequently, we have gathered external by Internet and phone calls. An example is taxi prices.

3.4.2 Qualitative data

In our analysis of the qualitative data we have applied Braun and Clarke (2006)'s "theoretical" thematic analysis. "Theoretical" thematic analysis is driven by the researcher's theoretical or analytic interest in an area. In this research “theoretical” means our framework, which we have used as a base in our analysis. However, we also strived to have an explorative approach to map potential new themes related to our research question. The theoretical thematic analysis has enabled us to test whether our findings were coherent with our framework.

Braun and Clarke (2006) define thematic analysis as “*a method for identifying, analysing and reporting patterns (themes) within data. It minimally organizes and describes your data set in (rich) detail*” (Braun & Clarke, 2006, p. 79). The thematic analysis is split into six stages, which are described in the table below.

1. Familiarizing with the data:	Transcribing, reading and re-reading data, making notes on initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts and the entire data set, generating a thematic map of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing a report:	Selection of vivid, compelling extract examples, final analysis of selected extracts, relating the analysis back to the research question and literature, producing a scholarly report of the analysis.

Table 2 - Six stages of thematic analysis

(Braun & Clarke, 2006)

We have gone through the six steps of the thematic analysis to discover if the subjects, topics and themes from our semi-structured interviews correspond with those topics that were included in our framework. With this in mind, we aim to test how valid our framework is. The results of the thematic analysis is illustrated in a thematic map, which shows how the sub-themes. We will show and elaborate on this map in chapter five.

The thematic analysis started by transcribing our interviews to familiarise with the data, which is phase one. Due to the choice of interview method we saw that many of the responses started out by having a high degree of relevance in regards to the questions asked, but continue in to other topics. However, as we had semi-structured interviews, we were interested in what themes these statements evolved into. Stage two was a classification of the answers given which we sorted in color codes. The following codes were used:

- Green = answers the question in a high degree of relevance.
- Orange = answers the question in a low degree of relevance.
- Blue = does not answer the question, but is relevant towards other subjects.
- Grey = little degree of relevance. (These were statements where the interviewees talked freely about topics that we could not relate to our research.

This was done in order to process and organise the coding but will not be illustrated in this research.

We aimed to identify aspects in the data that might form the basis for patterns across the data. Our analysis reviewed the codes we had developed and focused them on broader themes. Consequently, the answers were transformed into themes outward the color-codes which is defined as phase three (Braun & Clarke, 2006). Those themes that were highly relevant to our research question and framework were categorised as main themes, while others became sub-themes under the main themes.

We used the software program NViVo, a qualitative research analyst program to organise the transcribed data. Based on the organisation in NViVo we gained knowledge about different views regarding topics and it helped us to see the responses from different angles. An important aspect when analysing the data was to keep in mind that we were not solely looking for topics and answers that would support our beliefs and idea, but also those that would challenge or even discredit it.

In phase four, we evaluated the themes and looked for missing codes to determine if some of the themes actually were not themes (Braun & Clarke, 2006). We read each answer in a big picture perspective and shortened the answers to keywords or short sentences. At this point, we had a clear structure of themes and sub-themes that were relevant. Defining and naming is what Braun and Clarke (2006) argue is phase five. We analysed the themes in respect to what is of interest and why. This includes analysing the themes themselves but also in relation to each other. When naming the themes we wanted the names to be concise, punchy and immediately give the reader a description of what the theme is about, which Braun and Clarke (2006) claim is important. Lastly, phase six is defined as the "producing the report" (Braun & Clarke, 2006). At this phase we were summarising the analysis and defined the main findings from our findings.

3.5 Quality of the Research

The quality of the research concerns whether the research is trustworthy and believable, and whether it answers the questions it is set out to answer. Consequently, we will evaluate the research based on the research criterias trustworthiness, validity and replication (Bryman & Bell, 2015).

3.5.1 Trustworthiness

Bryman and Bell (2015) use the term of trustworthiness as an alternative criteria for evaluating qualitative research. According to Guba (1981), trustworthiness is made up of four different criterias; *credibility, transferability, dependability* and *confirmability.*

Credibility has been argued to be one of the most vital of the four in obtaining trustworthiness (Lincoln & Guba, 1985; Shenton, 2004). Credibility aims to ensure that the research is done under good practice and to test the data with members to ensure if they have correctly understood the social world and how congruent the findings are in terms of reality (Bryman & Bell, 2015; Guba, 1981; Shenton, 2004). To confirm the credibility, Shenton (2004) states that researchers can measure both triangulation and encourage for honest answers. In our research, we have obtained triangulation by having a wide range of informants in interviews and used primary and secondary data as supporting documents. Also, during and before each interview, we have stated to interviewees that they the can refuse to participate, hence increasing the credibility (Shenton, 2004).

Our research has focused intensively on a specific case study for OUH; which makes the findings hard to conclude and apply to other organisations or populations, hence decreasing the *transferability* of our research (Bryman & Bell, 2015; Shenton, 2004). Bryman and Bell (2015) claim that to obtain *dependability* in research, researchers need to adopt an 'auditing' approach, meaning that all findings and procedures are kept in an accessible manner to let other researchers keep trail of all phases of the research. Furthermore, the different phases of our research will not be published, merely this thesis. Therefore, the dependability is overall decreased. Lastly, the *confirmability* of our study is concerned with if we have been biased in our research and aims to measure objectivity (Shenton, 2004). We claim that since both authors have made the interview guide, the questions asked have been without underlying individual beliefs. Also, we have discussed the findings from interviews and made sure that we were critical and had both understood the results in the same way, hence increasing the confirmability of our results (Bryman & Bell, 2015; Shenton, 2004). However, we acknowledge that to gain information about OUH's HSCM, a lot of viewpoints are from OUH employees. Their knowledge about the current situation was important to our study, but we recognise that obtaining objectivity and unbiased views becomes more difficult due to this.

3.5.2 Validity

Bryman and Bell (2015) claim that validity is, in many ways, the most important criterion of a research. Furthermore, they explain validity as the integrity of the conclusions that are generated from a piece of research. We have focused on external validity in this research.

External validity is concerned whether the result of a study can be generalised beyond the specific research context (Bryman & Bell, 2015). We have focused on external validity to generalise our results and findings. However, Bryman and Bell (2015) argues that a single case study is problematic to generalise and apply to other cases. Therefore, we seek to generalise our framework to other cases where digitalisation can affect sustainability in HSCM.

As this research is an intrinsic case study, some issues are acknowledged regarding the external validity. Firstly, the case of our research is related to the hospital industry. To our knowledge, hospitals will get special permissions to fly UAVs in the cities, which other industries are not allowed to. Thus, we find the generalisability to decrease. Secondly, relevant factors for others will be distances between hospitals, the current transportation methods or the financial support they receive from investors. Moreover, the freight is rather special in this case, where biological material and RI are transported. Hence, the type of freight may reduce the external validity, based on the fact that this demands special treatment. Due to the increasing development in UAVs, it is relevant to consider the fact that costs related to UAV-infrastructure will be heavily reduced as technology develops and that their reliability and durability will increase. Therefore, the results from this case will be a good guidance, but they will need to consider recent developments because they will impact the entire business case. In that way, others will most likely receive relatively similar results, but there are many factors that need to be similar and thereby the generalisability and external validity of the case decreases.

Moreover, Malterud (2001) claims that findings from a qualitative study are not thought of as facts that are applicable to the population at large. Nevertheless, we want our findings and framework to be applicable as description, notions or theory within the same settings. Therefore, research articles have been deployed to increase the external validity, in the meaning that there are other researchers that have determined the same results as us. Lastly, according to Malterud (2001), validity and trustworthiness is improved by triangulation.

3.5.3 Replication

Research cases aims to be replicable according to (Bryman & Bell, 2015). Replicability compares research studies influenced with different situations and different subjects. Replication determines whether the basic findings of the original study can be applied to other participants and circumstances. It is important that our results are replicable, even though it is difficult to replicate a single case study (Bryman & Bell, 2015). We find that the project at OUH will develop with time. Consequently, researchers that attempt to replicate this study may get other results and findings as surrounding factors may have evolved. Developments within technology, legislations and costs will be main factors to determine the outcome of the study and may have effects on sustainability that has not been possible to take into consideration in our case study. Therefore, the overall replicability is decreased.

Each interview has been on the same basis and structure, where we have strived to use the same interview questions so we could analyse and compare answers at a later point. Some of the statements may be subjective and out of context. The interview objects may hold back information which they do not wish to share, or they tell us what they believe we want to hear. In addition, each interview will contain a lot of information, where not every aspect is relevant for the research project. From this, we acknowledge that the replicability may decrease. Moreover, the quantified data is collected and measured for a specific area and a specific hospital region. Thus, other circumstances may influence in other hospital regions.

4.0 Case description and results

In this chapter, we will present the results and empirical findings based on the analysis of the quantitative- and qualitative data. The results will prepare the research for a discussion, which is presented in the next chapter. Our framework will be used as a guideline in the presentation of our results. We will apply quotes from the interviews and refer to our calculations and secondary data.

The purpose of this research is to investigate how digitalisation affect sustainability in HSCM. As described in the methodology chapter we have chosen to do a case study of OUH.

OUH is a Norwegian University Hospital that is owned by the Norwegian government (OUS, 2019). It is the largest hospital in Norway with over 23.000 employees (OUS, 2019). In 2009, Rikshospitalet, Ullevål and Aker university hospital merged into what we refer to as OUH. In total the hospital consists of 325 buildings which are partitioned on Rikshospitalet, Ullevål, Aker and Radiumhospitalet.

OUH comprises patient treatment, research and education. They describe themselves as an organisation that work towards a superior patient and customer service (OUS, 2019). A new solution that OUH is going to implement is digitalised UAV based transportation in their HSCM (Appendix 10.2). The UAVs will transport biological materials and RI for PET-scans between hospitals, clinics, stations and laboratories. Today, OUH transport these products by own vehicles and taxis. Most of the biological materials are sent between Rikshospitalet and Ullevål. In addition, some are transported to other smaller clinics and stations in the Oslo-area (Appendix 10.2). Based on a meeting with OUH, we understand that RIs are used in PET-scans to detect tumours in a patient's body. The RI is an unstable isotope of an element, which means that it degrades spontaneously. The RI is produced at Rikshospitalet and transported to Ullevål, Aker hospital or other clinics that have a PET-scans by car.

Both biological materials and RI can be transported by UAVs (Appendix 10.2). Hence, we will first present our results of the current situation where these products are transported by ground-based vehicles. Secondly, we will present the results of a future situation, where the same products are transported by UAVs. Based on these results we will present two figures, where we see the differences of the two situations (Figure 2 and Figure 6). In each situation, we will go through our results on the three main topics: HSCM, digitalisation and sustainability.

4.1 Current situation

In this part we will elaborate on the current situation at OUH. The situation is divided into three parts, HSCM, digitalisation and sustainability.

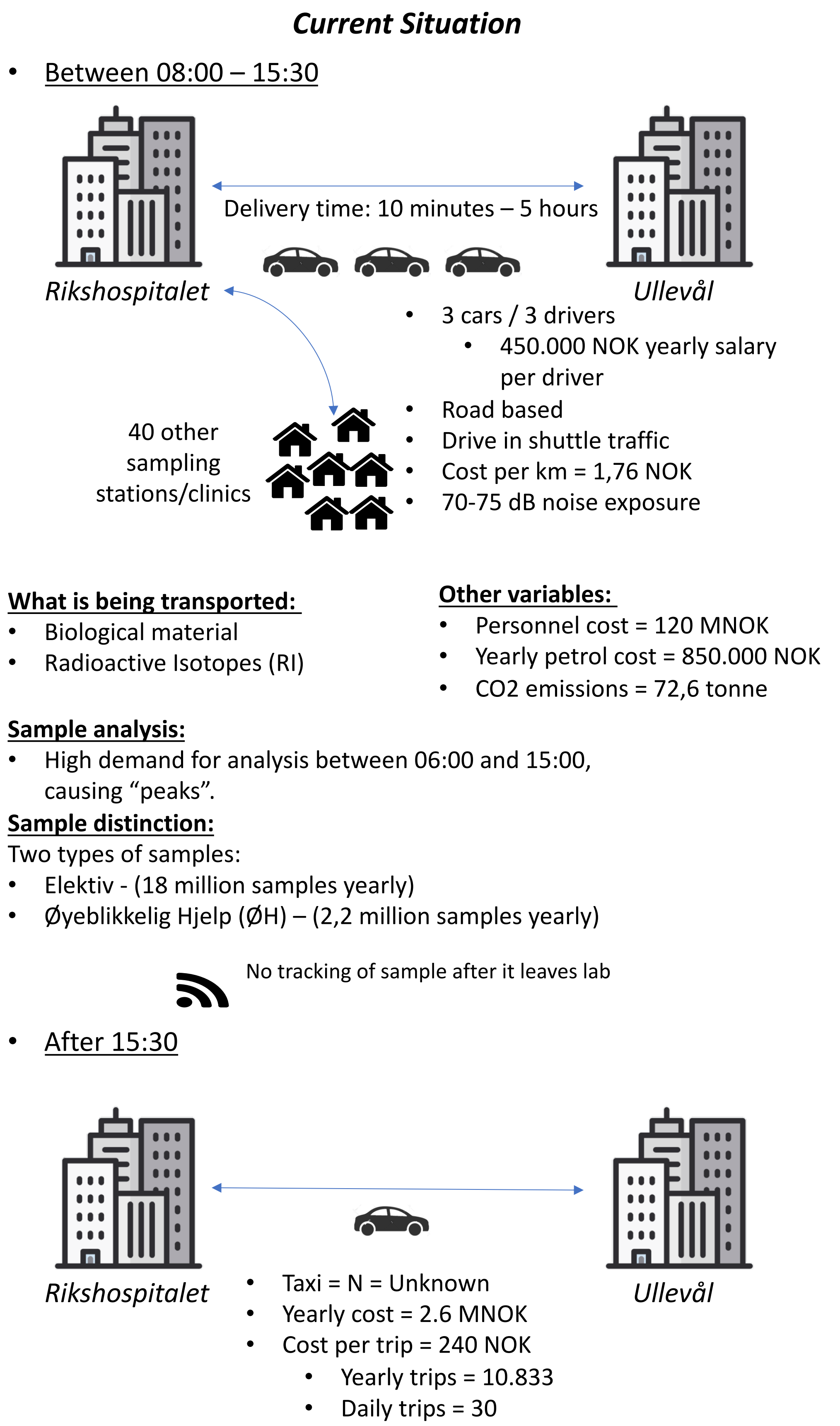

Figure 2 - Current Situation

4.1.1 HSCM

The results show that OUH has three own vehicles (Appendix 10.3). The vehicles are used to transport biological materials and RI in shuttle traffic between Ullevål and Rikshospitalet. Also, they transport to 40 other different stations and clinics in the Oslo-area. These vehicles are operational from 08:00 to 15:30 every day. Outward this period, OUH hires taxis to transport the products. The biological materials are transported 24/7. According to the interviewees, the 40 different stations and clinics result in a complex transportation network that lacks any specific plan and logistical thinking.

- *"This structure carries the mark of a service that has been developed without any plan, only because a need has occurred."*
  (Object 5, OUH)

The interviewees state that the transportation of biological materials and RI is vital to the patients as it is a subprocess in their treatment.

- *"We are totally dependent on those samples for everything we do."*
  (Object 5, OUH)

Transportation				
Salary cost			Cost per km	
Personnel:		3	Petrol cost per litre*	kr 17,03
Yearly salary per driver	kr	450 000,00	Number of litres (petrol)	50000
Total salary cost per year	kr	1 350 000,00	Yearly petrol cost	kr 851 500,00
			Distance travelled (KM)	484279
Taxi-transport			Cost per km =	kr 1,76
Number of taxis	Unknown			
Money spent on taxi transport	kr	2 600 000,00	* Circle K (2019)	
Cost per trip	kr	240,00		
Yearly trips		10833		
Daily trips		29,7		

Table 3 - Transportation costs

(CirkleK, 2019)

Our results give that costs related to transportation are three folded. First, there is a cost for the personnel that transports the samples between Rikshospitalet and Ullevål. Three employees are working at the transportation station with a yearly salary is 450.000 NOK each (statement from OUH). Secondly, our calculations show that during a year, OUH's vehicles consume 50.000 liters (Appendix 10.3), to a price of 17,03 NOK per litre (CircleK, 2019). This price is retrieved from Cirkle K's petrol prices, which changes daily. This gives an estimated yearly petrol cost of 851.500 NOK. The yearly mileage of 484.279 km results in a cost per km for OUH to be 1,76 NOK. Thirdly, OUH spends 2.600.000 NOK on taxi-transport (Appendix 10.3). Oslo Taxi give us an average cost per trip of 240 NOK, which is based on weekdays and weekend costs and the transport of goods, which adds a 25 % value-added tax (VAT). This results in an average of 30 trips by taxi each day. Currently, the transportation costs stand for 3,9 % of the total costs in OUH's HSC.

Transportation cost of total costs	
Total costs (personnel, taxi, petrol)	kr 123 851 500,00
Transportation costs (drivers, taxi, petrol)	kr 4 801 500,00
Transportation costs in % of total costs	3,9 %

Table 4 - Transportation costs in % of total

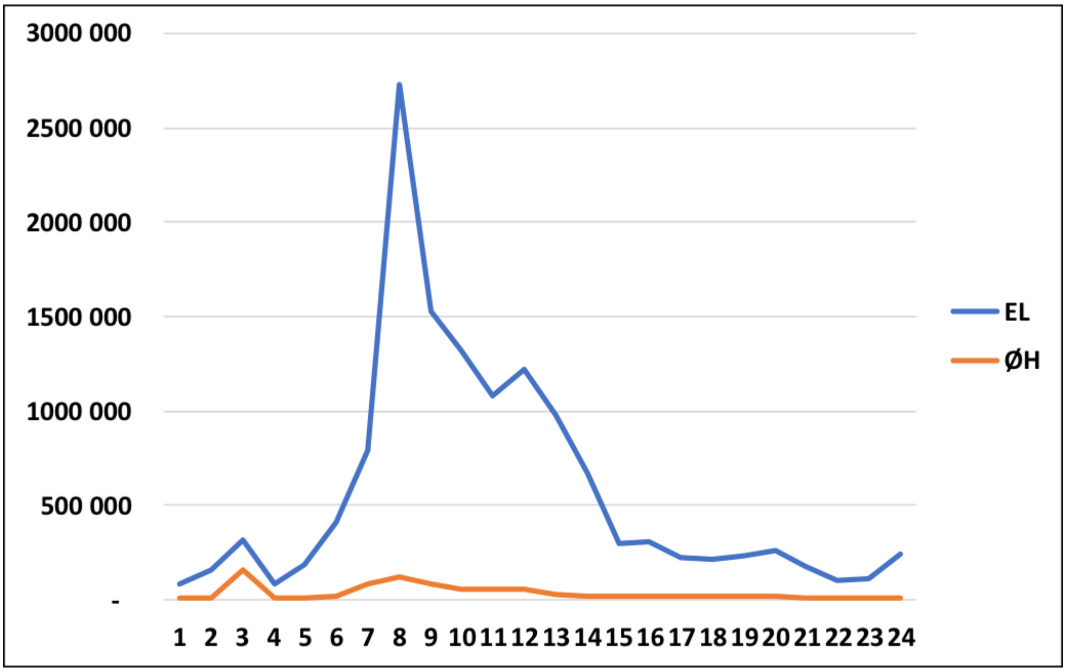

Figure 3 - Blood samples demand per year

(Appendix 10.3)

X axis = time of day, **Y axis** = number of glass samples[1], **Blue** = elektiv samples, **Orange** = ØH samples

Our results show that during a year, OUH has peaks regarding biological material sampling (Figure 3; Appendix 10.3). The biological samples have two types of

[1] Samples are split based on diversity of analysis, requiring several glass samples for different treatments (Appendix 10.3)

distinction: "Elektiv"-and "Øyeblikkelig Hjelp"(ØH)-samples. In total, there is a yearly demand for 18 million elektiv-samples and 2.2 million ØH samples (Appendix 10.3).

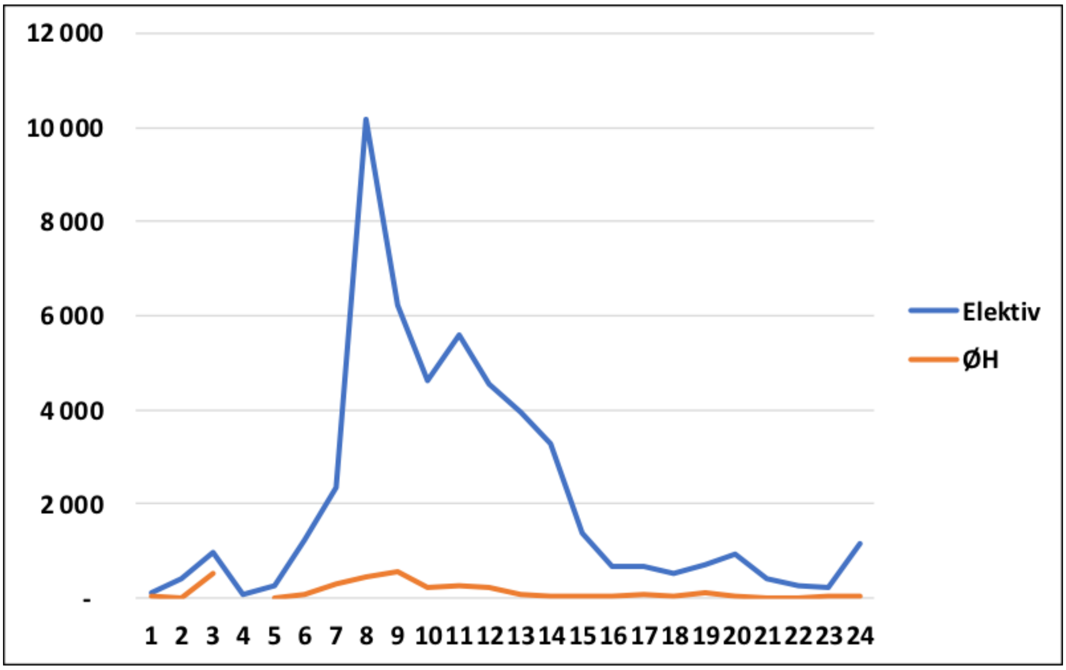

Figure 4 - Blood samples demand per day

(Appendix 10.3)

X axis = time of day, **Y axis** = number of glass samples, **Blue** = elektiv samples, **Orange** = ØH samples

From figure 4, we see that there is a daily peak in the period between 06:00 and 15:00 of approximately 41.000 samples. ØH-samples have to be analysed within an hour, while the elektiv-samples[2] are analysed when there is time, due to a routine based transportation system (Appendix 10.3). Our results show that the delivery and analysis of elektiv samples can take up to five hours. Interviewees state this is due to traffic congestion and that each vehicle waits until the trunk is fully loaded with samples before transportation. Time efficiency was recognised as an important factor for patient needs. OUH has limited resources concerning handling and transporting these samples (Appendix 10.3).

- *"If I am to point at one thing, it has to be the time cruciality. It takes often long time to bring a commodity from A to B… sometimes it take up to five hours if the car have to wait till its full."*
  (Object 2, Posten)

[2] Elektiv-samples are described as planned samples (Appendix 10.3)

- *"Our main task is to safeguard the patient needs. They rely on us to treat them and their biological materials in a time efficient way."*
  (Object 1, OUH)

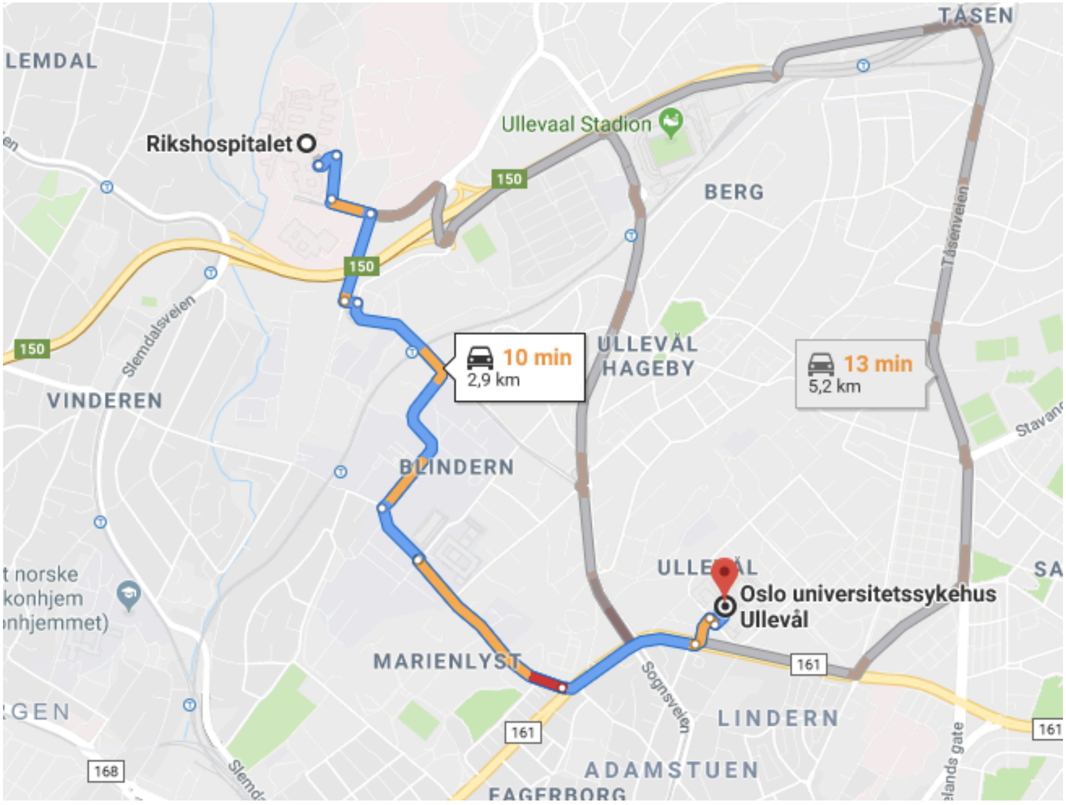

Figure 5 - Road based distance between Ullevål and Rikshospitalet (GoogleMaps, 2019b)

From figure 5, we see that the distance between Rikshospitalet and Ullevål is 2.9 km by road, assuming that the vehicles drive the shortest route. The distance to the other sampling areas varies in length, but are all within the municipality of Oslo. Based on the distance, the estimated transportation time is 10 minutes from Rikshospitalet to Ullevål.

It is stated in the interviews that OUH has not been focusing on environmentally friendly solutions. Their primary focus has been to provide superior patient service.

- *"I don't think the health sector has given any concerns on how to operate environmental friendly."*
  (Object 5, OUH)

4.1.2 Digitalisation

The interviewees state that the transport methods at OUH are manual, and to our knowledge, there is no usage of smart technology or digitalised solutions.

- *"It's a bit funny, some parts are highly technological… but the transportation of biological materials are run the "old fashioned way", manually."*
  (Object 3, Posten)

The interviewees highlight that OUH's transportation methods have a high degree of safety. The samples are transported in OUH's vehicles and with identified employees. After 15:30, the samples are transported with taxis, and OUH does not have any control of the exact location of the samples or any identification of the driver.

- *"I would imagine that a lot can go wrong in the value chain when you use taxis and such …"*
  (Object 4, IoTiX)

- "*...so your genetic material is placed in the backseat of a taxi which anyone can pick up. How safe is that?"*
  (Object 1, OUH)

Misidentification of biological samples	
Identity mistakes of all samples taken	1 %
Number of biological material samples at OUH (yearly)	20200000
= Number of affected samples	202000
Faults that occur before analysis (%)	59 %
Number of analysis misidentified before analysis at OUH (yearly)	119180
Based on report by Krogstad, Hafstad, Patrono, Saastad, and Flesland (2014)	

Table 5 - Misidentification of biological samples

(Krogstad, Hafstad, Patrono, Saastad, & Flesland, 2014)

Based on table 5, we see that 119.180 samples are misidentified before reaching the analysis phase (Krogstad et al., 2014). The interviewees highlight that OUH is missing a tracking system for the samples. When samples leave the stations or clinics, there is no system to determine where they are, until they reach the laboratory.

- *"We are operating with a tremendous amount of samples each day, and we admit it is hard to control where they are. Therefore we have discussed to implement some kind of tracking system…"*
  (Object 5, OUH)

When we asked the interviewees whether OUH's operations are cost-efficient, all the interviewees agreed that late and unpredictable deliveries are not cost-efficient. They claimed that the current deliveries are often late and other departments in the HSC that are dependent on the deliveries do not know when they will arrive.

Radioactive Isotopes		
Production cost per unit NOK:	kr	5 000,00
Production amount for one treatment		3,00
PET-scan for one person	kr	15 000,00
Number of scans today		4 000,00
Total production cost today	kr	60 000 000,00
The cost of RI-production is a parameter given by OUH		
We assume that all productions have to be made with three times the amount to treat one person (based on a statement from OUH)		

Table 6 - Production cost of RI

From table 6, we see that the yearly cost of producing RI used in PET-scans cost 5.000 NOK for one batch. The half-life[3] of the RI is short, and OUH produces on average, three batches to treat one person. The yearly cost of RI-production is estimated to be 60.000.000 NOK. This information is based on an explanation from OUH. They claim they have to produce this much RI because of unpredictable deliveries.

- *"... to send from the basement here to Aker Hospital in the "rush hour traffic" in the morning and half an hour goes by, you've already reduced*

[3] The radioactive element used in RI degrades spontaneously. It means that the lifetime of the product is short (Based on meeting with OUH)

the amount, so you have to produce for approximately three persons to treat one person or take one picture.”
(Object 1, OUH)

Salaries		
Personnel cost	kr	120 400 000,00
Total salary costs for drivers	kr	1 350 000,00
Salary costs related to handling and analysis	kr	119 050 000,00

Table 7 - Salaries for handling and analysis biological material

Table 7 illustrates the salaries of handling and analysing the biological materials at OUH. This calculation is based on OUH documents (Appendix 10.3). Without the salaries related to the drivers, we see that the salary cost is 119.050.000 NOK. The interviewees state that this cost is increasing.

- *“The major issue for OUH is that they never know exactly when the deliveries will arrive, due to traffic. Therefore, I would say that their biggest issue is the lack of predictability.”*
  (Object 2, Posten)

In respect to eco-friendly solutions, the results give that the current vehicles used by OUH are petrol-based (Appendix 10.3), while the taxis use a diversity of gasoline, diesel, or electric driven vehicles. These vehicles are road-based, and the interviewees claimed they are a source to particulate matter pollution.

- *“An issue that comes from an increasingly traficated road network is the particulate matter pollution…”*
  (Object 3, Posten)

4.1.3 Sustainability

The OUH-documents show that the vehicles owned by OUH drive 484.279 km per year (Appendix 10.3).

CO2-utlipp-kalkulator	
Kjøredistanse (km)	484279
1. Etter CO2-utslipp:	
Bilens CO2-utslipp per km (gram)	150
Utslipp i kg	72 642
2. Etter forbruk per mil:	
Bilens drivstofforbruk per mil	0,65
Drivstoff	Bensin
Utslipp i kg	73 029
Source: Pedersen (2018)	
Average CO2-emission of a car: 150 (Vegvesen, 2019)	
Assuming that all of OUH's vehicles uses gasoline	

Table 8 - CO2 calculations

(Pedersen, 2018; Vegvesen, 2019b)

Table 8 highlights the emission of OUH's vehicles. Assuming that the vehicles CO2-emission per km is 150 grams (Vegvesen, 2019b), the vehicles emit 76.642 kg CO2 each year.

OUH's transportation methods contribute to the disturbing noises that stem from the traffic in Oslo. A regular vehicle emits 70-75 decibel of environmental noise when driving in a city center (Paviotti & Vogiatzis, 2012). In addition to environmental noise and CO2-emissions, we find that the vehicles contribute to the emission of particulate matter pollution as mentioned above and maintenance and tear of the roads in general.

For OUH, it is essential that the working conditions are safeguarded. According to the interviewees, the employees at OUH are satisfied with the working conditions and their salaries. It is stated that the employees at the laboratories and clinics often have to work overtime and night shifts as there are delays in the deliveries of biological materials.

- "*...there is a growing concern that the nurses have to work several hours overtime to be able to analyse all the samples coming in. The overtime increases in line with the increasing amount of samples."*
  (Object 1, OUH)

The interviewees' highlight that the delays propagate in the entire value chain of OUH and is significantly contributing to their related costs for operations.

- *"Yes, I think that the delays we have with samples today and the total unpredictability propagates in the entire system and significantly contributes to the costs that we have in the hospital today."*
  (Object 5, OUH)

Our results show that OUH is a public healthcare institution that is owned by the Norwegian government. To generate profit is not a goal for OUH, but to reduce costs without degrading the patient service and needs is. OUH is constantly questioned whether their operations are the optimal solutions to provide the best patient treatment and care to the lowest possible cost.

- *"The hospital is supposed to be operating in an economical manner and at the same time take care of health and life, so it feels like the hospital is in a squeeze between money and the quality and then we see the transportation as a more and more central part of this dilemma."*
  (Object 2, Posten)

- *"We do research on both social research and economic research, but also technological and medical research here at OUH, and everything is related to new methods."*
  (Object 5, OUH)

The current situation at OUH is characterised by two types of transportation methods, own vehicles, and taxis, which transport biological materials between Rikshospitalet and Ullevål and RI. Table 3 has shown the costs that are related to transportation. Our results have shown that there are peaks related to analysis and handling of biological material. Also, OUH's transportation methods are not digitalised. The deliveries affect other operations in OUH's SC. Moreover, we have mapped sustainable factors at OUH. We will discuss our results in chapter five and their implications.

4.2 Future Situation

In this section, we will look at a future situation where digitalised UAVs transport biological materials and RI at OUH. We will go through our results with respect to the HSCM, digitalisation, and sustainability.

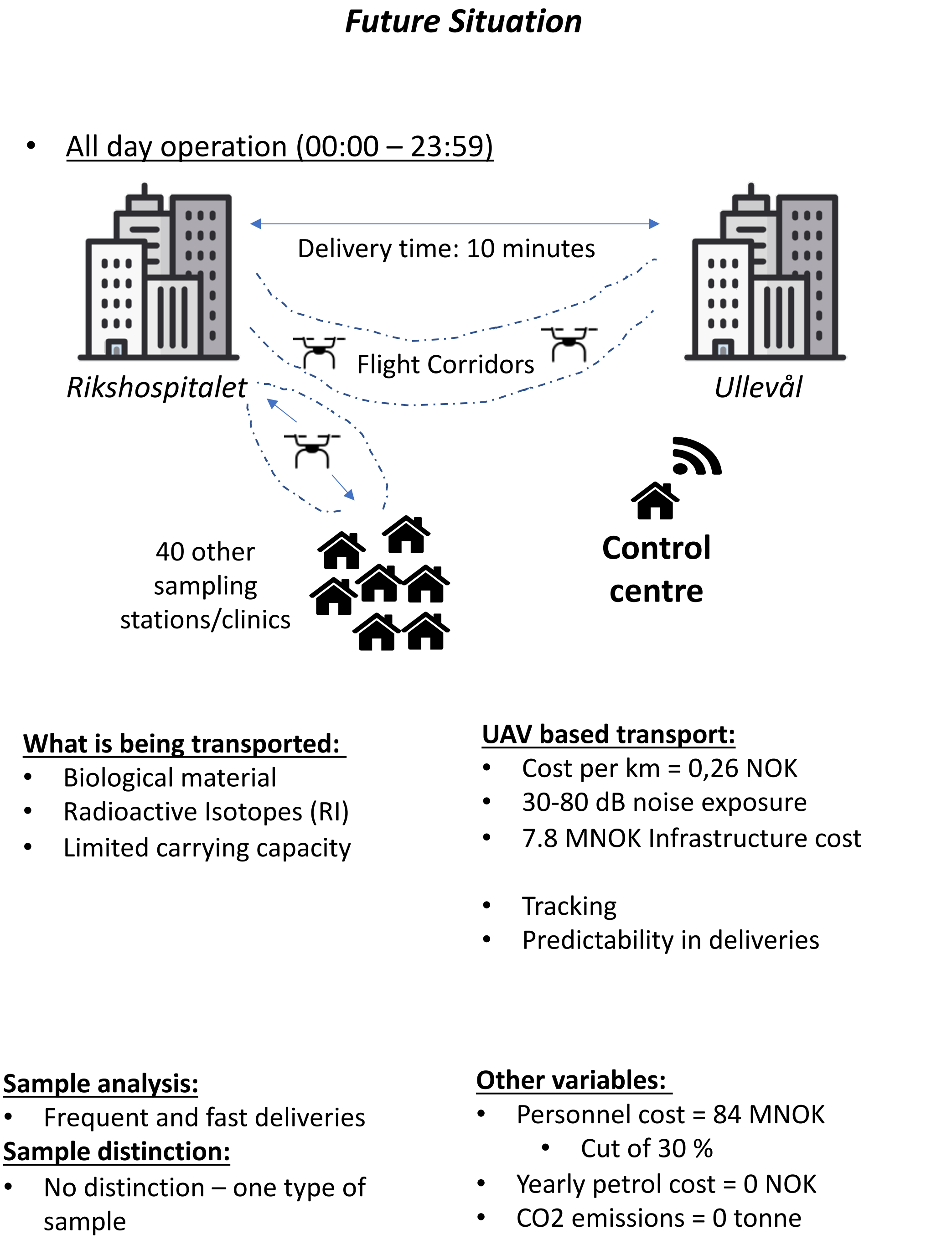

Figure 6 - Future Situation

4.2.1 HSCM

In a future situation, the interviewees claim that OUH can operate the transportation of biological materials and RI solely based on UAVs. The UAVs will be autonomous and be able to operate 24/7.

- *"...but this will be completely autonomous. There is not going to be anyone driving them, but there will be someone in a control centre and surveilling."*
  (Object 1, OUH)

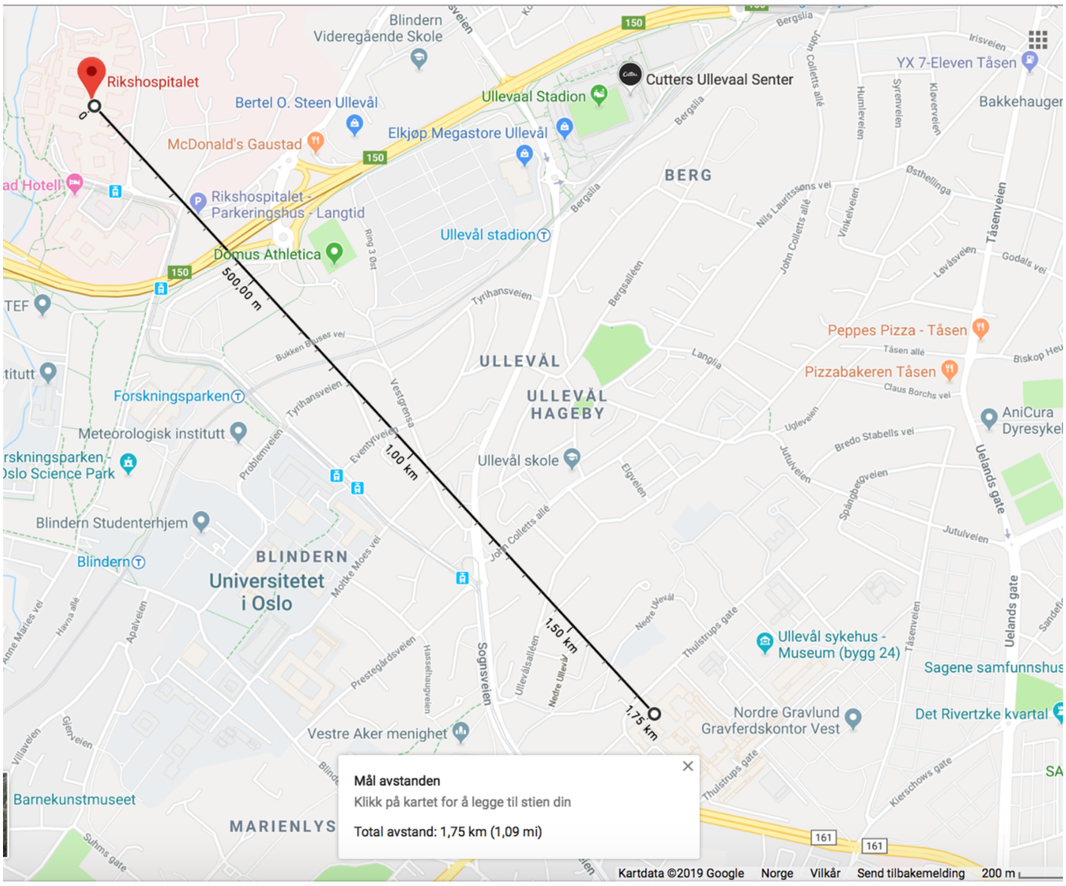

Figure 7 - Aerial distance between hospitals

(GoogleMaps, 2019a)

From figure 7, we see that the distance between Rikshospitalet and Ullevål is 1.75 km in aerial distance. We assume that the UAVs are allowed to fly in a direct route between the hospitals. From OUH documents (Appendix 10.3), we find that the predicted time UAVs will use between Rikshospitalet and Ullevål is 10 minutes.

Transportation		
Cost per trip		
Cost per trip (if 8KM)*	kr	2,08
Cost per KM	kr	0,26
Cost per trip =	kr	0,46
*Based on Drone delivery models for healthcare (Scott & Scott, 2017), and Up in the Air: A Global Estimate of Non-Violent Drone Use 2009-2015 (Choi-Fitzpatrick et al., 2016)		

Table 9 - Transportation cost UAV

(Choi-Fitzpatrick et al., 2016; Scott & Scott, 2017)

Our calculations in table 9 show that to transport a product one km with UAVs costs 0,26 NOK. The main transportation route is between Rikshospitalet and Ullevål. Using a UAV as a transportation method on this route will cost OUH 0,46 NOK. The distances to the other clinics are unknown, but the cost will be the (distance x UAVs cost per km). The exact number of UAVs needed to operate the entire transportation network is unknown, but the interviewees state that there has to be some form for back-up system.

- *"You will need to have different back-up systems to satisfy a certain safety demand."*
  (Object 5, OUH)

Infrastructure		
Estimated UAV infrastructure cost (US dollars)		900000
1 USD = 8.68 NOK (11.jun 2019)*	kr	8,68
Complete infrastructure** (NOK)	kr	7 812 000,00
*(Aftenposten, 2019)		
***50 base stations, 150 drones (400 km infrastructure)*		
Based on Drone delivery models for healthcare (Scott & Scott, 2017), and Up in the Air: A Global Estimate of Non-Violent Drone Use 2009-2015 (Choi-Fitzpatrick et al., 2016)		

Table 10 - Infrastructure costs

(Aftenposten, 2019; Choi-Fitzpatrick et al., 2016; Scott & Scott, 2017)

Table 10 shows that an investment in a complete UAV-infrastructure will cost approximately 7.812.000 NOK. This is based on creating 50 base stations and operating 150 UAVs. From the interviews, we find the costs related to an UAV-platform to be uncertain and may be very expensive as it has to be specialised to the hospital's needs.

- *"UAVs are more sexy than the platforms, and naturally it is more focus on the UAVs."*
  (Object 2, Posten)

According to the interviewees, the UAVs can efficiently transport biological materials and RI. They will depart frequently based on a schedule. Furthermore, our interviewees pointed out that by using UAVs, all samples will be prioritised with the same urgency.

- *"With UAVs, we know that samples can be transported separately and very frequently..."*
  (Object 1, OUH)

- *"So, having a better and more predictable practise means that the entire operation of the hospital is more predictable and ultimately, for the patients it means less waiting and a safer and better treatment. So, I'm absolutely sure this will have a great impact on our patients."*
  (Object 5, OUH)

In respect to the environment in a future situation the interviewees acknowledge that the hospital sector has to invest in environmentally friendly operations, but it is an additional benefit of implementing UAVs.

- *"OUH does not invest to save the environment, but we do it in a way that has a positive contribution to the environment, because we change to clean energy."*
  (Object 1, OUH)

4.2.2 Digitalisation

The results show that the UAVs use smart technology and are digitalised. According to the interviewees, the UAVs will be autonomous and can "communicate" with the ground and control centre due to smart technology. They can communicate where they are, distances, and what products they are transporting. In addition, the interviewees stated that digitalised UAVs have sensors as a part of their manoeuvring system.

- "*Usage of sensors in new technological devices is becoming very important. I find sensoring and smart technology to be a crucial part in how UAVs can operate.*"
  (Object 4, IoTiX)

When we asked about safety in a UAV-based situation, all interviewees agree that there is a risk of the UAVs to fall down or collide. It was stated that they would fall down at some point. Additionally, the results show that there is a risk for the UAVs to be hacked or hijacked.

- *"We need to have a mindset that we are transporting humans, meaning we can not allow them to fall down. However, it will happen."*
  (Object 1, OUH).

- *"The worst case scenario is if the UAV fall down and hit someone."*
  (Object 6, "Luftfartstilsynet").

- *"In respect to hacking of a UAV, it is possible to hack a plane or a Tesla..."*
  (Object 4, IoTiX)

"Luftfartstilsynet" is establishing aerial corridors were UAVs can fly to minimise accidents. Additionally, they are preparing legislation and protocols for UAV-transportation.

- *"...drone transport can operate in corridors, that are more or less temporary or established in beforehand…"*
  (Object 6, "Luftfartstilsynet")

Moreover, the interviewees state that safety is about keeping the biologic materials safe. The smart technology in the UAVs can be used to track the UAVs and the samples.

Cut in identification mistakes	
Number of mistakes	119 180,00
Cut %	45 %
Reduced number of misidentified samples	53 631,00
Identification mistakes with UAVs	65 549,00
Based on OUH documents	

Table 11 - Misidentified samples

(Krogstad et al., 2014)

In table 11, we have calculated the number of identification mistakes in a situation where UAVs transport the biological material. From Appendix 10.3, we have that OUH estimates a cut of 45% of misidentified samples, due to tracking of the samples. The number of mistakes is based on the report from Krogstad et al. (2014) and previous calculations. This is regarding mistakes that happen before the samples arrive the analysis phase.

Cost-efficiency is an important topic in the interviews about a future situation. It is stated that the UAVs will facilitate fast and predictable deliveries, which create repercussions in the HSCM.

- *"The technology of UAVs is expensive… There will be economic effects of the implementation, but on other levels than in the transportation itself. Additionally, it will enhance quality and predictability."*
  (Object 2, Posten)

From Appendix 10.3, we find that the production cost of RI for PET-scans is estimated to be cut by 50% on an average base. By using UAVs, OUH can calculate the exact time needed for transportation and treatment and produce thereafter (statement from OUH).

Salaries		
Yearly salaries personnel	kr	120 400 000,00
Cut in personnel costs		30 %
Saved salary costs	kr	36 120 000,00
Estimated new salary cost	kr	84 280 000,00

Table 12 - Salary cost

Table 12 illustrates a cut of 30% in salary costs that are related to the handling and analysis of biological material and RI (Appendix 10.3). The UAVs will be fully autonomous, and concerning the human capital, the interviewees agree that implementation of UAVs will replace some positions.

- *"Tasks that have previously been done by persons will in the future be done by UAVs. This will help to free up resources."*
  (Object 7, "Samferdselsdepartementet")

Several of the interviewees find the UAVs to have limited carrying capacity. From OUH-documents, we find that the needed carrying capacity is about four kg.

- *"An issue is the carrying capacity. So far, I do not think the carrying capacity is satisfying, but when it is UAVs will be profitable."*
  (Object 3, Posten)

In respect to operating eco-friendly, the results show that the UAVs will use an electrical power source. Besides, interviewees have highlighted that since UAVs are aerial based, they do not damage the existing road network or contribute to particulate matter pollution.

- *"A competitive advantage in respect to the environment is that the UAVs are electrical driven..."*
  (Object 7, "Samferdselsdepartementet")

4.2.3 Sustainability

From the report (Appendix 10.2), we see that OUH has made a plan for how they can reduce road-based transportation in the three following years after implementing UAVs in the HSCM. Together with "Sykehuset Innlandet" they will reduce the CO2 emissions with 1.500.000 kg the third year after implementation. An electrical engine will emit zero CO2 in transportation.

- *"The UAVs have to be driven by an electrical engine, which has no CO2 emissions."*
  (Object 2, Posten)

The noise is described as an issue regarding the environmental aspect of the usage of UAVs.

- *"I believe the biggest challenge will be related to noise, to be honest."*
  (Object 4, IoTix)

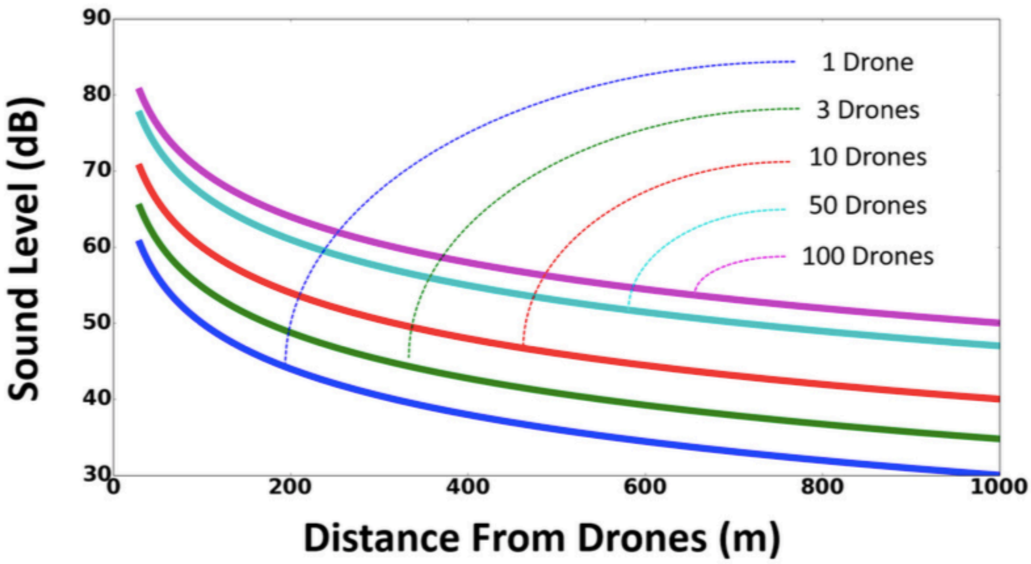

Figure 8 - Noise levels UAVs

(Lohn, 2017)

Lohn (2014) mapped the noise of UAV transportation. Based on the assumption that OUH will use similar UAVs as Lohn (2014) investigated, the environmental noise from UAV transportation is between 30 and 80 decibels, depending on the number of UAVs and their flight altitude.

In respect to particulate matter pollution, the interviewees stated that the UAVs are not a source of this sort of emission as they are not road-based.

- *"I see the traffic picture as a whole to be a problem to the environment. The fact that UAVs can fly contributes to a reduction of the traffic picture and particulate matter pollution.*"
  (Object 7, "Samferdselsdepartementet")

We find that there will be an undefined cost for charging the batteries of the UAV park. This is currently unknown since there are no accurate estimates of the necessary number of UAVs needed to operate.

- *"...Obviously, there will be a high cost for operating and maintaining such an infrastructure. I don't think it is possible to give a concrete answer, but you have to be willing to carry the costs; the investments, maintenance and recharging the batteries".*
  (Object 1, OUH).

The results show that the implementation of an UAV-infrastructure will be expensive. When we asked the interviewees about the sustainable costs related to the implementation, they highlight that any investments is expensive and that it is more interesting when the investment reaches a break-even point. It was also stated that if the investment can increase the customer- and patient service, their willingness to pay will increase.

- *"I would pay much more, twice as much at least, maybe ten times as much…"*
  (Object 4, IoTiX)

- *"If the costs turn out to be enormous, there will be no point in escalate the project. But at some point, the costs will reach a level which make the project profitable"*
  (Object 3, Posten)

The future situation for OUH is characterised by digitalised autonomous UAVs that are transporting biological materials 24/7. Our results have illustrated an estimated operational cost and infrastructure investment. The UAVs use smart technology and sensoring. The results have shown that there are safety aspects regarding UAV transportation and deliveries. Additionally, we have shown results in respect to the sustainable factors of implementing UAVs in OUH's SC. In chapter five, we will discuss digitalised UAVs in relation to HSCM and sustainability.

4.3 Case summary

In this section, we present the results from the "current situation" based on small goods vehicle transportation, and a "future situation" which is based on UAV transportation. We have summarised the differences in line with our framework to compare and contrast the two cases in our study in the table below.

		Current situation	Future situation - UAV
HSCM	*Transportation*	• 3 vehicles transporting between hospitals and sampling stations. • 48 daily taxi trips	• Undefined number of UAVs • Operate 24/7 • Solely UAV based transportation
	Cost. vs patient service balance	• Cost per KM = 1.76 NOK	• Cost per KM = 0.26 NOK
	Patient needs	• Transportation time varies between 10 minutes and 5 hours • Long waiting times	• Delivery time 10 minutes
	Structure	• ”Peaks” every day. • Elektiv and ØH samples • Complex SCM with over 40 different sampling stations	• Back-up system • Equal urgency of samples • Complex transportation network • Control centre • 7,8 MNOK in infrastructure cost
	Environment	• Not been focused on previously	• More environmentally friendly, but a secondary benefit
DIGITALISATION	*Smart technology*	• Lack of smart technology and digitalised solutions • Manual operations	• Able to “communicate” • Sensors • Digitalised autonomous transportation
	Safety	• No tracking system • 119.180 misidentified analysis yearly	• Tracking system • 65.459 misidentified samples yearly • Risk of falling down or collision • Regulations and corridors
	Eco-friendly	• Gasoline driven • Road based	• Electrical source • Aerial based
	Cost efficiency	• Salaries of 119.050.000 NOK for handling and analysis of biological material • Cost of RI	• 30 % cut in salaries • 50 % cut in costs related to RI production
	Delivery	• Unpredictable deliveries	• Predictable deliveries • Limited carrying capacity
SUSTAINABILITY	*Pollution*	• Emits 72,6 tonne CO2 each year • Contributes to particulate matter pollution	• Zero CO2 emissions • No particulate matter pollution
	Noise	• Cars emit 70-75 dB	• UAVs emit 30-80 dB
	Human capital	• 3 transporters	• No need for transporters • Unknown need for operators
	Patient service	• Questioned by government on solutions • Increasing demands from customers	• Efficient response and treatment
	Economy	• Increasing salaries and costs • Government owned	• Break-even
	Cost	• Personnel, taxi and petrol cost = 123.851.500 NOK.	• Personnel and infrastructure cost = 92.092.000 MNOK

Figure 9 - Case summary

4.3.1 Theoretical thematic analysis

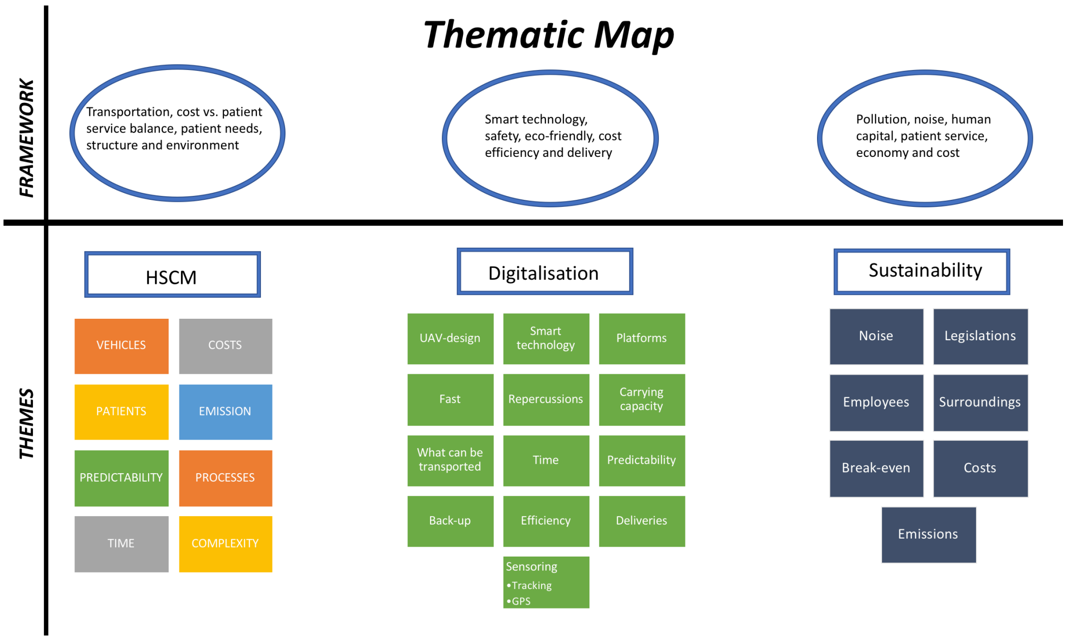

Figure 10 - Thematic map

Figure 10 shows the thematic map, which illustrates the sub-themes discovered in the six-step analysis of our semi-structured interviews (Braun and Clarke, 2006). The questions in the interviews were based on our framework. From the topics in the questions, we found several sub-themes. These sub-themes are shown in the thematic map, where they are categorised to either HSCM, digitalisation, or sustainability. As we found relevant sub-themes to all categories, we find our framework to be valid. As we can see, some of the sub-themes are relevant in more than one category.

As we had semi-structured interviews as data collection, the interviewed objects could elaborate on the sub-themes. We argue that this would not be possible if having a questionnaire, due to additional explanation on sub-themes during interviews.

As we strived to have an explorative view, we were able to identify a new theme, based on the thematic analysis. This theme is predictability. Predictability was a theme we did not expect to find, and we argue that this theme would not have occurred in this research unless we had a thematic analysis. We found that predictability is an essential theme in both HSCM and digitalisation.

5.0 Discussion

In this chapter, we will discuss our findings from the results. We will in this chapter compare the two situations to our research question and previously discussed literature. The discussion can be seen as a cross-case analysis. We will not differentiate on the current situation and the future situation in separate sections as in chapter four. For the discussion, they are intertwined.

5.1 HSCM

Transportation has been pointed out to be an essential operation in HSCM (Syed et al., 2013). Syed et al. (2013) claimed that the transportation of material and products affect the operationality of the hospital direct and indirect. They argued that transportation in HSCM is often complicated, which leads to delays and expensive care. We found that the transportation of biological materials and RI is critical to OUH as it is a part of the diagnostic and treatment of patients. Landry and Beaulieu (2013) claimed in their study that small entities in hospitals are dependent on rapid deliveries of medical supplies. We argue that this can be achieved both in the current and future situation. Currently, to achieve a flow of biological material between hospitals and clinics 24/7, OUH needs to hire taxis outward the period from 08:00 to 15:30, where OUH do not operate themselves. However, we argue that in a future situation, this can be done more efficiently and reduce costs as our findings show that digitalised UAVs will be able to transport 24/7. Haidari et al. (2016) claimed that UAVs ability to transport 24/7 can cut costs in SCs. We support this as OUH will be able to cut 2.600.000 NOK by removing the taxi service entirely, according to our research.

Furthermore, Bechtsis et al. (2017) have suggested that the implementation of digitalisation in HSCM can reduce costs without degrading the patient service. The findings from our results support this statement. When comparing the current and future situation, we see that OUH can reduce their costs per km related to transportation by using UAVs. Based on the findings from Choi-Fitzpatrick et al. (2016) and Scott and Scott (2017), we have estimated that the operational cost of UAVs is 0.26 NOK per km. The operational cost of the current vehicles at OUH is 1.76 NOK per km. Consequently, OUH can reduce their transportation costs by 85 % per km with UAV transportation. Kowalski (2009) highlighted the importance of not reducing costs in a way that degrades the delivered patient service, which D. Q. Chen et al. (2013) agree on. When comparing the two situations, we argue that a UAV based situation will reduce the operational costs in a way that does not degrade the patient service.

We found that an important factor in the patient service is OUH's ability to safeguard the patient needs. Ageron et al. (2018) stated that waiting times are one of several complex issues regarding the patient needs at any hospital. Our study has shown that there are long waiting times for responses towards analysing of samples at OUH. We see a difference in the delivery times when comparing the two situations. In the current situation, we found that the transportation of samples between Rikshospitalet and Ullevål can take up to five hours. In a future situation, we saw that the same transportation will take 10 minutes. Yoo et al. (2018) have stated that UAVs have the ability of fast transportations. We support this as UAVs can fly in a direct route. We argue that the peaks, queues, delays, and waiting times for patients at OUH can be partitioned if the UAVs can transport based on a schedule. We found that UAVs will not remove the associated 'peaks', but that they will contribute to smoothen out the curve and more evenly distribute the demand.

Our case showed that the current structure at OUH is characterised by daily 'peaks' related to the sampling of biological material. Between 06:00 and 15:00 OUH, our research has shown a demand for 41.000 samples, where the majority are classified as Elektiv-samples and others as ØH-samples. Due to a more reliable and fast delivery system, we found that all samples can be treated within an hour and with equal urgency. We argue therefore that there will be no difference between Elektiv- and ØH samples, which we found to be a more efficient structure. However, our study shows that a future structure will require an investment of approximately 7.812.000 MNOK. Although the infrastructural cost is a substantial amount, the results have shown the potential to decrease the operational costs. Nonetheless, to reduce the operational costs, there must be an infrastructure present, and we therefore claim the investment to be necessary.

We have seen in the literature that the hospital structure remains fragmented and manual. G. Johnson (2014) highlighted that as a result, processes have become slow and that the HSCs are unstructured. Our research has shown that the current structure of OUH has only evolved because a need has occurred and has been made without any real plan. Consequently, this supports the findings from Duffield et al. (2007), who claim that hospitals have struggled to find a strategically correct structure. A proposed countermeasure to improve the organisation structure and speed up processes is to increasingly use innovation (S. M. Lee et al., 2011). However, literature has pointed out that in hospitals it is a hard task to benefit from innovations due to a rapid innovation pace and being that hospitals are knowledge-intensive and struggle to keep track with recent developments (D. Q. Chen et al., 2013). The fact that OUH is planning to use UAVs as their primary way of transporting biological material emphasises the statements by De Vries and Huijsman (2011) that a digital structural change is happening in HSCM. In the same way, UAVs can be considered as innovation and knowledge demanding which D. Q. Chen et al. (2013) state makes it increasingly difficult for HSCM to implement.

Chong et al. (2015) have suggested that digitalisation can reduce complexity in HSCM. Our study shows that a future situation with digitalised UAVs will remove the need of having several transportation methods which we find is a source to reduced complexity. OUH can focus on one system that is connected to a control centre, but we found that there will have to be an undefined number of UAVs that needs to be monitored. However, the findings showed that the UAVs will fly based on a schedule, which we argue enhance the flow of transporting biological materials between departments. In line with Seuring (2013) we see that an investment in UAVs can be a strategic investment to make HSCM processes more efficient. But, our findings show that a future situation needs to have a back-up system if there are any malfunctions related to UAVs.

Brambilla and Capolongo (2019) argue that multiple operations in HSC contribute to pollution and are not environmental friendly. Furthermore, Buffalo et al. (2014) claim that hospitals have not been focusing on environmental solutions but solely prioritised the care delivery model (LaPointe, 2016). This is in accordance with our findings. From the results of the current situation, we see that OUH has given little thoughts on how their SC affects the environment. Nevertheless, the literature recognises a change in the hospital sector (Brambilla & Capolongo, 2019), as their operations contribute to a significant part of emissions (Savage & Vernon-Mazetti, 2017). Consequently, HSCM wants to become more environmentally friendly. When looking at the future situation, we found that OUH acknowledges that their operations can be more environmentally-friendly and look at the UAV-implementation as a green investment. However, the research showed that the investment in UAVs is not to make OUH's SC greener, but it will be regarded as an additional benefit.

5.2 Digitalisation

Empirical findings have claimed that digitalisation is a trend that can provide several sustainable advantages to SCM, such as cost efficiency, eco-friendly solutions, and safety (Cavada et al., 2014). However, Gibb and Haar (2009), McKone-Sweet et al. (2005) and Chandra and Kachhal (2004) have all found that HSCM has not been able to benefit from the trends of SCM. Our research supports the literature as we found OUH's current transportation methods to be manual and do not use any kind of digitalisation. Both Cavada et al. (2014) and Gomez et al. (2015) has stated that digitalised UAVs are cost-efficient and provide fast and safe deliveries. Our research has shown that to deliver safe and efficient treatment in a cost-efficient way is important to OUH. We found that currently, OUH has not adopted a digitalised transportation to their HSC and can not benefit from the trends presented by Cavada et al. (2014). However, our case shows that a future situation, with digitalised UAVs, can draw on the benefits of a digital SC and transport biological materials and RI more time efficient than current transportation methods.

Gharibi et al. (2016) have stated that digitalised UAVs use smart technology in their operations. We found that the UAVs used for transportation in OUH's SC will be digitalised and use smart technology to "communicate", track samples, and share their positions. From the results of the current situation, we identify an issue concerning the tracking of vehicles and samples at OUH. de la Torre-Bueno (2014) has stated that the lack of tracking systems in HSCM degrades the patient service and patient safety due to mix-ups of the samples. A report from Krogstad et al. (2014) showed that 59 % of all samples are misidentified before being analysed. We found that in a future situation, the misidentified samples are predicted to decrease by 45 % due to traceability. However, we can not conclude that this is isolated coherent with transportation. We acknowledge that there are several internal processes between sampling and analysis, and we can not determine which SC process leads to misidentification. We argue that with increased traceability on all processes, this can be reduced. However, from our research, an estimated 45 % reduction has been connected to a future digitalised transportation with the ability to track samples. In accordance with Cavada et al. (2014), we argue that this is related to the integration of physical-, digital- and human systems. Moreover, tracking of samples increases the safety and ensures that samples are ethically handled, which was highlighted by Meslin and Quaid (2004) as an important part of accommodating to the patients' needs. Although there are positive aspects of tracking, we argue that a tracking system could be adopted in OUH's SC without having the need of implementing digitalised UAVs.

On the other hand, the previous theory has been split in whether UAVs themselves are a safe transportation method. Several scholars have addressed digitalised UAVs as a safe transportation method as it is autonomous and reduces traffic accidents (Afman et al., 2018; Haidari et al., 2016; Kaya et al., 2016). Zhang et al. (2013), on the other hand, claim that there is a risk for the UAVs to fall down or collide into something. Based on our research, we find both arguments to be valid. The UAVs will be autonomous due to digitalisation and use sensors to navigate in established corridors that reduce the risk of colliding into objects or people, which Regjeringen (2018) has stated to be important to make the transportation safe. Afman et al. (2018) found that UAVs reduce potential casualties related to transportation. As there will be no people physically transporting the samples, as the UAVs are autonomous and unmanned, we therefore find a total reduction of potential casualties for transporters. However, we support Afman et al. (2018), and Zhang et al. (2013) who claim that UAVs may fall down and risk casualties for people on the ground as there may be malfunctions in the digitalised systems. Nevertheless, we argue that the current manual transportation operations are less safe than a future situation due to that they are manned and pose potential injury threats to transporters. However, a future situation poses more threats to the surroundings on the ground.

Furthermore, there was acknowledged a risk that the digital systems of UAVs being hacked or hijacked. Regjeringen (2018) has addressed this as a safety issue. However, in line with Afman et al. (2018), our findings showed that the UAVs will be regulated and there will be legislation concerning security measures, like sensors. To reduce the risk of UAVs to harm someone or something if they fall or collide, "Luftfartstilsynet" has stated that there will be established corridors where the UAVs can operate. Based on sensors, the UAVs will fly safely within these corridors. Nevertheless, we find the current transportation methods to be safer than UAVs, due to an uncertainty regarding the relation between digitalisation and potential hacking and hijacking attempts.

This research has highlighted the eco-friendly perspective in OUH's SC. From the current situation, we saw that OUH uses ground-based transportation methods driven on gasoline, which scholars claim is a significant contributor to a severe amount of environmental threats (Azadi et al., 2015; Björklund, 2011). Barth et al. (2015) find that ground-based and gasoline driven vehicles contribute to CO_2 emissions and particulate matter pollution. It has been suggested that digitalisation can make transportation more eco-friendly (Brambilla & Capolongo, 2019). In a future situation, we found the transportation method to be electrically driven and aerial-based. In line with Rosser Jr et al. (2018), we find the electrical driven UAVs to be more eco-friendly than ground-based vehicles. On the other hand, we found that the electrical engine in UAVs limits the carrying capacity. This has been pointed out by Figliozzi (2018), which compared UAVs to trucks.

Figliozzi (2018) gets support from Haidari et al. (2016) who have highlighted the carrying capacity of UAVs to be an issue in SCM. By comparing the two situations, we did find that the current vehicles have a higher capacity than the UAVs. Nevertheless, our research has shown that this is not a potential issue to OUH. Lohn (2017) found that UAVs are more efficient for 'last-mile'-deliveries, which are characterised by low weight parcels. The deliveries of biological samples and RIs are relatively light and weigh up to four kgs and will be transported on short distances. However, to cope with the amount of samples, we find that there will have to be frequent departures and multiple UAVs operating at once. We acknowledge that the capacity restraint is dependent on the case and what is being transported.

A surprising finding was that digitalised UAV based transportation creates predictability in deliveries. To our knowledge, there is no previous literature addressing digitalisation as a source to predictability in HSCM. Bechtsis et al. (2017) and Barth et al. (2015) have highlighted the UAVs ability to deliver fast and reduce costs. However, we find that the UAVs does not only affect the operational costs but creates repercussions in the SCM. We argue that predictable deliveries are affecting the whole HSC as the hospital will be able to plan operations more accurately. We argue that this is coherent with information sharing and the ability of UAVs to communicate where they are and when they will arrive (Michel, 2017). We agree with Michel (2017), and find that information sharing around a 'digital core' can positively affect the departments planning- and forecasting activities. Our study has shown that predictable transportation times enables the possibility of producing the exact amount of RI needed. We found that this may reduce the production cost by 50%. Consequently, in relation to more predictable deliveries, and information retrieved from OUH documents, there can be additional reduction of 30 % in salary costs (Appendix 10.3). We argue that both cost reductions are a result of digitalised UAVs that address issues that the current, un-digitalised transportation methods struggle with, such as unpredictability and uncertainty in transportation.

5.3 Sustainability

Savage and Vernon-Mazetti (2017) claim that multiple operations in HSCM are a source to the pollution of the environment. Barth et al. (2015)'s study found that transportation is a main contributor to the increased pollution. Our results support this finding, where currently OUH's vehicles drive 484.279 km yearly and emit approximately 72,6 tonne of CO_2-emissions each year. Compared to a future situation, UAVs will contribute to zero CO_2-emissions due to an electrical power source which Barth et al. (2015) have stated. Consequently, we measure the UAVs to be more sustainable in terms CO_2-emissions. This has a positive effect on the planet pillar (Elkington, 1997). By using UAVs instead of ground-based vehicles, we find that there will be a reduction of road wear, which is already heavily impacted. Also, UAVs will not contribute to any particulate matter pollution. We therefore argue that a future situation with UAV based transportation will remove many of the negatives that are associated with the current situation and its relation to pollution, which contributes to a more sustainable environment (Elkington, 1997).

Literature has identified noise as harmful to the environment (Goines & Hagler, 2007). Comparing the two situations, we saw that both types of vehicles are a source to environmental noise. Paviotti and Vogiatzis (2012) found that an average car emits 75 dB of noise in the city centre. According to Lohn (2017), UAVs emit between 30 and 80 dB of noise. The noise from UAVs will be different from cars and depends on the altitude that the UAVs will operate in. However, we argue that the UAVs will not create a noticeable louder noise than the vehicles used in the current situation, but we acknowledge that the noise will be of a different kind. Therefore, we find the noise to be disturbing to the surroundings, which corresponds with Sinibaldi and Marino (2013)'s findings.

Our research showed that an implementation of digitalised UAVs would change the need for human capital at OUH. Literature has pointed out that human capital has been necessary in businesses for decades and is essential for the overall performance and competitiveness (Barney, 1991; Hitt et al., 2017). In the current situation, we found that three transporters are working at OUH's transport station. Autonomous UAVs will replace these in a future situation. However, in a future situation, we saw a need for a control centre, monitoring the UAV transportation. We assume that to keep the infrastructure operational 24/7, there will be a need for at least three operators that can work eight hours per day each. Consequently, we argue that replacing the transporters with UAVs is not in line with the people pillar (Elkington, 1997), but we see that the UAVs creates new positions. This corresponds with the findings of Hanifan and Timmermans (2018) that digitalisation is a source to new positions that interacts and digitalisation (Merlino & Sproģe, 2017).

Based on our findings, UAVs will reduce delays in the HSC that currently cause employees to work overtime. We argue that overtime can be reduced due to a more predictable and optimal flow of processes in OUH's SC, where employees can, to a higher degree, be sure of the process- and transportation times due to information sharing. Furthermore, this can be the foundation for less stressful working environments. We argue that a more predictable schedule will let employees plan upcoming events and reduce necessary overtime that is related to delays.

Staniškienė and Stankevičiūtė (2018) claim that the people term is often overlooked in SCM. However, our study shows the opposite. One of the main reasons for OUH to implement UAVs was to enhance patient service. We found that UAVs will be able to contribute to more efficient and predictable responses, where interviewees have highlighted that it will improve patient service and treatment. Consequently, positively affecting the people-pillar of Elkington (1997). In addition, our research has shown that patient service is of importance to OUH and HSCM in general, supporting De Vries and Huijsman (2011)'s findings that health service needs to be delivered more efficiently. Our study shows that OUH are questioned by the government if their solutions are sustainable. We argue that they also will be questioned with a UAV based situation, but argue that OUH will respond to their customers' requirements to a greater extent. However, the balance between costs and service is an ongoing issue, where McKone-Sweet et al. (2005) claims that finding the balance is difficult due to short product life cycles, which makes products costly. Interviewees have claimed that the UAV-technology will develop with time, and may cause the need for upgrading software, infrastructure or hardware, and consequently negatively affecting both the people and profit pillar of Elkington (1997).

Comparing the two situations, our findings show that a UAV based situation is estimated to be more cost sustainable. Hence, we argue that such an investment will be more sustainable in terms of profit pillar of Elkington (1997). Our calculations show that currently, OUH has annual costs for personnel, taxi, and petrol close to 123,9 MNOK. Our research has shown that a future situation will, based on digitalisation be more independent, having the ability to remove taxi-costs, reduce salaries by 30 % and also remove petrol costs which Kaya et al. (2016) found in their study. The future situation has based on estimates from our results, the possibility of reducing the annual personnel costs to 84,3 MNOK. Moreover, a future situation will require an estimated one-time investment of 7,8 MNOK for the infrastructure (Table 10). Based on our findings and estimations by previous scholars (Choi-Fitzpatrick et al., 2016; Scott & Scott, 2017), we see that UAVs will have a financial impact on OUH's SC. However, we acknowledge that the calculations are estimations and support the findings of Regjeringen (2018) and Haidari et al. (2016). They claim that to determine the future financial impacts for UAVs in HSCM, there needs testing to find actual costs and not estimations.

Feige et al. (2013) stated that businesses have to focus on the break-even point when they are investing in new solutions. This is in accordance with our research, as all of the interviewees agreed that the UAV transportation will at some point reach a break-even point. Based on our findings, we find the costs related to UAV-platforms to be uncertain. We argue that this is due to the lack of technology with respect to the platform. Based on studies such as Haidari et al. (2016), we argue that the technology will develop over time and reduce the costs of UAVs and platforms. We see that there will be a one-time investment for an infrastructure, but based on the reduction in costs the investment will reach a break-even point. Hence, we argue that an investment in a digitalised UAV infrastructure will be measured to be sustainable in Elkington (1997)'s profit pillar.

Comparing transportation costs solely, we find that the current transportation costs to be low in the total HSCM costs. Currently, driver salaries, taxi-and petrol costs isolated amount to 3,9 % of the total costs that we have been presented. In addition, the current situation is based on an existing infrastructure with no costs for OUH. The fact that transportation costs amounted to such a small percentage was surprising to us, and based on reviewed literature and previous knowledge, we expected this to be vastly higher. Since the costs for the current transportation methods are in isolation small, we argue they are currently economically sustainable in terms of the profit pillar (Elkington, 1997). On the other hand, our results show that a future situation will have overall reduced costs. We argue that the primary reduction in costs is due to the repercussions that UAVs facilitate for other processes in the SC for OUH, such as a reduction in RI and salary costs. We had not anticipated that UAVs would have this effect in beforehand for an HSCM.

5.4 The case as one

In this section we will discuss the HSCM of OUH in the entirety and see how a digitalised UAV-implementation affects the SC as one. Derwik and Hellström (2017) argues that efficient SCM is one of the core competencies of an organisation. Hugos (2018) argued that an efficient SCM includes how an organisation is able to align the whole SC, including suppliers, resources, customers and innovations. With this as a base, we argue that to determine whether digitalisation affects sustainability in a HSCM, we have to look at the entirety of OUH's SC. Our research has enlightened that the current transportation network at OUH is complex, time consuming, unpredictable and lacked focus on environmental solutions. Rechel et al. (2010) found that bottlenecks occur in HSCM due to slow processes and poor connection between departments. We argue that the transportation of biological materials and RI can be seen as a bottleneck in the HSCM of OUH, since the delays affect other departments in the HSC. Carrillo-Larco et al. (2018) has suggested that digitalised UAVs can remove the bottlenecks in SCM.

Our research has shown that the UAVs will be digitalised using smart technology and sensors. In line with Garg et al. (2018) we argue that the UAVs will be part of a potential intelligent transportation system at OUH. Using digitalised UAVs enables HSCM to move the transportation of from ground to air creating a better flow of products. Our study shows that sensoring, smart technology and information sharing with aerial transport is source for sustainable effects by using UAVs. By transporting samples outward of the ground-based traffic picture, samples can be delivered faster, more predictable, more cost efficient, in a direct route between locations, but with uncertain safety aspects. We argue that this can be achieved as a consequence of the digitalised part of UAVs. They will not be manned by a driver and can operate both 24/7 to allow for autonomous delivery (Murray & Chu, 2015).

Moreover, we found that digitalised UAVs are able to share information on where they are, what they are transporting and when they will arrive. We argue that digitalisation UAVs can cope with the bottlenecks highlighted by Rechel et al. (2010) better than the current situation in HSCM. We see that this facilitates for an increased planning of activities in the HSC, which reduce delays due to better connectivity between departments.

As a consequence, we found that a future situation will facilitate for an improved overall sustainability for HSCM. Ding et al. (2018) have addressed the importance of acknowledging all pillars to create a sustainable business. Measured in the three pillars of TBL, we firstly find that the profit-pillar is overall positively affected by digitalisation. Scholars have stated that a businesses' ability to be profitable is vital (Sneirson, 2008), which we found that digitalised UAVs positively contributes to in HSCM. Our results show that for OUH, they can reduce operational costs, remove the need for taxi services and petrol costs, and affect costs in other departments positively.

We found a potential risk of UAVs falling down or being hacked, causing threats to surroundings. Our case showed that the current situation is more operational safe for the surroundings. There is a need for testing and proof of the percentage of how often UAVs will fall. However, it does not surpass the improved patient service that can be achieved by using digitalised UAVs. Our research has showed that predictable and fast deliveries will affect the patients at OUH. As Jin et al. (2019) stated that patients demands a higher overall service, we argue that faster response times will increase the patient service and affects the people-term of the TBL-principle (Elkington, 1997), in a positive way. Lastly, autonomous UAVs will replace the three transporters. Although OUH consist of over 23.000 employees (OUS, 2019), the reduction of three drivers is a small percentage, it is a negative effect on the people pillar of Elkington (1997).

We found that in a future situation there can be a complete reduction of CO_2-emissions but argue that this could have been achieved with other electrical transport solutions. Our case shows that this is not due to digitalisation direct. However, by being aerial based, we find a complete reduction of particulate matter pollution. We find that the increased frequency in departures may facilitate for noise exposure and can affect the surroundings negatively, however, the reduced CO_2-emissions and particular matter are positive effect for the planet-pillar (Elkington 1997).

6.0 Conclusion

The objective of this research was to investigate how digitalisation can affect sustainability in an HSCM. The research question of this study is: "*How can digitalisation affect sustainability in a hospital supply chain management?"*.
In order to answer our research question, we have compared two situations in an HSCM based on a framework developed for this research. The framework included HSCM, digitalisation and sustainability. In our research, digitalisation was operationalised as digitalised UAVs. Sustainability was based on the TBL-principle, "planet", "people" and "profit". The two situations that we compared was a current situation without digitalised UAVs, and one future situation with digitalised UAVs.

Based on this study, we find the unpredictability of ground-based transportation methods to propagate negatively in HSCM-processes. Our research has shown that HSCs need to address the issue of poorly synchronised information sharing between transportation and its interaction with dependent departments. As a result of the current methods, "planet", "people" and "profit" are affected negatively in an overall assessment. Our research has found that digitalisation is one way to affect sustainability in HSCM. Digitalisation enables for autonomous processes that can make processes interact and contribute with information sharing to increase flow of products in HSCM. Our study has found among other things multiple cost reductions in HSCM, improved patient service and reduced CO_2-emissions as a result of using digitalised solutions in HSCM. This research has found factors in HSCM that currently needs improvement: "transportation", "cost vs. patient service balance", "patient needs", "structure", and "environment". This study has found that digitalisation can affect these factors in a way that meets the needs of present generations, without degrading the prospect for future generations.

- Theoretical implications

Our research is in accordance with Pinzone et al. (2012) and Shaw et al. (2010) stating that the hospital structure must become more strategic. Our study supports previous literature and theories that innovative and digitalised transportation methods are a method for sustainable solutions (Björklund, 2011; Brambilla & Capolongo, 2019). We find that sustainability work needs to address all pillars of triple bottom line to map sustainable effects (Ding et al., 2018). Further, we support the findings of Borén et al. (2017) that there is a need of more research on sustainable effects of innovative transportation methods in HSCM. We do not find that HSCM lacks behind other SCM in taking advantage of digital solutions (Chandra & Kachhal, 2004; McKone-Sweet et al., 2005), but agree that the SC-philosophy is not present (Aronsson et al., 2011). Our research showed that the activities are a consequence of a need that has occurred.

- Managerial implications

Despite having focused on some specific theories, we have found insights in using digitalisation to gain sustainable effects in HSCM. From a sustainability standpoint, we find that managers must increasingly take into account and weigh the positive against the negative sustainable effects of an implementation of digitalisation in the SC. Our research finds that processes that were not a main priority will be sustainably affected by increased use of digitalisation. An example is that we see that the relevant HSCM has patient service as a focus, but digitalisation in HSCM may actually cause repercussions for processes that are not initially intended. Furthermore, we propose that SC-managers become aware that they have the financial backbone to sustain a complex and costly digital investment over time, supporting Bechtsis et al. (2017) findings, that there is no guarantee that the project will yield positive results due to an increased use of digitalisation. Lastly, when implementing a digitalised product in HSCM it is important to know all particularities of the product as it will be a part of patient treatment, which has been highlighted in this study.

The main finding of this research was how digitalised UAVs provide *predictability* in the HSCM. We found that it had a profound effect on sustainability in HSCM. Among other, we found that predictable deliveries affect both people and profit. Consequently, we want to add predictability to our revised framework.

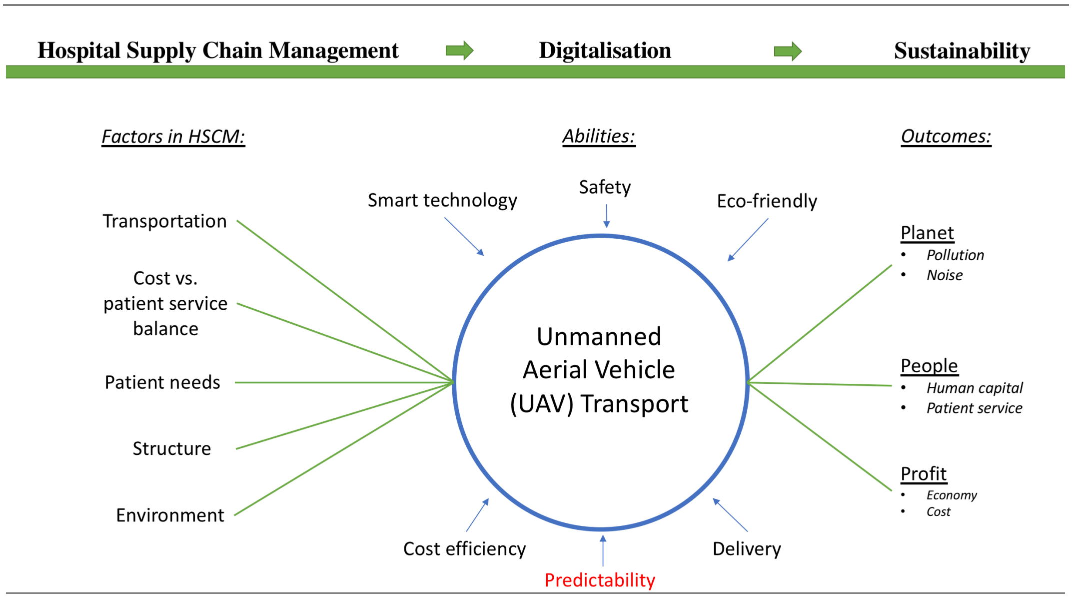

Figure 11 - Revised framework

7.0 Limitations

This research has primarily focused on applying a framework for an intrinsic single case study. Due to limitations in time, this framework has not been applied to other sectors, organisations or companies which would help determine the validity of our chosen framework.

Our framework is established with a high focus on factors to consider in this project regarding both digitalisation and sustainability. We have chosen a selection of theories, but other could probably also be applied to explain the challenges in HSCs. Therefore, our research has been limited by the nature of theories and could possibly have an other outcome if other theories were applied. In addition, we acknowledge that UAVs are only a small part of the term *digitalisation*. It is likely that the findings of how digitalisation can affect sustainability in a HSCM would have been different, had we investigated this with another measure than the usage of UAVs. However, we find our results as valid within this specific field of digitalisation.

The cost calculations in this thesis are also restricted regarding UAV implementation. The total cost is unknown and not documented due to the fact that this is almost every time done through tender processes were costs are kept confidential. In addition, we have not gained information to conclude on the necessary number of UAVs, and their associated costs, that are needed for this operation.

A final limitation is regarded to the depth obtained from interviews. We wanted to interview several more people from OUH, but due to lack of available time from their part it was not feasible. We acknowledge that with more recipients and interview objects we could have increased the reliability of statements and obtained a higher relationship between qualitative and quantitative data. In addition, the interviews have been limited to our surrounding environment and it could be interesting to have gathered data from other hospitals in Norway.

8.0 Further research

Throughout our research we have identified multiple interesting topics and angles in respect to the abilities of digitalised UAVs have on sustainability. We recommend that further research looks at how developments within UAV-technology might affect sustainability in ways that have not been considered in this master thesis.

This research has found that digitalised UAVs is a source to predictability in HSCM. We recommend further research if predictability is a source from digitalisation in general, and if so, what sustainable effects can it bring in HSCM.

As we found our framework to be valid in this study, we recommend further research on the applicability of this framework in other HSCM.

Lastly, it became evident that there were disagreements whether the noise that stem from digitalised UAVs actually affect the community nearby the UAV-network. Our research find the noise to be sustainable, but we acknowledge that this is a field yet to be look upon. Hence, further research in respect to noise intensity and level is recommended.

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10.0 Appendix

10.1 Interview guide

The interviews were held in Norwegian, but for this purpose we have translated the questions to English.

Identification:

1. What kind of connection do you have to OUH and to their UAV-project?
2. What do you know about UAVs?

OUH/Project

Current Situation:

1. How does the transportation network within OUH's SC look like today?
2. Can you elaborate on how the current structure at OUH affects patient needs?
3. What kind of products are OUH transporting within their SC?
4. What would you say are the biggest challenges and benefits with the transportation OUH today?
5. How does OUH provide excellent patient service without compromising on budgets?
6. What are OUH's thoughts of environment?
7. Does OUH use any kind of digitalisation or smart technology in their current transportation?
8. How are the current deliveries cost-efficient?
9. Can you elaborate on OUH's current transportation methods in regards to pollution and noise?
10. How does OUH facilitate and meet the patient needs and how do OUH?
11. Do you think that hospitals are considered to be eco-friendly?
12. How does the transportation methods affect the surroundings and safety?
13. How does OUH facilitate for sustainable human capital?
14. What measures do OUH do to gain profit?

Future situation:

1. How will a transportation network look like with UAVs in OUH’s SC?
2. What kind of products can be transported with UAVs within OUH’s SC and how will it be structured?
3. What are the biggest challenges and benefits with an implementation of UAVs in OUH’s SC?
4. How will UAVs affect deliveries and patient needs in the HSCM of OUH?
5. How will the UAVs be digitalised and facilitate the usage of smart technology?
6. To what degree do you think UAVs will affect the patient service and care?
7. How do UAVs affect safety? What types of risks do you find by using UAVs in a hospital supply chain?
8. What costs do you think needs to be considered in relation to an implementation of UAVs?
9. What are the eco-friendly impacts of implementation of UAVs?
10. From your perspective, what are the typical environmental aspects that can come from digitalised UAVs, like noise and pollution?
11. How can the UAVs affect cost-efficiency in OUH’s SC?
12. Can you elaborate on the safety aspect of UAVs?
13. What aspects regarding the surroundings do you find necessary to consider when implementing UAVs?
14. How will UAVS affect the human capital in OUH’s SC? Will UAVs remove need for human capital or create new job opportunities?
15. What economic effects will an implementation of UAVs give in OUH’s SC?

10.2 Application to Norwegian Government

DEL 1: Innovasjonen

1. Overordnet idé

Prosjektet skal demonstrere verdien av og forberede storskala elektrisk autonom dronefrakt av biologisk materiale og PET-skann radio-farmaka i helsesektoren med mål om bedre pasientnytte, bedre sykehusøkonomi og effektivisering av prosesser.

Basert på en konseptstudie om bruk av droner til transportformål i Helse Sør-Øst, vitenskapelig tilnærming i prosjektet og erfaringer fra reelle dronetester skal prosjektet belyse nødvendige premisser for storskala dronefrakt og legge grunnlag for kommersielle løsninger.

2. Innovasjonsgrad

Prosjektet skal simulere, teste og evaluere bruk av elektriske transportdroner til kort- og langdistansefrakt av biologisk materiale og PET (Positron Emisjons Tomografi) skann radiofarmaka i tre sykehusområder, Sykehuset Innlandet (SI), Stavanger Universitetssjukehus (SUS) og Oslo Universitetssykehus (OUS). Således vil landets to største helseregioner som dekker 75 % av pasientgrunnlaget i Norge delta i prosjektet. Prosjektet representerer en unik og flerfaglig partnergruppering med de tre sykehusene, Syklotronsenteret, Posten Norge, Forsvaret og Transportøkonomisk institutt. Samspillet mellom disse forskjellige partnerne gir en flerfaglig innovasjonskraft som muliggjør senere kommersialisering.

Tjenestekvalitet: Dagens transporttjenester for medisinsk materiale i helseforetakene er veibaserte tjenester som er delvis konkurranseutsatt, delvis ad-hoc taxi transport og gjennom sykehusenes egne kjøretøyer uten tydelige krav til sikkerhet og sporbarhet. Transporttiden er uforutsigbar og kan ta mange timer avhengig av øvrig trafikk og vær. Dette kan påvirke prøvekvaliteten. Prosjektet skal bidra med kunnskap som tilrettelegger for en overgang fra veibasert transport til fullt sporbar dronetransport i helsesektoren gjennom trinnvis testing og evaluering av droneforsøk. Innovasjonen utløses i det helsesektoren tar i bruk denne kunnskapen ved innføring av operativ dronefrakt av biologiske materialer og PET-skann radiofarmaka (radioaktive isotoper).

Geografi: I Hedmark og Oppland hentes det blodprøver på over 109 steder, og en betydelig andel av disse stedene ligger flere timers transport unna laboratoriet til SI. Tilsvarende mottar SUS blodprøver og annet prøvemateriale fra 135 steder, der noen leveranser også inkluderer båttransport. OUS har lokasjoner på 40 steder og transporttiden til laboratorium utgjør den vesentligste faktoren i tid til analysesvar foreligger. Innføring av dronetransport vil redusere ulempen knyttet til geografisk spredning og kan representere kritiske tidsbesparelser for helsesektoren og deres pasienter.

Logistikk og transportløsninger: I utformingen av droneløsninger vil prosjektet få viktig bistand fra Posten Norge og Transportøkonomisk institutt (TØI). Begge har kompetanse og erfaring med drift og analyse av storskala landsdekkende transportløsninger. Dette muliggjør kunnskapsoverføring og analyser som gir grunnlag for innovasjon både i helsesektoren og andre sektorer. Med Posten Norge som partner kan droneløsningen integreres i et nasjonalt logistikksystem som muliggjør optimal utnyttelse av dronekapasiteten.

Prosjektet støtter realisering av regjeringens transportplan og dronestrategi

Prosjektet understøtter regjeringens målsetting uttrykt i nasjonal transportplan 2018-2029 (meld.St.33) om å *«utvikle et transportsystem som er sikker, fremmer verdiskaping og er omstilt til lavutslippssamfunnet». Meld.St.33* understreker viktigheten av å *«gripe mulighetene som ny teknologi gir ved å sørge for tilrettelagt infrastruktur og sikre et robust og oppdatert regelverk som tilrettelegger for bruk av ny teknologi innenfor transportsektoren».* Videre sier den samme meldingen: *«I Norge er det god plass både til lands, til vanns og i luften, og denne plassen legger til rette for bruk av droner. Norge har også utfordrende topografiske og klimatiske forhold, som gjør at det er mulig å dra stor nytte av droner. Regjeringen vil legge til rette for en markedsdrevet og samfunnstjenlig utvikling av dronenæringen».*

Med verdens nest lengste kystlinje og store geografiske og klimatiske variasjoner gjennom året har dagens veibaserte transport en rekke utfordringer som dronetransport har potensial for å redusere. Innovasjonen kan bli et grunnlag for en nasjonal implementering utover helsesektoren av dronebasert transport hvor Norge er i en unik posisjon internasjonalt som testarena sett fra et transportsynspunkt.

3. Verdiskapingspotensial

Det er flere verdiskapingspotensialer i å transformere dagens transportløsning i helsesektoren:

- Pasientverdi gjennom ***desentralisering av spesialiserte helsetjenester***
- Økonomiske gevinster gjennom ***mer effektiv PET isotop distribusjon***
- Utnytte erfaringer og kunnskap i prosjektet ved fremtidige endringer i sykehusstruktur for å oppnå mulig ***samordning av sykehusinfrastruktur og funksjoner*** for laboratorietjenester
- Miljømessige- og sikkerhetsgevinster ved ***overgang fra veibaserte transportløsninger til droneløsninger***
- Understøtte ***Forsvarets behov for rask transport av blodprodukter*** ut i felt
- Oppbygging av ***ny kompetanse i Norge knyttet til en luftbasert dronetransport*** med muligheter også utenfor helsektoren
- Ny ***kommersiell forretningsmulighet i Norge*** ved tidlig pilotering med internasjonal synlighet.

Pasientverdi: Den økende andel eldre i befolkningen kombinert med stadig flere som lever lenge med multiple kroniske sykdommer gir en stadig større gruppe som har behov for helsetjenester nært sitt hjem. Redusert pasienttransport er et viktig helsepolitisk mål, og dronetransport kan være en av flere faktorer i utvikling av lokal diagnostikk og oppfølging med kort svartid for helsestasjoner, fastleger og lokalsykehus.

Økonomiske gevinster:

SI har etablert en mobil PET/CT enhet (bildet) som reiser rundt i Innlandet. En drone med PET radiofarmaka kan lande i umiddelbar nærhet av- eller direkte på en slik enhet. Med bruk av drone vil transporttiden for PET radiofarmaka fra Oslo til eksempelvis sykehuset på Lillehammer kunne reduseres fra dagens 2.5 timer til ca. 45 minutter og fra Haukeland universitetssykehus til Stavanger fra fem timer til under en time. Redusert transporttid av radiofarmaka til en slik PET-skann enhet vil øke diagnostisk kapasitet betydelig innen en rekke sykdomsperspektiver, f. eks. innen kreftdiagnostikk. Lang transporttid med dagens løsninger gjør at en stor andel av radioaktiviteten tapes (halvering hvert 109. minutt), og det må produseres et betydelig overskudd av isotoper i kostbare og sentraliserte syklotroner for å ha en tilstrekkelig aktivitet igjen ved leveranse utenfor produksjonssted. Innføring av mobile PET skannere kombinert med dronetransport vil tilrettelegge for at pasienter i økende grad kan tilbys bildediagnostikk og blodanalyser på lokale sykehus eller ved mobile enheter og således slippe reiser til de sentrale universitetssykehusene for undersøkelser.

Reduserte kostnader ved endringer i fremtidig sykehusstruktur: SI skal sommeren 2019 ut med et anbud for transport av prøver, og det er et ønske å åpne opp for ny teknologi og tjenester knyttet til bruk av droner. Det planlegges også et nytt sykehus sentralt i Innlandet der bruk av droner kan planlegges inn i prosjektet. SUS skal bygge et nytt akuttsykehus som skal stå ferdig innen 2023. En rekke funksjoner skal være igjen i eksisterende sykehusbygninger 4 kilometer unna, og dette vil medføre et betydelig transportbehov mellom de to lokasjonene. Bruk av droner mellom disse to enhetene vil kunne tilfredsstille kravene som stilles for en fremtidig tidskritisk transporttjeneste. Vårt prosjekt vil derfor, basert på samarbeidet med både SI og SUS, kunne ha direkte effekt på beslutningsprosesser og løsningsvalg når disse nye sykehusene skal planlegges og bygges. En stabil døgnbasert dronetransport vil kunne åpne for en konsolidering av kostbare medisinske laboratorier ved sykehusene.

Miljømessige- og sikkerhetsmessige krav og gevinster: Nye transportløsninger må tilfredsstille kravene i «WHO's Laboratory Biosafety Manual» fra prøvetaking til forsendelse, mottak og analyse av prøve. Dette krever derfor en ubrutt kjede med forutsigbar temperaturkontroll, leveransetid og IKT-løsninger som sikrer at uvedkommende ikke kan få tilgang til materiale eller ta kontroll over transporten. Transport av PET radiofarmaka vil dessuten være underlagt særskilte krav for å tilfredsstille lovbestemt sikring av potensielt farlig materiale (radioaktivitet). I tillegg til de sikkerhetsmessige gevinstene ved dronefrakt vil det være positive miljøeffekter i form av redusert utslipp. Som et eksempel utgjør dagens veibaserte transport for OUS og SI over 5,5 millioner kilometer per år. OUS har som mål å redusere veitransport med 25% hvert år de tre påfølgende årene etter prosjektslutt. Dette tilsvarer en reduksjon i CO_2 utslipp for OUS og SI på 250 000 kg CO_2 første året, 750 000 kg CO_2 etter to år og hele 1,5 millioner kg CO_2 etter tre år.

Forsvarets behov: En viktig oppgave for Forsvarets sanitet er å behandle skadde soldater ute i felt. Ved å utnytte droner kan medisiner og blodprodukter raskt fraktes ut i felt med minimal risiko for personellskader.

Ny kompetanse i Norge: Ettersom det stilles ekstreme krav til dronetransport i helsesektoren, vil en slik implementering kunne overføres til de fleste andre logistikksektorer som krever effektive og tidskritiske transporttjenester. Erfaringene fra dette prosjektet kan også benyttes inn mot fremtidige regulering av dronetransport.

Kommersiell forretningsmulighet: Implementering av dronetransport innen helsetjenesten vil gi grobunn for en rekke nye kommersielle muligheter relatert til sikkerhetsløsninger, automatiske laste/losse løsninger med robotisering, kommunikasjonsløsninger og IKT plattformer for droneoperasjoner. Dette vil kunne representere betydelige vekstmuligheter, nasjonalt og internasjonalt, for norske selskaper, både oppstarts bedrifter og større selskaper. Helsesektoren alene representerer en stor forretningsmulighet med over 60 sykehus i Norge og over tusen hentesteder for prøver.

4. Forskningsbehovet
Det er ingen omfattende litteratur og forskning på dronefrakt generelt og dronefrakt i helsevesenet spesielt, og kunnskapsmengden knyttet til effekter og konsekvenser ved overgang til dronefrakt er helt marginal, både i forhold til samfunnsmessige konsekvenser og lokalmiljø (utslipp og støy) og for sykehusene i form av logistikk, økonomi og pasientnytte. Dronefrakt innebærer også nye og ukjente risikoaspekter ved transport av biologisk materiale og PET radiofarmaka. TØI vil i prosjektet studere effekter på transport og miljø ved overgang til dronefrakt for å danne grunnlag for en trinnvis utvikling av droneoperasjoner for å sikre ønsket transporteffektivitet for sykehusene og økt samfunnsnytte. Risikofaktorer og uønskede hendelser som er forbundet med dronefrakt, samt kompenserende tiltak for å møte disse, vil bli beskrevet for at sykehusene skal ha et godt grunnlag for å utforme droneoperasjoner på en sikker og forsvarlig måte. Kvalitetssikring av biologisk materiale etter lengre transporter vil bli undersøkt i et samarbeid mellom SI, OUS og Forsvaret. Samarbeidet med Forsvaret gir en unik mulighet til å starte testing raskt og med total kontroll over alle sikkerhetsutfordringer. Gjennom flytester på forsvarets lukkede områder på Rena og Terningmoen kan droneforsøkene monitoreres ned til minste detalj under flyvning. Dette er viktig for vurdering av kvaliteten av det biologiske materialet etter droneflyving, og for å kunne kartlegge og håndtere viktige forhold rundt sikkerhet.

5. Prosjektorganisering og samarbeid
Intervensjonssenteret (IVS) ved Rikshospitalet har høy kompetanse og erfaring fra å lede komplekse nasjonale og internasjonale prosjekter med flerfaglig innhold og vil ha prosjekteierskap og ledelse. Prosjektet har en styringsgruppe med toppledere fra partnerne, som alle har budsjett og organisatorisk myndighet i sine organisasjoner i tillegg til en faglig innsikt i prosjektets utfordringer (se vedlagte CVer). Styringsgruppen møtes ved beslutningspunktene (jfr. kapittel 8b) og ellers hvis nødvendig for å sikre prosjektets fremdrift.

Prosjektrolle	**Samarbeidspartnere**	**Finansiell og/eller utførende**	**Realisering**
OUS ansvarlig H1	SI, SUS, forsvaret	Finansiell og utførende	Realisering
TØI ansvarlig H2 og H3	Alle	Utførende	-
Posten ansvarlig H4	OUS, SI, SUS	Finansiell og utførende	Realisering
Syklotronsenteret ansvarlig H5	OUS, SI, SUS, Posten	Finansiell og utførende	Realisering
Forsvarets sanitet: test og kvalitetssikring	OUS, SI og SUS	Finansiell og utførende	Realisering

Sykehuskompetanse på internasjonalt nivå: OUS, SI og SUS er tre ledende helseinstitusjoner i Norge som representerer bruker- og pasientdimensjonen, og har medisinske kompetansemiljøer på høyt internasjonalt nivå. Sykehusene har også den kompetansen og instrumentering som er nødvendig for å vurdere kvalitet av det transporterte biologiske materialet etter en dronetransport.

Dronepartner: Flere teknologibedrifter, norske og internasjonale, har vist interesse i vårt prosjekt og disse kan på sikt levere gode droneteknologiløsninger for prosjektet. Konkrete løsninger og samarbeidspartner vil bli bestemt etter kommunisert beslutning fra forskningsrådet, men før prosjektstart Q3 2019 for å sikre en effektiv oppstart.

Norges største logistikkoperatør: Posten Norge har en landsdekkende storskalaoperasjon i Norge som kan representere en sterk synergi med luftbasert transport av medisinske varer. For å oppnå god dekning og økonomi må luft og vei kombineres, samt forskjellige typer last. Posten har over 300 lokasjoner spredt over hele Norge som kan være velegnet som omlastningsstasjoner fra drone til veibasert transport. Posten har også en sterk innovasjonskraft som er vist gjennom blant annet utvikling av nye el-bil løsninger og autonom postkasseløsning.

Anerkjent utredningskompetanse: Transportøkonomisk institutt er et nasjonalt senter for samferdselsforskning med ansvar for å drive og fremme forskning til nytte for norsk samfunns- og næringsliv. TØI sin kjennskap til transportsektorens spesielle utfordringer og muligheter gjør de til en egnet forskningspartner i analyse og utviklingen av dronefrakt i helsevesenet.

Droneerfaringer i Forsvaret: NATO og det norske Forsvaret har lang erfaring med bruk av droner og dette vil vi søke å utnytte i prosjektet.

DEL 2: FoU-aktivitetene

6. Mål

Hovedmål: ***Dette prosjektet skal forberede storskala autonom dronefrakt av biologisk materiale og PET-skann radiofarmaka i helsesektoren med mål om bedre pasientnytte, effektivisering av prosesser og basert på gode miljø- og risikoanalyser.***

For å oppnå dette hovedmålet har prosjektet følgende delmål og forventede resultater.

Delmål	Forventede resultater
Evaluere og forberede medisinsk tidskritisk transport mellom sykehus, både kort og langdistanse	• Simulering med ulike transportavstander (tider), fysiske påvirkninger (varighet, turbulens, temperatur) for å etablere bruddgrenser (ved hvilken belastning skade inntreffer) for holdbarhet av biologisk materiale. Test av effekten av hver fysisk faktor og deres samlede effekt, samt individuelle karakteristika for de forskjellige biologiske materialer. • På bakgrunn av ovenstående, en klassifisering av relevante droner i forhold til vær/vind-situasjoner, støyprofiler, hastighet, rekkevidde, sikkerhet og transportevne. • Detaljert definisjon av dronetest og pilot scenarier • Funksjonelle tester for verifikasjon og oppdatering av antagelsene i samarbeid med forsvarets sanitet.
Vurdere samfunnsnytte og logistikkpotensialet ved dronefrakt av biologisk materiale og PET-skann radiofarmaka	• Identifisering av potensialet for transporteffektivitet ved bruk av drone • Kartlegging av miljøeffekter (utslipp og støy) og forventninger om effekten ved skalering • Definerte krav til logistikksystem for dronefrakt
Analysere behovet for tiltak for å sikre dronefrakt av biologisk materiale og PET-skann radiofarmaka	• Kartlegging av verdiene i dronefrakten • Definisjon av akseptabel tilstand for verdiene under og etter en uønsket hendelse • Identifisering av hvilke typer hendelser som kan true dronefrakten • En oversikt over hendelser der det må settes inn risikoreduserende tiltak før storskala dronefrakt
Utføre og evaluere kombinert luft- og veibasert transport	• Effektiv overgang fra luft- til veitransport • Operasjonell modell for kombinerte laster • Modell for bruk av elektriske Vertical Take Off and Landing droner for langdistanse transport
Utføre og evaluere PET-skann radiofarmaka transport	• Definerte transport- og pakkekrav til transport av PET radiofarmaka i henhold til europeiske myndighetskrav • Identifiserte transportbegrensinger grunnet værforhold • Definerte muligheter for vektreduksjon av transporten

7. FoU-utfordring og -metode

Droneforsøk: Dronetransport av biologisk materiale som for eksempel blodprøver kan påvirke prøvekvalitet. Både turbulens og akselerasjon vil kunne påvirke blodets tilstand i forhold til koagulasjon, separasjon av serum osv. og forstyrre prøvens karakter i forhold til analyseprosedyrer. I litteraturen finner vi bare marginale analyser av slike effekter [1-4], og foreliggende kunnskap er utilstrekkelig for å iverksette slik transport i stor skala og over lengre avstander som eksempelvis Oslo Lillehammer og Bergen Stavanger.

Studier så langt er gjort på prøver fra friske frivillige. Det er også nødvendig å teste unormale prøver fra syke pasienter, for eksempel blodprøver med avvikende verdier. Det kreves forskning på en rekke problemstillinger:

- Hvordan påvirkes blod, blodprøver/annet biologisk materiale av turbulens, akselerasjon, langflytid, takeoff og landing? Hva er effekten av disse ulike fysiske påkjenningene hver for seg, og hvor går toleransegrenser når prøvene utsettes for flere av disse fysiske påkjenninger samtidig og over lengere transporter?
- Hva må være krav til transportmiljøet i dronen for at slike skader skal forbygges?
- Hvordan håndteres utfordringer til ulike karakteristika ved forskjellige prøver; noen må ha fysiologisk temperatur, noen skal fryses og noen skal bare kjøles.

Både normalt biologisk materiale og prøver fra pasienter med ulike tilstander (krever godkjennelse fra Regional Etisk komite) må gjennomføres som kontrollerte studier, dvs. dobbel blind laboratorieanalyse av biologisk materiale som sammenligner analyser med og uten dronetransport. Innledende testforsøk må gjøres for å skape grunnlag for statistiske analyser for nødvendig sample størrelse beregninger i de ulike scenarier.

Risikofaktorer: Frakt av medisinske prøver og PET-isotoper innebærer med dagens transportløsning en risiko. Som eksempel er en av dagens transportmetoder ordinære drosjer med tilfeldige sjåfører til frakt av medisinske prøver mellom sykehus. Dette gir sykehusene lite kontroll over prøvene under frakten. Dronefrakt vil gi økt kontroll med selve transporten, men også skape nye sårbarheter. Sentrale FOU-utfordringer som prosjektet skal svare på i denne sammenhengen er:

- Hva er risikoen tilknyttet dronefrakt av PET radiofarmaka, blod og medisinske prøver? Og hva kan vi gjøre for å redusere denne risikoen?

Siden droneteknologien er ny, er også litteraturen på feltet svært begrenset. Risikofaktorer som har blitt drøftet inkluderer droner som krasjer i bemannede luftfartøy [5], droner som krasjer i/forstyrrer bilførere [6], droner som faller ned og treffer mennesker [7], droner som forstyrrer (ville) dyr, droner som krasjer med farlig gods og derfor medfører forurensning [8] og droner som kan kidnappes og brukes for kriminelle formål [9]. Prosjektet skal kartlegge risikofaktorer mer systematisk og gjennomføre en helhetlig risikoanalyse i henhold til norsk standard for sikringsrisikoanalyse (NS5832:2014) [10]. Gjennom systematiske og løpende litteratursøk, observasjon av testflygningene i prosjektet (hva kan gå galt?), intervjuer med droneeksperter, intervjuer med brukerne av transport av medisinske prøver og PET-radiofarmaka og intervjuer med beslutningstakere vil vi gjennom hele prosjektperioden bygge en bred kunnskapsbase innen dronefrakt av denne typen leveranser.

Logistikk og miljø: De siste få årene har det kommet stadig flere eksempler på uttesting og bruk av droner til frakt av ulike typer forsendelser. Det finnes både pessimistiske og optimistiske anslag på hvor stort markedspotensialet blir og hvilke effekter droner har på transport og miljø. SESAR [11] antyder at medisinske leveranser er ett av segmentene hvor droner kan være kostnadseffektive og få relativt stor utbredelse. Det er imidlertid behov mer forskning som kan dokumentere erfaringer med dronebruk i helsesektoren og si noe om hvilke transport- og miljøvirkninger dronebruk kan gi. Viktige FoU-spørsmål er:

- Hvordan påvirkes logistikkeffektivitet og transportomfang når veibasert transport erstattes med droner? Og hvilke miljø- og støyendringer medfører transport med droner?

Det finnes lite litteratur på konsekvensanalyser ved bruk av droner til frakt av varer, spesielt miljøpåvirkninger. Dette skyldes hovedsakelig at det er en relativt ny anvendelse og at det foreløpig eksisterer lite operativ bruk av droneteknologi innen varelevering. Vi vil i dette prosjektet sammenligne data fra operasjoner med og uten bruk av droner for å belyse effekten på transporteffektivitet og miljøpåvirkning, og beregne oppskaleringspotensial for funnene.

8a. Prosjektplan – Hovedaktiviteter i prosjektet

Følgende hovedaktiviteter med tilhørende 'tasks' utgjør plan for gjennomføring av prosjektet.

H1: Medisinsk kort- og langdistanse dronetransport	**Ansvarlig Oslo Universitetssykehus dr.med Karl Arne Johannessen**	**Kostnad KNOK 6.400**	**Eksperimentell utvikling**

I denne hovedaktiviteten skal vi forberede medisinsk tidskritisk transport mellom sykehus, både kort og langdistanse gjennom ulike simuleringer og tester. OUS som prosjektleder og samarbeidende sykehus har

solid vitenskapelig kompetanse, og IVS har lang erfaring i ledelse av prosjekter som er tverrfaglige, går på tvers av institusjoner/miljøer og over lang tid.
Task 1.1 Simulering med ulike transporttider, fysiske påvirkninger (varighet, turbulens, temperatur) for å etablere bruddgrenser (ved hvilken belastning skade inntreffer) for holdbarhet av biologisk materiale. Teste effekten av hver fysisk faktor og deres samlede påvirkning samt individuelle karakteristika for de forskjellige biologiske materialer.
Task 1.2 Repeterte tester for å etablere sikkerhetsnivåer for å unngå identifiserte bruddgrenser ved å definere nødvendige marginer for medisinsk faglig forsvarlig transport.
Logistikk og tidskritiske kriterier.
Task 1.3 Simulere krav til øyeblikkelig hjelp-service med kartlegging av ulike tidsintervaller (tilbringertjeneste til drone, lasting/flight/lossing) for å kunne definere rammer for optimaliserte trafikkmønstre.
Task 1.4 Teste ulike tidsvariable trafikkmønstre for å identifisere handlingsrom for trafikal miks av ordinær/ øyeblikkelig hjelp transport som grunnlag for bærekraftig dronebruk og definering av nødvendig portefølje av droner.
Task 1.5 Identifisere, beskrive og utrede beredskap for situasjoner som påvirker tidskritisk transport.
Task 1.6 Simulere ulike økonomiske scenarier for aktuelle transportrutiner basert på servicegrad for å innfri medisinsk behov, intern logistikk og egenskaper for biologiske materialer.
All tilnærming vil bli basert på vitenskapelig metoder; randomisering, kontrollerte forsøk, anerkjente statistiske metoder i analysene og dokumentasjon for publisering i internasjonale tidsskrifter. Arbeidet i denne hovedaktiviteten strekker seg over alle fasene i prosjektet (jfr. kapittel 8b).
Resultatene i denne hovedaktiviteten skal fremlegges i en endelig prosjektplan for utvidet produksjon.

H2: Transport og miljøvirkninger	**Ansvarlig Transportøkonomisk institutt Jardar Andersen, Ph.D**	**Kostnad KNOK 2.150**	**Industriell forskning**

TØI har erfaring fra analyser og evaluering av pilotprosjekter innen varelevering og logistikk. Basert på sammenligninger av operasjoner med og uten droner vil vi i denne hovedaktiviteten evaluere effektivitet i operasjonene, virkninger på trafikkmengder, samt miljø- og støyeffekter.
Task 2.1 Sammenligne effektiviteten før og etter introduksjonen av dronefrakt for å kunne fastslå potensialet for tids- og kostbesparelse. Sentrale faktorer er leveransevolum, leveransefrekvens, ledetid og kostnad per leveranse.
Task 2.2 Analysere potensial for oppskalering av frakt med droner. Analysen vil være knyttet til prosjektets ulike tester med dronefrakt av biologisk materiale, i hovedsak fase 3 og 4 (jfr. kapittel 8b).
Task 2.3 Beregne redusert utslipp (for komponentene CO, CO2, HC, PM og NOx) forbundet med overgang fra veitransport til dronetransport med utgangspunkt i prosjektets dronetester.
Task 2.4 Registrere opplevd plage som funksjon av hvilke aktiviteter som forstyrres, støynivået ved start og landing samt langs frakt korridorene, frykt for at dronen skal gjøre skade på mennesker, biler eller bygninger eller skape farlige situasjoner i trafikken. Virkningskurver vil bli etablert med bakgrunn i beregnede eller målte støynivåer og sensitivitet for støy, og sammenlignes med plagenivåer fra veg-, helikopter og flytrafikk.
Arbeidet i denne hovedaktiviteten dokumenteres i to kvalitetssikrede og offentlige TØI-rapporter:
Leveranse 1 vil dokumentere erfaringer fra fase 2 og 3 av prosjektet som innspill til fase 4. Leveranse 2 vil dekke evaluering av operasjonene i fase 4 og synliggjøre mulige storskalaeffekter.

H3: Risikoanalyse og tiltak	**Ansvarlig Transportøkonomisk institutt Sunniva Frislid Meyer, Ph.D**	**Kostnad KNOK 2.250**	**Industriell forskning**

Denne hovedaktiviteten gjennomfører en risikoanalyse for kombinert luft- og veibasert dronefrakt av medisinske prøver og PET-radiofarmaka. Med dronefrakt generelt og dronefrakt i helsevesenet spesielt har man så begrensede erfaringer at det er vanskelig å beregne sannsynligheten for en hendelse. Norsk standard for sikringsrisikoanalyse (NS5832:2014) [10] beskriver hvordan det er mulig å gjennomføre en risikoanalyse når sannsynligheten er vanskelig eller umulig å beregne. Vi vil ta utgangspunkt i denne standarden ved utarbeidelsen av risikoanalysen i hovedaktiviteten. Denne standarden inkluderer bl.a. følgende punkter:

(1) verdivurdering – kartlegging og rangering av verdiene (både materielle og ikke-materielle) som skal beskyttes
(2) fastsettelse av sikringsmål – hva er ønsket eller akseptabel tilstand for verdiene under eller etter en uønsket hendelse?
(3) trusselvurdering – hvilke typer hendelser kan true verdiene definert i (1)?
(4) sårbarhetsvurdering
(5) sammenstilling av risikobildet

Arbeidet i hovedaktiviteten vil resultere i en konsekvenstabell som beskriver mulige uønskede hendelser, konsekvensene av disse uønskede hendelsene og hvor høy sannsynlighet vi kan akseptere for hver av de uønskede hendelsene uten at det må settes inn kompenserende tiltak. Uønskede hendelser med uakseptabel risiko (i henhold til sikringsmålet i (2)) identifiseres for risikoreduserende tiltak. Denne hovedaktiviteten er knyttet til fase 2,3 og 4 i prosjektet og resultatene vil gi løpende rådgiving til hovedaktivitetene H1, H4 og H5 og være spesielt sentrale ved beslutningspunktene D2 og D3 (jfr. kapittel 8b).
Arbeidet vil resultere i en kvalitetssikret og offentlig TØI-rapport som beskriver risiko tilknyttet dronefrakt i helsesektoren og en vitenskapelig artikkel om gjennomføring av risikoanalyser i henhold til NS5832:2014.

H4: Kombinert vei- og luftbasert transport	**Ansvarlig Posten Stian Andersen**	**Kostnad KNOK 1.900**	**Eksperimentell utvikling**

Postens primære rolle i et droneøkosystem er å håndtere fysisk vareflyt ende til ende ved å kombinere vei- og luftbasert transport. Postens mer enn 300 distribusjonspunkter og 18 sorteringsterminaler spredt over landet kan utnyttes til drone landing/take-off og integrasjon med videre veibasert transport. Posten har også relevante storskalaløsninger for logistikk, booking-/planlegging og sporing for å understøtte en effektiv kombinert vei- og luftbasert transport.
Task 4.1 Studere og foreslå kombinert last scenarier for kombinert luft/vei transport med nasjonal dekning og bruk av Postens infrastruktur for å oppnå god økonomi.
Task 4.2 Lage en operasjonell modell inkludert last-scenarier for kombinert kort og langdistanse drone- og veibasert transport.
Task 4.3 Pilotere kombinert vei- og luftbasert transportløsning med forskjellige laster.
Arbeidet i denne hovedaktiviteten er primært knyttet til fase 3 i prosjektet med viktig bidrag inn mot beslutningspunktet D3 (jfr. kapittel 8b).

H5: PET radiofarmaka transport	**Ansvarlig Norsk Medisinsk Syklotronsenter Ørjan Apeland**	**Kostnad KNOK 1.300**	**Eksperimentell utvikling**

Norsk medisinsk syklotronsenter AS (NMS) produserer og selger PET radiofarmaka med kort halveringstid til klinikker over hele landet. NMS vil i dette prosjektet utvikle en modell for bruk av droner for å korte transporttiden av radiofarmaka fra syklotron produksjonssted og til distribuert PET-skann analyse.
Task 5.1 Leveransesikkerhet ved dronetransport – herunder tekniske utfordringer og begrensninger grunnet vær og føreforhold.
Task 5.2 Utvikling av nye «dronevennlige» transportløsninger: I dag transporteres radiofarmaka i hetteglass i potter laget av wolfram. I tillegg anvendes UN-godkjente transportkasser i plast. Total vekt av hele kassen er ca. 20 kg. Det vil bli undersøkt muligheter for vektreduksjon av transportløsningen.
Task 5.3 GDP (Good Distribution Practices) er regelverket som danner rammene for distribusjon av legemidler og prosjektet skal kartlegge hva som kreves for at dronetransport skal tilfredsstille dette regelverket.
Task 5.4 Opplæring og regelverksklarering for transport: Produktene er radioaktive og transporten faller bl.a. inn under DSB (farlig gods) og dronetransport av PET-radiofarmaka tenkes uttestet ved hjelp av et ikke-radioaktivt dummy-produkt. Det vil utvikles testprotokoller med spesifikasjoner og toleransekrav for å belyse punktene over. Prosjektet gjennomføres i tett dialog med DSB og Luftfartstilsynet. Testing vil utføres ved Forsvarets anlegg på Rena og Terningmoen, i samarbeid med SI, OUS og Forsvaret. Arbeidet i denne hovedaktiviteten vil skje i tilknytning til fase 3 og 4 i prosjektet og gi viktig kunnskap til beslutningspunktet D3 (jfr. kapittel 8b).

Tabell 8a: Prosjektets kostnadsbudsjett fordelt på hovedaktiviteter

Nr.	Tittel	Kostnads-budsjett (1000 kr)	Kostnad: Industriell FoU	Kostnad: Eksperimentell utvikling
H1	Medisinsk kort- og langdistanse dronetransport	6 400	0	6 400
H2	Transport & miljøvirkninger	2 150	2 150	0
H3	Risikoanalyse og tiltak	2 250	2 250	0
H4	Kombinert vei- og luftbasert transport	1 900	0	1 900
H5	PET radiofarmaka transport	1 300	0	1 300
Sum	Hele prosjektet	14 000	4 400	9 600

Tabell 8b: Prosjektplan – Sentrale milepæler for FoU-aktivitetene
D1, D2 og D3 illustrerer viktige beslutningspunkter i prosjektet.

Fase 1	M1	Q2, 2019	Prosjektkontrakt med droneleverandør (før prosjekt kickoff)
	M2	Q3, 2019	Kick off prosjektteam, detaljere løsningskonsept, planer og styringsstruktur
	M3	Q4, 2019	Plan for dronetest godkjent av luftfartstilsynet
	D1	**Q1, 2020**	**Prosjektgjennomgang med styringsgruppe og beslutte første dronetest på forsvarets lukkede område, gjennomgang av arbeidspakkestatus med mulige korreksjoner og håndtere «out of line» situasjoner**
Fase 2	M4, M5	Q1-Q3, 2020	VLOS dronetest og etablering av bruddgrenser på forsvarets lukkede Rena område
	M6	Q2, 2020	Godkjennelse fra luftfartstilsynet for flyvning utenfor lukkede områder
	M7	Q3, 2020	Første versjon av risikoanalyse ferdig
	M8	Q1, 2021	Godkjente krav og bruddgrenser for transport av biologisk materiale
	D2	**Q1, 2021**	**Prosjektgjennomgang med styringsgruppe og beslutte dronetest med sykehuset Innlandet, gjennomgang av arbeidspakkestatus og håndtere «out of line» situasjoner**
Fase 3	M9, M10	Q1 – Q3, 2021	BVLOS dronetester mellom Rena, Terningmoen ("points of care") og Sykehuset Innlandet med biologisk last
	M11	Q2, 2021	Prosjektavtale med eVTOL drone leverandør
	M12, M13	Q3,2021- Q2,2022	Kombinert vei- og luftbasert transport (octocopter og eVTOL) ved bruk av Postens infrastruktur med PET radiofarmaka og kombinert last
	D3	**Q4, 2021**	**Prosjektgjennomgang med styringsgruppe og beslutte utvidet dronetest i Oslo, Innlandet og Stavanger, gjennomgang av arbeidspakkestatus og håndtere «out of line» situasjoner**
Fase 4	M14	Q1, 2022	Gjennomgang av endelig risikoanalyse, transporteffektivitets- og logistikkanalyser fra TØI
	M15, M16	Q1-Q2, 2022	Dronetest med last mellom Rikshospitalet - Ullevål, Hamar - Lillehammer og Stavanger - Haugesund
	M17	**Q2, 2022**	**Endelig prosjektrapport, økonomisk analyse og prosjektplan for utvidet produksjon**

9. Kostnader og finansiering
Tabell 9: Partnernes kostnader og bidrag til finansiering av prosjektet (i 1000 kroner)

Partner	Navn på partner	Totale kostnader til FoU-aktivitetene hos partner (personalkostnader og indirekte kostnader + utstyr + andre driftskostnader)	Egenfinansiering og annen finansiering fra partner (egeninnsats + kontantbidrag)
P1	Oslo Universitetssykehus	6 500	2 500
P2	Sykehuset Innlandet	1 000	1 000
P3	Stavanger Universitetssjukehus	1 000	1 000
P5	Transportøkonomisk Institutt	3 000	0
P6	Syklotronsenteret as	500	500
P8	Posten	1 000	1 000
P10	Forsvarets sanitet	1 000	1 000
Total	Sum	14 000	7 000

10. Øvrige samarbeidsrelasjoner for FoU-aktivitetene
Helse Vest IKT AS er et ledende miljø i Norge for planlegging og implementasjon av IKT-løsninger i sykehusene. En full implementasjon av droner for transport mellom sykehus og ut i distriktene vil kreve en

avansert IKT-løsning for å støtte en kostnadseffektiv og trygg operasjon. IKT områder som må adresseres for en produksjonsfase er cyber security, overvåkning, kommunikasjon og avansert logistikk. Vi vil ha Helse Vest IKT som en partner gjennom prosjektet for å legge til rette for et videre samarbeid med å etablere en IKT-plattform for senere full produksjon i Helse Vest og Helse Sør-Øst.
Dangerous Good Management (DGM) Norway er en partner til Syklotronsenteret AS i forbindelse med transport av PET radiofarmaka. DGM er et privat kommersielt selskap, tilhørende en global organisasjon som har hovedfokus på å bistå kunder med diverse regulatoriske utfordringer. DGM er et viktig bindeledd overfor myndigheter og bransjeorganisasjoner, og er et ledende selskap internasjonalt. DGM er representert i de fleste globale forum for farlig gods, som f.eks. IATA, FIATA, UNESCE og IMO.
Forsvarets Forsknings Institutt er en viktig kompetanseorganisasjon i Norge som vi allerede har et godt samarbeide med knyttet til droneutfordringer.
Østnes helicopters er et selskap med solid flyfaglig kompetanse og er en representant for Airbus i Norge. De vil bidra i prosjektet med flyfaglig kompetanse og er en viktig premissleverandør og partner i valg av droneteknologier og gjennomføring.
Vi vil holde luftfartstilsynet løpende orientert og søke nødvendige tillatelser for dronebruk utenfor forsvarets lukkede områder.

DEL 3: Realisering av innovasjonen og utnyttelse av resultater
11. Plan for realisering av innovasjonen
Det er de tre helseforetakene i samarbeid med forsvarets sanitet, Syklotronsenteret og Posten som vil realisere løsningene sammen og hver for seg.

1. Produksjonsmodell inkludert økonomisk modell for utvidet kort og langdistanse transport av blod, blodprodukter og biologiskmateriale. Dette vil understøtte sentralisering av visse sykehustjenester som eksempelvis laboratorier.
2. Forsvaret vil utnytte resultatene i å implementere en løsning for blodtransport til «point of care».
3. Det er planlagt et nytt Mjøssykehus hvor bruk av droner kan gi mulige kostnads- og produktivitetsgevinster ved konsolidering av bl.a. laboratorier på et sted. Erfaringene fra dette prosjektet vil inngå i planleggingen av det nye Mjøssykehuset.
4. Det skal bygges et nytt sykehus i Stavanger som vil være 4km fra det eksisterende sykehus og dette er en mulighet for en rask og trygg dronetransport mellom sykehusene.
5. Posten vil evaluere og pilotere kombinert luft- og veibasert transport av medisinske prøver og annen ikke-medisinsk last mellom sykehusene og hentesteder som kan være flere titallskilometer fra sykehus. Dette danner grunnlag for Posten til å introdusere en kombinert drone- og veibasert kommersiell og generell transportløsning i Norge.
6. Syklotronsentrene i Norge vil kunne sette i produksjon dronebasert transport av PET-skann radiofarmaka med store økonomiske gevinster og pasientnytte.

12. Risikoelementer

Risiko	Konsekvens	Tiltak	Sannsynlighet	Alvorsgrad
Tidsriktig tilgjengelighet av droneteknologier.	Gir usikkerhet mtp. tidsplan.	Være forberedt på å tidsskifte dronekravene og/eller skifte dronepartner i prosjektperioden.	Lav/medium	Høy
Myndighets-godkjennelser.	Gir usikkerhet mtp. tidsplan.	Tidlig involvering og dialog med luftfartstilsynet.	Lav	Høy
Ikke-akseptabel kvalitet av transportert materiale.	Skyver fasene.	Forlengelse av kvalitetsaktivitetene og dypere studier.	Medium	Medium
Test av PET radiofarmaka flytransport.	Eksponerer PET- delen og realismen i radiofarmaka-transport.	Tidlig identifisere egnet drone og sikkerhetsløsninger i forhold til kravene for farlig transport.	Medium	Medium
Finansieringsrisiko, iverksettingsrisiko	Ambisjoner senkes og	Sikre at prosjektet er støttet på høyeste nivå i OUS og hos alle	Lav	Medium

og organisatorisk risiko.	delprosjekter forsinkes eventuelt kan ikke avsluttes.	partnerne med styringsgruppe av toppledere som har budsjett og myndighet til organisatoriske korrektive tiltak.		

13. Øvrig samfunnsøkonomisk nytteverdi og bidrag til bærekraftig samfunnsutvikling

Utover den direkte nytten for involverte parter fra offentlig sektor vil prosjektet bidra til kompetanseutvikling hos de involverte FoU-partnerne som gjør dem i stand til å ligge i front internasjonalt innenfor forskning på dronebasert varetransport. Erfaringer fra prosjektet vil være nyttige også for andre sykehus i Norge utover de som er direkte involvert i prosjektet. Transport med droner er upløyd mark i Norge, og derfor vil den nye kunnskapen om transport med droner også komme til nytte for andre sektorer enn helsesektoren. Prosjektet bygger opp under regjeringens dronestrategi [7] og ambisjonen om markedsdrevet og samfunnstjenlig utvikling av dronenæringen.

Videre forventes det at droneoperasjonene vil medføre betydelige utslippsreduksjoner. Estimatet til Oslo universitetssykehus er at operasjonene i Innlandet og Oslo alene vil kunne bidra til en CO_2-besparelse på 1.500 tonn allerede etter tre år. Vellykkede droneoperasjoner vil støtte opp under FNs bærekraftsmål om å *bygge solid infrastruktur, fremme inkluderende og bærekraftig industrialisering og bidra til innovasjon* (mål 9), *bærekraftige byer og samfunn* (mål 11), samt målet om å *stoppe klimaendringene* (mål 13).

Det reduserte behovet for pasienttransport til sentrale sykehus for undersøkelser har en betydelig samfunnsøkonomisk gevinst og vil gi økt pasientverdi.

14. Formidling og kommunikasjon

Helse- og omsorgsdepartement, samferdselsdepartementet og luftfartstilsynet er viktige premissleverandører og vil bli holdt orientert og lyttet til. Prosjektet vil også ha jevnlige workshops med tema teknologiske løsninger, sikkerhet, medisin og invitere organisasjoner innen næringsliv, medisin, IKT, forskning og utvikling i Norge og internasjonalt. Prosjektet vil også publisere artikler i vitenskapelige publikasjoner, populær-vitenskapelige magasiner og nyhetspresse. Det vil bli laget en egen delt web-løsning for kommunikasjon internt i prosjektet og til partnere.

DEL 4: Øvrige opplysninger

15. Etikk og samfunnsansvar

Prosjektet vil følge alle OUS etiske retningslinjer. Vi vil sikre at utveksling av data er i henhold til GDPR og etablere en struktur som hindrer uautorisert tilgang til data.

16. Rekruttering av kvinner, kjønnsbalanse og kjønnsperspektiv

Rekruttering av prosjektdeltagere vil følge OUS sine standard guidelines.

17. Utlysningsspesifikke tilleggsopplysninger

Referanser:

1. Amukele, T.K., et al., *Can unmanned aerial systems (drones) be used for the routine transport of chemistry, hematology, and coagulation laboratory specimens?* PloS one, 2015. **10**(7): p. e0134020.
2. Amukele, T.K., et al., *Drone Transport of Chemistry and Hematology Samples Over Long Distances.* American journal of clinical pathology, 2017. **148**(5): p. 427-435.
3. Thiels, C.A., et al., *Use of unmanned aerial vehicles for medical product transport.* Air medical journal, 2015. **34**(2): p. 104-108.
4. Lippi, G. and C. Mattiuzzi, *Biological samples transportation by drones: ready for prime time?* Annals of translational medicine, 2016. **4**(5).
5. AUTHORITY, N.C.A. *Aeronautical Information Circular*. 2018. AIC.
6. Kim, K., et al., *Drones and traffic safety: Preliminary risk assessment.* Transportation Research Board, Washington, DC, 2017.
7. Regjeringen, *Norges dronestrategi* 2018.
8. la Cour-Harbo, A., *Mass threshold for 'harmless' drones.* International Journal of Micro Air Vehicles, 2017. **9**(2): p. 77-92.
9. Nentwich, M. and D.M. Hórvath, *Delivery drones from a technology assessment perspective.* Overview report, 2018(2018-01).
10. *Societal security - Protection against intentional undesirable actions - Requirements for security risk analysis* Norwegian Standard.
11. SESAR, B., *EuropeanDroneOutlookStudy, European Drones Outlook Study-Unlocking the value for Europe.* . 2016.

10.3 OUH Documents

Noen makrotall:

Analyser:	**Hastegrad**	
RH:	ØH	Elektiv
RH:		
Pasientnære analyser:	2 020 000	
Analyser som sendes til sentralt lab:		
15 mill på RH	834 774	14 861 666
UL:		
Pol	329 436	1 389 414
Innlagt	1 054 720	1 838 939
4.6 mill på UL	1 384 156	3 228 353

Nå jobbes det med "UL legges ned" – hva kan spares på lønn/transport, og hva koster Drone??

Dagens transport relatert til UL:

Kjørte km 484 279

Drivstoff (liter) 50 000

Kjøpt transport: Taxi +++: ca. 2.6 mill.

Aktivitetene består av planlagte prøver (elektiv) og øyeblikkelig hjelp (ØH) prøver

I tillegg er det poliklinisk (Pol) og innlagt aktivitet. Disse to kategoriene har noe ulike profil på øyeblikkelig hjelp og planlagt.

Noe av det som har vært sett på i utredning av nytt sykehus og droneprosjektet er:

Hvordan gjøres aktiv aktivitetene i dag, lite sporing

Bakketransport, spesielt på vei lager problemer når det er kø, vinter etc.

Miljø; utslipp biler (miljø)

Vi kjører 12 ganger rundt ekvator per år…

Personalkostnader:

Totalt ca. 120.4 mill. personalkostnader på laboratoriet Ullevål.

Usikkert hvor mye som kan elimineres, men vi bruker p.r. 30 % på kost, og ser at vi kan kutte andre steder. Mulig å kutte 50% på RI kostnader.

Per analyse utført er personalkostnader ca. kr. 14.40

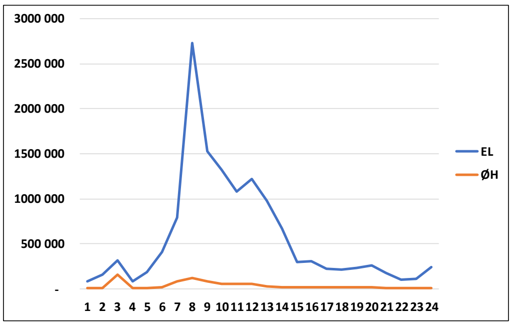
Øvrige driftskostnader antas uendret (kjemikalier/tester/maskiner etc.)

Kostnader til Dronetranspot er enda ikke avklart. Men de vil med stor sikkerhet gå ned over tid.

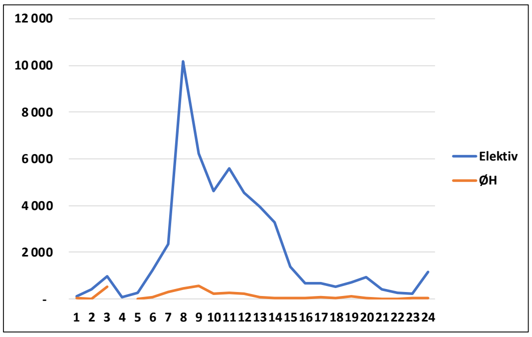
Logistikkmessig er det spesielle tider på døgnet som betyr utfordringer, spesielt fordeling mellom innlagt, polikliniske og i perspektivet øyeblikkelig hjelp/planlagt. Simultane topper mellom kl 8-12 lager utfordringer med høyt behov for transport.

Det ligger an til å bli maks 4 kg per transport, det er gunstig. Men dette avhenger veldig av om man kan endre intern logistikk, f. eks. om man kan "forskyve" en aktivitet med 30 minutter vil det kunne redusere "peak" volum, og derved ta ned maksimal volumene som utløser høyt antall droner. Slik det er i dag (nedenstående kurver) må vi ha mange droner for å ta toppene. Det er store forskjeller mellom UL og RH. VI skal først drone UL til RH, så trolig RH til UL en periode når de bygger. Men dette vet vi ikke enda.
Vi tror også at vi kan kutte kostander og få økt sporing med droner. Bruker 45% som estimat.
Noen driftsvolumer Rikshospitalet. Dette er antall analyser. Konverteres til antall testrør og vekt senere.

Totalvolum (helt år):

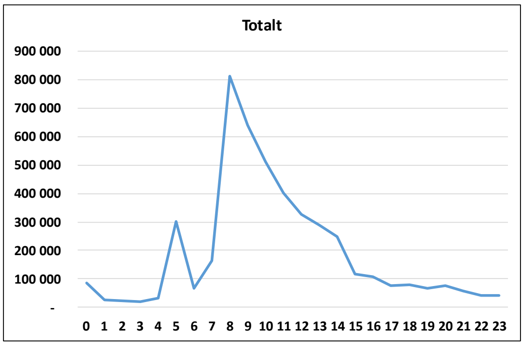


Snitt dag:

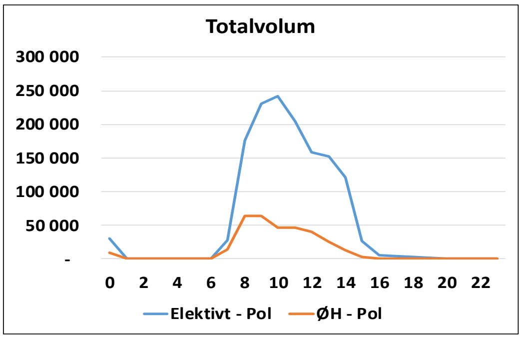


Ullevål:

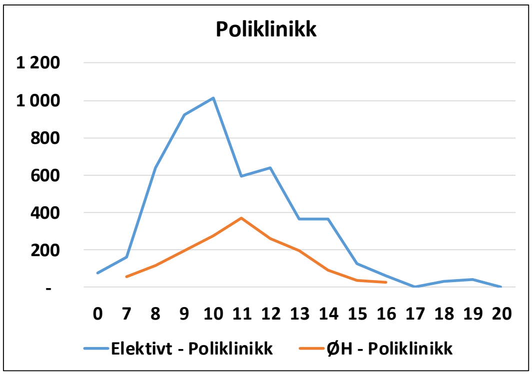
UL:



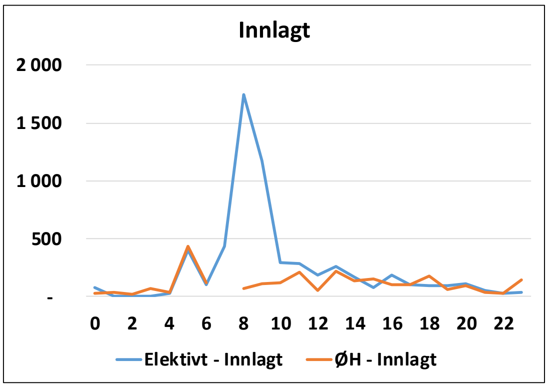
UL: Fordeling Pol ØH/Elektiv:



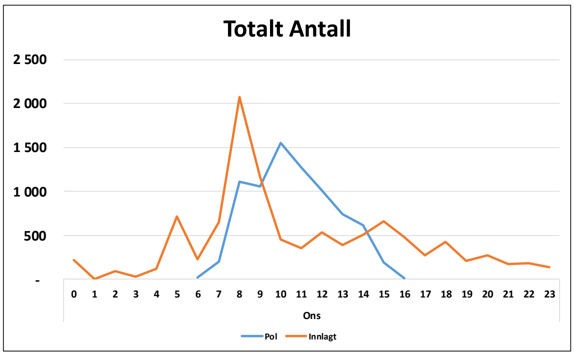
Snitt/dag på pol:



Snitt /dag innlagt:



Fordeling Innlagt/Pol: Begge har topp formiddag



Dronekostnader:

Basert på disse aktivitetstallene skal "dronefamilie" = antall og miks av droner beregnes. Det må gå flere transporter per time. Kanskje 3-4. Men det er ikke endelig enda.

Kostnader blir således en funksjon av droners vekt, antall flighter, batterier/lading/service etc.

Vi legger til grunn 100 % autonomitet + automatisk lasting/lossing, så det kommer jo kostnader derfra også; drift, vedlikehold, avskrivninger etc. Men mest sannsynlig blir det kjøpt en total service = kjøpe en transport tjeneste.

6 Transportlogistikk når prøver må fraktes mellom sykehus

6.1 Frakt til eksternt transportpunkt

Ved et automatisert felles prøvemottak ved kjernelaboratoriet er det naturlig at alle prøver fraktes dit der de automatisk sorteres for analyse i kjernelaboratoriet eller for videreforsendelse til hovedlaboratoriet. I fase 1 vil mange prøver fra Aker Sykehus og Radiumhospitalet fraktes til Ullevål.

Slik det er lagt opp med kun et kjernelaboratorium på Aker hvor det skal være store akuttmedisinske, indremedisinske og kirurgiske avdelinger, vil svært mange prøver til Avdeling for mikrobiologi måtte sendes til Ullevål sykehus i Fase 1 og til Gaustad i Fase 2. Det er ikke lagt opp til å ha noen form for dyrkningsbaserte analyser (inkludert resistenstesting) av prøver på Aker. Dette er fortsatt hjørnesteinen i bakteriologisk diagnostikk. I tillegg vil alle spesialanalyser både innen molekylærdiagnostikk og serologi måtte sendes til laboratoriet på Rikshospitalet.

Blodbanken vil ha stort behov for prøver og blodprodukter mellom lokasjoner. På dagtid har vi som antydet i annet punkt pr i dag allokerte sjåfører som håndterer denne transporten (og også håndterer levering av blodprodukter) og leverer direkte til laboratoriet, og det er flere grunner til at en tilsvarende ordning vil være hensiktsmessig også i fremtiden

6.2 Transportteknologi mellom sykehus

Forutsetningene for å kunne drive Aker/ Rikshospitalet og Radiumhospitalet er at man har hyppige og sikre transport/ logistikkløsninger (ikke avhengig av kø på ringveien, ikke avhengig av vær og budsjettkutt som fjerner transporttilbud for å spare penger etc).

6.2.1 Bil

I dag foregår all frakt av blodprøver, biologisk materiale og blodprodukter innen OUS med bil. I tillegg kjører tre biler mellom laboratoriene ved OUS og andre helseinstitusjoner utenfor OUS. Fordelen med bil er at den kan ta store volumer. Utfordringen er at biltransport er tidkrevende og uforutsigbar da den er sårbar for trafikkbildet.

Dagens transport mellom Radiumhospitalet og Rikshospitalet fungerer fint, både med tanke på person- og prøveflyt, men den er kostbar, og må «stadig» forsvares for at den fortsatt skal opprettholdes. Det er sannsynlig at en tilsvarende «drakamp» om behov for transport av prøver vil oppstå også i fremtiden

RMF og PAT mottar avdøde fra OUS (Ullevål, Rikshospitalet og Radiumhospitalet), legevakt, andre sykehus, sykehjem i Oslo, Politiet, andre regioner og utlandet. Avdøde må oppbevares inntil beskjed er gitt om obduksjon skal utføres og/eller begravelsesbyrå kan hente ut. Lokale lager(kjølerom) benyttes i og utenfor OUS (begrenset kapasitet)

Godt skjermet adkomst for intern/ekstern transport og pårørende - viktig at dette ivaretas.

Begravelsesbyråer skal ha anledning til å være tilstede ved stell, og henter i dag på Ullevål, samt leverer og henter p Rikshospitalet. Mye logistikk rundt biler/frakt av døde. 7500 anløp per år, utgjør ca. 30 per dag. Dette innebefatter levering av mors, levering av kiste og uthenting av mors i kiste eller på båre.

Kapell: Pårørende kommer og tar avskjed/følger begravelsesbilen

6.2.2 Droner

De senere årene er det gjort forsøk med transport av medisiner, blodprøver, blod og annet biologisk materiale med droner. I en rekke land i Afrika brukes droner rutinemessig for å frakte blod og medisiner til fjerntliggende strøk. I St Gallen i Sveits har det sveitsiske postverket i samarbeid med det amerikanske dronefirmaet Matternet fraktet blodprøver mellom sykehus, og fløyet over tettbygde strøk, men det er foreløpig små droner med lite nyttelast. I USA og Canada er det flere prosjekter der man forsker på dette.

Ved OUS har vi utredet mulighetene og kravspesifikasjonene til å flytte mesteparten av det blodprøvevolumet og blodproduktene som i dag fraktes med bil over på en droneplattform.

Ved å utnytte droner for transport vil flytiden mellom Ullevål og Rikshospitalet være på ca. 70 sekunder, og noen få minutter mellom alle de fire store sykehusene i regionen, og med forutsigbar transport tid. Med av og pålasting, tid til landing etc, vil dronetransport mellom sykehusene i OUS i fase 1 og 2 ta ca. 10 minutter fra landingsplass til landingsplass.

Luftfartstilsynet har strenge krav til å fly med droner i Norge og innenfor Ringveien er det bare tillatt ved samfunnsnyttig frakt.

I Oslo kan værforholdene skifte. Dronen må derfor tåle ekstreme vind og temeraturforhold. Den må ha minimal følsomhet for ytre påvirkninger som e fremmede elektroniske signaler og vær/vind, noe som må simuleres og kvalitetssikret. Det er også potensielle støyproblemer med en drone som må analyseres, og som vil sette rammer for dronedesignen for å oppnå et akseptabelt støynivå. Vi forutsetter droneavgang hvert 15. minutt døgnet rundt. Dvs at det kontinuerlig vil være droner i luften.

Det må etableres en operasjonssentral for dronekontroll. Her vil dronepilotene til enhver tid ha full kontroll på dronene ved sanntids overvåkning av drone systemene, tilgang på værradar, kommunikasjon med annen luftfart og ha mulighet for manuell intervensjon.

De tenkte operasjonene skal foregå over til dels tett befolket område og i luftrom som deles med bemannede ambulanse- og politihelikoptre, småfly og Forsvarets aktiviteter. Dette vil utløse særskilte tiltak for å tilfredsstille kravene til operativ pålitelighet og sikkerhet, ikke minst gjennom ”sense and avoid” (kollisjonsunngåelse).

Teknologiske løsninger som nærradar for assistert og fullautomatisk takeoff/landing. Dette inkluderer å lokalisere landingsplass med høy nøyaktighet og styre dronen til/fra landingsplass med centimeterpresisjon.
Det er i 2019 ingen droner som kan tilfredsstille alle krav, men antagelig vil en slik teknologi være tilgjengelig om få år. Droner vil være mye mindre forurensende enn den ganske omfattende biltrafikken som pågår mellom sykehusene i dag og være relativt billig. Droner vil gi en god fleksibilitet, vil være litt tregere enn rørpost, men mye raskere og mer forsutsigbar enn bil.

6.3.1.1 Konsekvenser for pasientbehandlingen

At analyserepertoaret er spredt på 5 sykehus medfører mye intern transport og mange feilleveringer av prøver sendt fra eksterne rekvirenter. Feilleveringer skyldes at siden det ikke er et felles prøvemottak, må eksterne rekvirenter vite nøyaktig i hvilket laboratorium de enkelte analyser utføres.

Mange prøver har kort holdbarhet, dvs analyser må utføres innen bestemt tid for at analysesvaret er korrekt, blant annet RI. Feilleveringer eller lang intern leveringstid evt. kombinert med ekstern leveringstid kan medføre at prøver blir ødelagt.

Mange prøver er unike, dvs de kan ikke tas på nytt. Manglende prøvesvar kan medføre feil eller forsinket behandling og eventuell ny prøvetaking hvilket kan være tidskrevende og vanskelig for en del pasienter(veldig syk, lang reisevei til legekontor etc)

Mer poliklinisk behandling og kortere liggetid har medført at flere prøver blir sendt inn til laboratoriene fra pasienter eller primærhelsetjenesten. Mange klinikere forlanger analysering på OUS hvis de skal følge opp pasientbehandlingen. Årsak til dette er å forsikre seg om at endringer i analysesvar er forårsaket av endring i pasient og ikke ulike analysemetoder .

7 Prøvemottak

Et fullverdig prøvemottak er stedet der prøvene ankommer laboratoriet med en av de ovenfor nevnte transportmetodene. Det foretas oppakking, sortering, registrering og fordeling til analyse/forsendelse. Prøvemottak er plasskrevende. Det må automatiseres mest mulig, inn til prøvemottaket, i prøvemottaket og ut fra.

Felles prøvemottak vil være et fremskritt for alle rekvirenter. Alle transportveier vil ende i det samme prøvemottaket og derved elimineres risikoen for feilsendinger og forsinkelse av prøvesvar og evt ødelagte prøver. Et døgnåpent felles prøvemottak vil sikre at alle prøver blir håndtert riktig, straks de er ankommet prøvemottaket.

Muligheter inn til prøvemottak- internt:

One - One rørpost forsendelse, rett til bulk loader og videre på bånd.

Rørpost med patronåpner/robot, rett i bulk loader eller på bånd

AGV

Portør.

Prøveheis (se eks fra Gibosort)

Muligheter inne på prøvemottak, til analyseenheter lokalt:

Båndløsning der rack sendes automatisk. Rack kan lastes i vogner automatisk og kjøre på skinner langs vegger og tak (Haukeland).

AGV

Prøveheis.

Muligheter ut fra prøvemottak, til analyseenheter eksternt:

Rørpost direkte til drone/ bil (patron pakkes ikke ut, plasseres bare i dronen/bilen, og settes i nytt rørpostsystem ved ankomst).

AGV

Gibosort til blodprøver link: (http://www.gibocare.dk/index.php/latest-news/140-gibosort-installed-at-nordsjaellands-hospital-hillerod)

7.1 Internt felles prøvemottak for alle laboratoriefagområder på Aker:

Det vil kun være interne prøver (+ legevakten) som kommer inn til prøvemottaket. I tillegg blir det mye sortering og videresending av alle prøvene som skal til analysering ved Ullevål i fase 1 og Rikshospitalet i fase 2

7.2 Internt og eksternt felles prøvemottak for alle laboratorieavdelingene på Gaustad i fase 2

Her vil det være mye større krav til logistikk.

Man vil både motta store mengder prøver internt, fra de andre sykehusene i OUS (Aker og Radiumhospitalet), Lovisenberg og Diakonhjemmet og også fra primærhelsetjenesten.

I tillegg vil man motta prøver fra andre helseforetak både innen HSØ, men også resten av landet (spesialanalyser og referansefunksjoner ved bl.a. MIK).

Det er derfor viktig med god transport mellom prøvemottak og de enkelte spesiallaboratoriene, helst kort avstand.

Forskningsprøver mottak/ fordeling og oppbevaring (inkludert biobank): Plasskrevende virksomhet, mye må gjøres manuelt som følge av behov for spesialbehandling av prøvene, samt at frysere og kjøleskap tar stor plass (avhengig av prøvemengde, vanskelig å angi omfang). Naturlig at denne virksomheten legges til prøvemottak og evt noe til poliklinikken (prøvetaking for voksne)

Generelle kommentarer:

Felles prøvemottak er plasskrevende, men må prioriteres

Det må være gjennomtenkte løsninger for god logistikk av prøver både fra sykehuset og fra eksterne rekvirenter inn til prøvemottak og fra prøvemottak til laboratoriene.

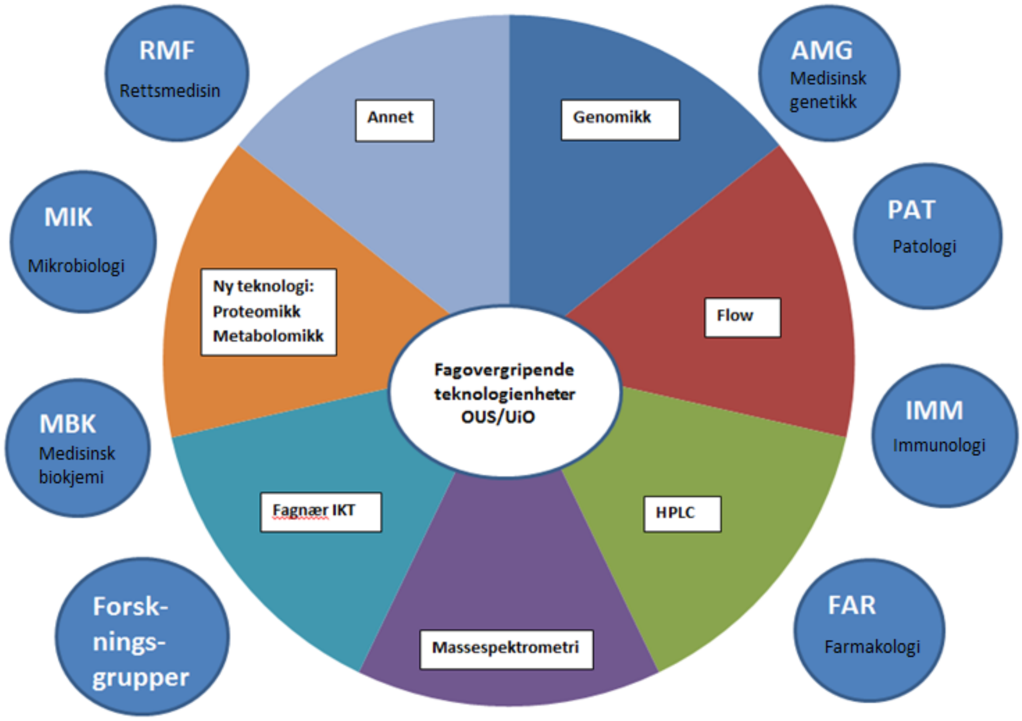
PAT har såpass ulike prøverepertoarer at det kan være utfordring å være tilknyttet et felles prøvemottak, jamfør alle bøttene med formalin som krever annen håndtering enn blodprøver. På den annen side kan et felles prøvemottak som er innstilt på å håndtere alt materiale som skal til PAT, sikre at prøvene blir korrekt behandlet uansett når på døgnet de ankommer.

Blodbank: I dag går alle tilsvarende prøver rett til Blodbanken 24/7. Det er egne dedikerte bud til dette. Et felles prøvemottak må være automatisert med minimalt tidsforbruk for å utføre disse tjenestene bedre enn i dag. Ved manglende elektronisk rekvirering så vil vurderinger, hastegrad, strenge krav til rekvirering etc gi utfordringer og forsinkelser i prøveregistrering, logistikk.

RMF har egne prøvemottak til Rettstoksikologi via egen postboks i Oslo sentrum. Til rettsgenetikk og rettspatologi kommer prøver og dokumenter via OUS post/varemottak og distribueres uåpnet til mottakersted der prøver registreres i RMFs egne fag/saks systemer. Lik kommer naturligvis direkte til obduksjonssal, transportert av begravelsesbyrå som omtalt tidligere

8 Drift av felles laboratorieområde

Laboratoriene i OUS drives i dag etter fagområder, men et alternativ vil være å organisere driften etter hvilken teknologi som trengs. Dette kan vise seg å være mer effektivt enn dagens organisering. Et felles areal for analyser vil kunne være en arena for å prøve ut en slik organisering av laboratoriedriften.



Volumer etter fase 1

MBK:

MBK: 60% av Ullevåls prøvevolum flyttes til Rikshospitalet og 40% flyttes til Aker. Sterkt forenklet kan dette estimeres til at man må forstørre analyseparken med minimum 50%. Det er mulig at kapasiteten på instrumentene pr dags dato ikke er fullt utnyttet, men man må ha et visst antall instrumenter for å holde prøveflyt oppe til ønsket nivå (1 time alle prøver). Analysehall medfører en rekke avanserte arbeidsprosesser og iberegnet driftsstans må man ta høyde for at noen av instrumentene i en gitt prosent av tiden (10-20%) er nede pga vedlikehold og uforutsette avbrudd i produksjonen

MIK:

Betydelige volumer av prøver må sendes fra Aker til Rikshospitalet. For mye av serologien, vil man ha noe av samme tankegang som beskrevet ovenfor av MBK. Alle analyser bør foretas daglig og ikke utsettes pga. manglende areal til effektiv utnyttelse av resurser. Ved a samle alle laboratorier i et felles areal, bør det være mulig å ha tilstrekkelig personale i døgndrift som kan utføre alle ØH- og hurtiganalyser.

8.1 Hva slags utstyr kan drives felles for de ulike laboratoriefagene?

Blodbank: **Immunologi og blodbank**: helautomatiske blodtypemaskiner kan muligens kobles til bånd i fremtiden, men vi er usikre på gevinst. Maskinene krever kontinuerlig oppfølging (være ved maskin) store deler av tiden og det er lite hensiktsmessig at maskinene er langt unna blodbankens utleveringssteder og andre arbeidsplasser da disse har en del avhengigheter til hverandre. Generelt må analysekvalitet være styrende for valg av analyseplattform. God logistikk og prøveflyt i lab er viktig og må være styrende for valg av instrumentering og plassering av instrumentene. Det må ikke legges opp til at personalet må bruke masse tid på forflytning.

Detaljer om laboratoriearealene på Rikshospitalet og Aker.

Samlet areal på en flate til analysehall er nødvendig for driftseffektivt og plassbesparende utnyttelse av ressurser

Ved stor nok grunnflate, kan prøvehåndtering automatiseres fra prøvemottak til oppbevaring av prøver etter analysering, kombinere flere fagfelt til samme instrument, bygge automasjon i midten, støttevirksomhet valideringsrom/ kontor (dvs menneskeaktivitet rundt med vindu for dagslys! Viktig!)

Arealer til prøveanalysering for prøver som ikke kan settes på automasjonsbånd kan være på andre flater, men må ha direkte transport med automatisert heis/rørpost **og** fullautomasjon, dvs større analysevolum og flere analyser på mindre areal enn i dag, men for å opprettholde et visst svartidsperspektiv (innen 1 time), må man ha en viss størrelse på instrumentparken (se punkt om Volumer lenger opp)

Areal til varelager for reagenser som oppbevares i frys, kjøl eller romtemperatur må være tilknyttet laboratorienes areal for analysevirksomhet, slik at transporttid er < 5 minutter og transportveien eliminere ristninger. Tilstrekkelig med lagerrom er kritisk for god og effektiv laboratoriedrift. Det er betydelig behov for nærlager (kjøle-, fryse- og ordinære rom), men også større lager som kan plasseres noe lenger unna til større leveranser av reagenser og annet laboratoriemateriell.

Kapasitet for de ulike laboratoriefagene på arealet tildelt i fase 1:

Sannsynligvis må også flere analyser flyttes fra Rikshospitalet til Ullevål (dvs. utvidet aktivitet) pga. manglende tildelt laboratorieareal på RH i fase 1.

9. Fremtidsvisjoner

Med et felles LIMS, etablerte rørpostsystemer (konvensjonell og One - One rørpost) både innad og mellom sykehusene i OUS samt etablert dronetransport er det sannsynlig at alle prøver til og fra laboratoriene vil følge det samme systemet. Det vil være analysetiden som vil være den viktigste faktoren for når et prøvesvar vil foreligge. Transporttiden vil med riktig planlegging kunne holdes under 20 minutter fra prøvetagning til prøvemottak uansett om prøven må fraktes fra et sykehus til et annet. Dette gjelder også de andre sykehusene i Oslo-området hvis droner tas i bruk. Hvis en slik logistikk blir rutine, vil behovet for øyeblikkelig hjelp bestillinger bli betraktelig lavere.

Det er sannsynlig at moderne analyseutstyr også vil redusere analysetiden.

Det kan være hensiktsmessig at mye analyseutstyr eies og drives felles av de ulike laboratorieavdelingene, slik at utstyret utnyttes maksimalt. Den avdelingsspesifikke kompetansen vil være viktig i tolkningen av resultatene. Men også her må vi forvente at kunstig intelligens vil spille en viktigere rolle i fremtiden.

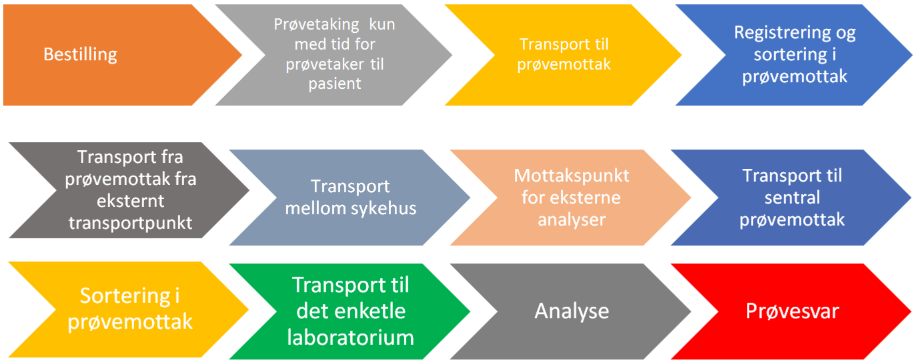
I planleggingen av laboratoriearealet må det tas i betraktning at prøver som i dag kun utføres på et fåtall av pasientene kan bli vanlig hos nesten alle pasientene. Dette gjelder spesielt gensekvenseringsanalyser som i dag utføres ved AMG, men også for MIK Både analysetiden og prisen på denne typen analyser faller raskt. En viktig årsak til at helgenomsekvensering ikke allerede er en fast bestanddel av den diagnostiske prøvemenyen, er mangelen på kapasitet til stordataanalyse, det vil si muligheten for å håndtere de store datamengdene og automatisere tolkningen av funnene. Det er bare et tidsspørsmål før dette er på plass. Men dette er avhengig av IT infrastrukturen i det nye sykehuset inkludert god data-lagringskapasitet. Det er en forutsetning for moderne laboratorietjenester at man har et effektivt LIMS koblet til pasientjournalsystemet og en IT infrastruktur som tar høyde for BIG data og kunstig intelligens i analysen.

Forholdet mellom bruk av PNA og sentralisert analyse vil sikkert endres. Men med en effektiv logistikk både i transport, mottak og analyse er det sannsynlig at PNA forbeholdes prøver der umiddelbart svar er viktig. Med de store volumene og kravene til pålitelighet og kvalitet vil nok de fleste prøvene analyseres sentralt de neste årene.

Vedlegg 1 til laboratorielogistikk rapport:

Generell kommentar om bygging av laboratoriearealer på Rikshospitalet, Aker og Radiumhospitalet

Det er viktig å utforme arealene slik at det blir lett å sette opp nye produksjonslinjer og ikke minst bytte ut laboratorieinstrumentene uten at det blir driftsavbrudd. Det må derfor sikres at utstyr kan fraktes inn i bygget gjennom yttervegger slik at en utskiftning ikke forstyrrer drift. Siden laboratoriene vil trenge et betydelig nærlager foreslås lageret bygget med samme bæreevne, strømtilførsel, vann og avløpstilgang som produksjonsarealene. Derved kan man ved utskriftning av en produksjonslinje anlegge den nye produksjonslinjen i lagerarealet før det gamle utstyret demonteres. Laboratorieinstrumentenes levetid er ca. 8-10 år og det er derfor viktig å ta hensyn til dette.



Logistikkflyt ved sentral analyse når blodprøven er tatt i annet sykehus enn der den skal analysere samme sykehus. Tid til prøvetaking og analysering på instrument er ikke tatt med i beregning.

Kommentar: Ikke overraskende er det transporten mellom sykehusene som utgjør det største usikkerhetsmomentet. Selv med en dedikert bil som bare frakter prøver av en kategori (f. eks prøver og blodprodukter mellom blodbank og de andre sykehusene) er det variasjon i transporttid. Biokjemiske prøver er avhengig av budbilens transportrute og personalbussen mellom Radiumhospitalet g Rikshospitalet. Etter kl. 1600 er man avhengig av ledig taxikapasitet. Her vil bruk av droner utgjøre en viktig rasjonaliserende faktor som kan få store konsekvenser for sykehusdriften.