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Hans E. Comtet

Drones in Healthcare Systems: Insights from a Multi-Level Perspective

Doctoral thesis

NTNU
Norwegian University of Science and Technology
Thesis for the Degree of
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Preface

This article-based thesis is submitted to the Norwegian University of Science and Technology (NTNU) for partial fulfillment of the requirements for the degree of philosophiae doctor (PhD). The doctoral work was performed at Oslo University Hospital, at the Intervention Center.

The main supervisor from NTNU was Martina Keitsch and the co-supervisors were Ole Andreas Alsos and Mari Bjerck. Karl-Arne Johannessen was the main supervisor of Oslo University Hospital, with Erik Fosse as co-supervisor. Miriam Begnum, who had previously worked and completed her PhD at NTNU, acted as an additional supervisor.

This thesis is part of a project to "Research an implementation of Unmanned Aircraft Systems (UAS) for the fast and secure transport of biological material and blood products" in Oslo University Hospital. The Norwegian Research Council funded the work under the HELSEVEL program (Grant No. 282207/2018) [1].

Abstract

The process of integrating technological developments into existing practices is not straightforward. This thesis examines the potential usefulness of the concept of system innovation as a means of enhancing the ability of healthcare systems to integrate drone solutions into laboratory logistics by using Oslo University Hospital, Norway, as the primary study object, using its transport to different locations as the study topic.

The primary research question asks if and eventually how drones can become part of a future healthcare transport system. From a broader perspective, the thesis also investigates some principal factors of possible significance in the successful integration of new technologies into mature processes that are “locked in” with the current operations of an organization. The underlying basis of the analysis is that healthcare institutions are socio-technical systems with interrelated human, social, and organizational characteristics. The analysis in this thesis of this socio-technical system uses the multi-level perspective, whereby the overall system is divided into distinct levels representing individual clinics, hospitals, and the overall healthcare institution. In the context of this framework and during the course of developing this thesis, three separate research papers related to the integration of drones into healthcare systems have been published in peer-reviewed journals. Based on the motivations, methodologies, and results of these three studies, the thesis describes their basis in the multi-level perspective, using the outcome of the research papers to identify factors that may possibly affect the successful implementation of new technologies in existing organizations. In addition, the thesis discusses how healthcare institutions may be considered socio-technical systems by eliciting the views of healthcare personnel towards new technologies and identifying the changes that technology, specifically drones, may contribute toward a sustainable healthcare system. In this way, the results presented in this thesis, in part, move beyond the original research question to more widely discuss how large-scale organizations can successfully realize the benefits of technological change.

The usefulness of the multi-level perspective and the concept of socio-technical systems in identifying and obtaining these benefits is described, and the implications for various stakeholders and policymakers are outlined and discussed. The overlying contribution of this thesis may be the usefulness of applying the multi-level perspective to an innovation project and the projection of a broader analytical framework beyond a protected space for experimentation and learning processes of drone integration. Although drones may have a limited impact on current organizational processes in the healthcare sphere, the thesis concludes that drones are perceived positively by healthcare workers, suggesting that future innovations could indeed enhance the current procedures used in such socio-technical systems.

Dedication

To Maia

Acknowledgments

In writing this section, I reflect on the wonderful PhD period that I enjoyed. I am grateful for the opportunity and support I have received during this journey.

My supervisor from Oslo University Hospital, Karl-Arne Johannessen, has been excellent in challenging me throughout the past three years. His incredible knowledge and life experience were a true inspiration. I learned a lot from him on multiple subjects and I am grateful to have worked with him while studying this PhD.

My supervisor from NTNU, Martina Keitsch, was a fantastic resource and supervisor. I always thought she knew where I was going, which gave me great security in the many phases of the research project, where I felt somewhat lost. Thank you, Martina, for your valuable advice, guidance and all the great discussions we had!

I also want to thank my co-supervisors, Ole Andreas Alsos, Erik Fosse, and Miriam Begnum. I appreciate their support during this project on various topics and in different phases. Sometimes, the only guide you need is a conversation, someone who clarifies your thoughts or shows you alternative pathways. Thank you for all that and for motivating and supporting me along the way!

I would also like to thank all Ph.D. students I met at *Bygg 20* (office building at the old Gaustad Hospital), at the Intervention Center, and NTNU. Knowing that others are in similar situations and that you can reach out is always helpful. And, of course, the cuisine at *Bygg 20* was amazing! Also, thank you to all who have read and commented on my work in different settings or have somehow participated in this work and contributed to the research results during these three years. Thank you, Ashis Jalote Parmar, for your valuable comments in the end!

One consequence of the Covid-19 restrictions was that my PhD was more isolated than otherwise. However, my neighbors and I had regular Friday afternoon aperitifs. A special thanks go to Lilleba, my 85-year-old neighbor and one of the regulars at the meet-ups, who has always read my published articles first. Thank you, Snippen, for your support!

Most importantly, on the home front, I want to thank my dear wife, Maia, for encouraging, motivating, and supporting me during this journey. I truly feel humbled and grateful for all the arrangements you made so that this PhD was possible. Therefore, I want to dedicate this thesis to you. I also want to mention our daughters, Lara and Liv. Thank you for your support, love, visits to the office and the whiteboard drawings! Who knows, maybe drones will be part of your

future lives.

Finally, a big thank you to my family and friends for believing in me and supporting me and for the love you gave me.

Oslo, June 21st, 2023.
Hans Comtet

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Acronyms

AI Artificial Intelligence. 2

BVLOS Beyond Visual Line of Sight. 2

EASA European Aviation Safety Agency. 2
EVLOS Extended Visual Line of Sight. 2
EXCEL Spreadsheet Software (Microsoft). 29

MDPI Multidisciplinary Digital Publishing Institute (Basel, Switzerland). 24, 51
ML Machine Learining. 2

NTNU Norwegian University of Science and Technology. iii, ix, 19

PDSA Plan-Do-Study-Act. 48
PhD philosophiae doctor. iii, ix, 20, 58, 64
PubMed Database of biomedical literature. 51

SPSS Statistical Software Suite (IBM). 29
STRN Sustainable Transition Research Network. 64

UAS Unmanned Aircraft Systems. iii
UAV Unmanned Aerial Vehicle. 1, 2

VLOS Visual Line of Sight. 2
VTOL vertical take off and land. 2

Glossary

facilitator Someone who helps to structure and process interactions, so that groups are able to function effectively and make high-quality decisions. 55, 60

HELSEVEL Research program for health service research. iii, 19

multi-level perspective The multi-level perspective (MLP). v, xv, 3, 6–9, 11, 12, 15, 18–21, 28, 36, 39, 41, 46, 48, 50, 53, 55–59, 63, 64

Oslo University Hospital Consists of four main institutions located inside the area of Oslo, and several minor facilities: Rikshospitalet (The National Hospital, offering local, regional, and national services), Ullevål University Hospital (local, regional, and national services), Radiumhospitalet (a specialized cancer hospital), and Aker University Hospital (local and central hospital).. iii, v, ix, xv, 9, 19, 20, 29, 30, 36, 37, 40, 42, 48, 55, 56, 58

Sustainable development Sustainable development describes social, economic, and environmental aspects of sustainability. The aspects are interconnected, however often understood and weighted differently. 60

transition The contemporary discussion about transitions discusses how change occurs and how change can be managed and directed towards a sustainable future in complex systems such as healthcare. In this thesis similar to system innovation. 9

wicked problem A wicked problem is ill-defined. In contrast to tame problems, where everybody agrees on what the problem is. 16, 50, 53, 59

Chapter 1

Introduction

Technological innovations promise an opportunity to create sustainable services in many sectors, including healthcare, which is the system of interest in this thesis. In the healthcare sector, technological developments and new research-based discoveries have opened new opportunities for patient diagnostics and treatment, as well as in the fields of communication and logistics. Changes in healthcare methodology have the potential for better and more efficient treatment, but may also harm patients and increase costs if not controlled. Healthcare systems are generally changing as patients become increasingly well-educated, with greater access to online medical sources and help, and solutions such as telemedicine are continuously improving.

An interesting upcoming solution is Unmanned Aerial Vehicle (UAV), commonly termed “drones.” Since 2015, numerous studies have been performed around the world on drone transportation in medical logistics. Drones have been suggested to improve transport services of biological and other materials between doctors, laboratories, hospitals, and even transport home to patients. The estimate of transporting medical supplies and premium deliveries in 2050 is a fleet of 100,000 drones throughout Europe [2]. SARS-CoV-2 pushed the development towards solutions that do not require patients to leave their homes in multiple parts of health care, and telemedicine has become a common term in the last few years. For example, the use of digital platforms to treat patients has increased since 2020 in most developed health systems, and drones appeared to provide useful transport solutions when distancing and lock-downs during the pandemic were extensive [3, 4].

In the following sections, drones and technological adaptation in healthcare are introduced. Next, the research perspective, motivation, aims, and research questions addressed in this thesis are presented. Then the potential contributions to the field are elucidated. Finally, the organization of the remaining of this thesis is outlined.

1.1 What is a drone?

An Unmanned Aerial Vehicle (UAV) is commonly referred to as a drone, reflecting that they make a similar sound to male bees once airborne [5]. Drones describe autonomous or remotely controlled/managed aerial vehicles that fly and can carry cargo [6, 7].

Drones can range from large military-sized vehicles to commercially available micro-drones. Their flight distance, altitude, and payload capacity vary considerably [8]. Drones can be classified as fixed-wing, rotor-driven, or hybrid, combining these solutions, enabling vertical take-off and landing [9–11].

Currently, fixed-wing drones have longer flight ranges and greater payloads but require a runway or launch platform [12]. Rotary-wing drones can take off and land vertically (VTOL). This makes them easier to navigate in urban environments, but they currently offer a limited flying range, lower speed, and smaller payload capacity [13]. This may change considerably during the next 2-3 years.

The flexible design of drones means they are now used in multiple ways, including for transportation. Drones may reduce travel time compared to traditional road transport [14, 15] and can often access areas that are difficult to reach by ground transport [13].

Drone technology combines multiple technologies and areas of expertise that have been transferred from a wide variety of industrial sectors, that is, software and hardware engineering, Artificial Intelligence (AI), and Machine Learining (ML) [16]. Furthermore, drones can be integrated with mobile technology [16, 17].

The European Aviation Safety Agency (EASA) is continuously developing regulations for drone flights in Europe [18]. Regulation categories include visual line-of-sight (VLOS), beyond visual line-of-sight (BVLOS), and extended visual line-of-sight (EVLOS), which refer to visual observers keeping track of the drone [19]. The full potential of autonomous drones for transport will be realized when drones are integrated into airspace and do not require additional observers [20].

1.1.1 Technological adaption in healthcare

Humans of all age groups increasingly become drivers of patient action and autonomy [21, 22]. Based on the observed acceptance of new technologies in most populations and age groups, expectations related to technological solutions should be anticipated to surge in the future with regard to redesign and more user-friendly services than we traditionally have organized. Due to the increased use of technical solutions, the public may demand data integration and collaboration among experts. Different actors will have to work together seamlessly to achieve sustainable healthcare systems, with the aim of generating services, goods, designs, and social values that can eventually define the system itself [23].

It is well accepted that healthcare systems are complex [24–26] and that the use of automated and interconnected technologies has the potential to make different topics and services more integrated and therefore more robust and effective. However, the diffusion of new technologies in health services competes with mandatory regulations, quality demands, and organizational structures. Klitkou et al. [27] described the positive feedback of an established technology or structure as “lock-in.” A potential result of multiple lock-in processes may be rigid institutions, and such systems may prefer incremental changes rather than radical innovations.

An aging population, a more comprehensive range of lifestyles, and a general increase in healthcare costs force most developed healthcare systems worldwide to work more efficiently. The combination of technical, social, and system components represents an immense but complex, and in part diffuse, solution space [28] in which sustainable concepts and new services can be developed.

The development described above may require research methodologies to manage complexity and promote sustainable system innovation [23]. The multi-level perspective is used to structure the research to explore drones in healthcare and to broaden the analysis from a traditional “technological-push” model towards system innovation. The multi-level perspective is described in more detail in Section 1.2, but in brief, it illustrates three analytical levels: landscape, regime, and niche. The *landscape* is the macro-level, presenting the broader political, social, and cultural processes of society that are expected to change slowly and outside the control of socio-technical regimes. The *regime* is the meso-level formed by practices, routines, and leading technologies. The *niche* describes the micro-level, providing ’protective spaces’ for radical and path-breaking alternatives whose performance may not be competitive against existing technologies in the regime.

There is a broad body of literature that relates to system innovation. This literature also includes the research streams of socio-technical theory and transition management theory [29]. While the multi-level perspective explores socio-technical systems, transition management is more focused on exploring alternative trajectories [30]. However, because both research streams have a similar basis, this thesis does not distinguish between them. A system approach acknowledges system mechanisms, such as feedback loops and information flows, that change over time in a dynamic and nonlinear way [31–33]. In general, system theory can be used to bring the technical and social parts together [34]. However, this depends on how strongly researchers or other stakeholders are bound by their disciplines, background, or culture [35].

The word “system” comes from the Greek verb *synhistanai*, meaning “to stand together” [36]. System science, a neutral term chosen by Mabry et al. [32], involves conceptualizing the solution space as a system of interrelated parts (i.e., the “big picture”). This meaning and conceptualization of a system are applied in this thesis.

Technological components can be combined in new ways and integrated with other technologies. For example, Gruson [37] wrote that intelligent processes, integrating big data and real-time data management, automation, the blockchain, the Internet of Things, and enhanced user experiences are all critical elements of the smart digital laboratory. This refers not only to the technology itself, but also to the knowledge around a particular technology. Technological innovations in one industry could potentially result in spillovers in other industries or sectors that share similar needs [38, 39]. For example, Meunier et al. [39] argued that, although military drones appear different from driverless cars, they share the same autonomy capacities, making these two types of vehicles more similar to each other than, for example, differing cars are in their car-system.

In this thesis, "healthcare" or "health care" encompasses actions that aim to promote, maintain, and restore individuals' physical and mental well-being. "Healthcare systems" describe a broader perspective that includes all actors, institutions, and resources that undertake health actions [40].

Sustainable healthcare systems refer to multiple characteristics that vary from affordability, accessibility, acceptability, and quality of health services [22]. It may also be used as an overarching term that covers change initiatives aimed at value-based healthcare [41]. In Norway, sustainable healthcare systems are intended to be economically efficient, have high patient satisfaction, sufficient staffing of health professionals, high-quality equipment, and highly respected hospital institutions [42].

The innovation process can be described as the development and implementation of new ideas. People engage in this process over time and in relation to others, often in an institutional context [43]. Furthermore, the innovation process includes the diffusion of technologies and markets [44]. From a system perspective, positive feedback loops may support the broader acceptance of an idea, whereas negative feedback loops may limit and restrict wider diffusion and institutional changes [45].

The use of drones in the healthcare context is relatively new. Although there is growing literature on its potential, drone technology, as well as knowledge of flight surveillance, take-off and landing, and loading, is still immature [46–49]. Furthermore, drones have mainly been evaluated from a technical perspective, and the evaluation of drones from a socio-technical perspective about the public acceptance of drones and those in the system affected by drones may add value. In a socio-technical approach, technology is used as a supportive tool in the system's design. This includes changes to processes, followed by changes to the role that humans play in the system. If existing services need to be redesigned, the attitudes of healthcare workers towards drones in healthcare may therefore be relevant. It is the ambition of this thesis to contribute to this knowledge.

1.2 Research perspective

This section presents a brief overview of the concept of system innovation, which forms the theoretical background for this thesis. However, a detailed review is considered outside the perspective of the thesis.

1.2.1 Socio-technical systems

Socio-technical systems describe the interrelatedness of human, social, and organizational factors. Human actors, social groups, and their relations sustain and reproduce these systems. Rules and institutional factors coordinate human actions. In addition, socio-technical systems also consider technical aspects in the design of organizational systems [50]. Figure 1.1 illustrates the three interrelated analytical dimensions. Note that, in practice, these dimensions are always interrelated.

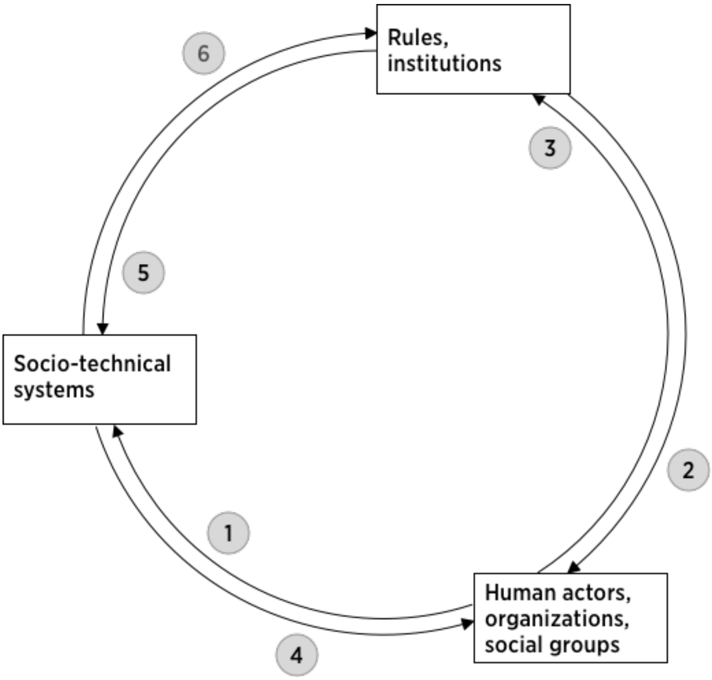

Figure 1.1: Three interrelated analytical dimensions (adapted from Geels [51])

Geels [51] lists six interactions between these analytical dimensions:

1. Elements and linkages in socio-technical systems are reproduced by actors in their activities.
2. Actors operate in the context of institutional rules and routines.
3. Actors support and reproduce rules in their activities.
4. Socio-technical systems form a structuring context for activities and enable and constrain social groups.
5. Social groups share rules, but rules can also be embedded in artifacts and practices.
6. Technological conditions also shape rules and institutions.

1.2.2 The multi-level perspective

Socio-technical system frameworks have been developed to analyze and understand the transition processes of technology and social change [52]. The multi-level perspective has been firstly developed by Geels [51, 53, 54] and was further elaborated by other authors such as Gaziulusoy to understand how system innovation occurs [29]. The multi-level perspective framework in the thesis is illustrated in Figure 1.2.

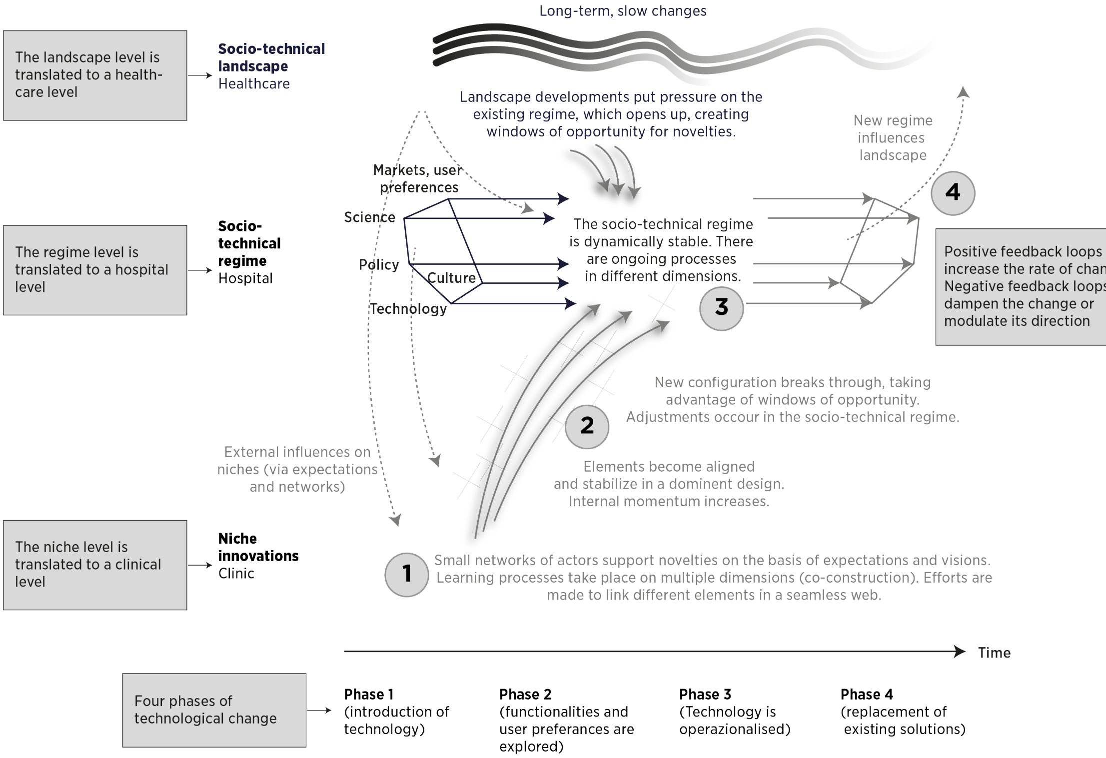

Figure 1.2: Multi-level perspective of the system innovation model (adapted from Geels [51, 53, 55])

The structure of a socio-technical system in the multi-level perspective has three levels: micro (niche), meso (regime), and macro (landscape). These terms may be regarded as corresponding to the institutional levels of the clinic, hospital, and healthcare, based on Fuenfschilling et al. [56] who showed that the conceptualization at the institutional levels provides a suitable structure for the analysis of socio-technical systems.

The multi-level perspective conceptualizes technological change in terms of four phases [31, 57]: the introduction of technology within the existing environment; the exploration of functionalities and user preferences; application of change in daily operations; and gradual replacement of existing solutions.

Additionally, the multi-level perspective assumes that transitions have three dimensions: the speed of change, the size of the change, and the period of change [31]. Positive feedback loops (self-reinforcing) increase the rate of change, creating more of their output. Negative feedback loops (self-correcting) dampen the change or modulate its direction [58].

Raven et al. acknowledges that the three analytical levels do not describe actual entities but are helpful for categorizing and better understanding socio-technical change [59]. The levels used in this thesis emerged during discussions and are based on a common understanding.

This thesis applied the regime level to hospitals with different healthcare groups. Niches are equal clinics where new ideas are introduced and tested. The landscape level is translated into health, in general, as part of larger social trends and changes.

Heiskanen et al. [60] argue that although the importance of users has been acknowledged in transition analysis, most transition analyzes operate with data on a macro level. Therefore, the conceptual organization of clinics, hospitals, and health in this thesis was beneficial in having a user focus.

Hospitals are influenced by pressures from the general healthcare system and niche innovations on a clinical level. Change might be triggered by iterative development circles within the regime or more radically from niche developments. Regimes (i.e., hospitals) represent the central dimension, characterized by a stable configuration in the socio-technical system until a new technology emerges [61, 62]. Compared to other industries where a core technology may dominate, hospitals function through the interplay of multiple technologies [62].

The multi-level perspective divides the regime into five sub-regimes: technological and product regime; science regime; policy regime; socio-cultural regime; and user, markets, and distribution networks regime.

Technological and product regime The technological and product regime can be characterized by its ability to meet functional requirements. The main functional requirements for institutional services are predictability, quality, and efficiency.

Science regime The science regime is characterized by the acquisition of new knowledge and expertise.

Policy regime The policy regime can be characterized by the relation, actions, attitudes, and values between employees and leaders.

Socio-cultural regime The socio-cultural regime has the main requirement of establishing a learning environment and routines as an organization responds to innovations, in this case, drones.

User and market regime The user and market regime is required to adjust and adopt new technologies in line with an organization and its stakeholders' needs and abilities.

Niches (i.e., clinics) are a protected space for radically new innovations; they require protection because their cost efficiencies, technical performance, and usability often need improvement [63]. Drones can be considered a niche innovation. The challenges of drone transport related to meteorological conditions, transport safety and security, and currently short flight ranges, still need to be solved. Niches provide the space for experiments and learning processes and the development of social networks that support innovation [64].

Deeper structural trends characterize the landscape (i.e., healthcare). The landscape level cannot be deliberately changed, according to multi-level perspective [65]. However, landscape changes can generate opportunities for niches [66]. The multi-level perspective refers to such opportunities as “windows of change.”

Raven et al. point out that an essential contribution of the multi-level perspective is the fact that transitions need a fruitful coupling of developments at all three levels [59]: First, niches are needed to develop, nurture, and experiment with new technologies or practices without the regime’s interference. Second, the regime needs to be open and adaptive to accept innovations. Third, the pressure of the landscape creates windows of opportunity for innovations to break through. In a later phase, this can contribute to an attitude that is more open to innovation in general.

Raven exemplified destabilizing landscape pressures to include socio-economic, demographic, political, and international trends, but also events like wars or environmental disasters [59]. According to Geels, the landscape may also include shared cultural beliefs, symbols, and values that are difficult to deviate from [51].

The landscape concept has been criticized, among others, for being relatively unspecific and for focusing too much on destabilizing influences on regimes. Geels suggests paying more attention to landscape developments that may help stabilize exiting regimes [66]. For example, the automobility regime is increasingly facing landscape pressures that destabilize (i.e. discussion of climate and fossil fuel use) and stabilize (i.e. preferences for speed, time savings, and private property) [67]. In terms of drone implementation, growing technological awareness of, for example, automated solutions may be seen as a landscape process that can challenge regime performance and create opportunities for niche developments.

In summary, in healthcare systems, there may be a tension between the perceived need for potentially disruptive innovation and the aims of ensuring patient safety and high-quality care with equitable access [68]. Consequently, Geels points out that a balanced assessment of transitions should address destabilizing and stabilizing landscape developments [66].

1.3 Research motivation

The motivation for this thesis is an interest in the broader system innovation that may arise from the establishment of drones in healthcare. The challenge of innovation should not only be considered from an economic point of view but also in terms of the societal consequences in the aftermath of the innovative activity [69].

System innovation is defined as a transition from one socio-technical system to another. The term transition reflects the idea of a path towards a new state [70]. In this thesis, the term transition is used interchangeably with system innovation. A transition ends when the emergent technology is embedded in the regime and thus creates a new social-technical system.

According to Geels, technology is often the entry point to the multi-level perspective and the socio-technological system at hand. This is, to some extent, due to implicit technological determinism. However, as Opoku et al. [71] argue, even if technological determinism is a mechanical mode of explanation, it does not mean that technology is uncontrollable or that technological development within a particular context will lead to automatism. Transitions are rather the outcome of co-evolutionary processes. This means that the interaction between subsystems influences, but does not determine, other systems [30]. For example, technical change co-evolves with institutional change—although they shape one another, neither determines the other.

Besides generic system and level assessments, Geels [72] requests that user practices, such as the initial development, diffusion, uptake in user practices, and social embedding, could receive more attention. This insight is very relevant for this thesis because a user focus is necessary to understand how drones are perceived today and how they could be socially embedded at the Oslo University Hospital in the present and future.

The research in this thesis is motivated by the learning of applying the multi-level perspective in an innovation project. Furthermore, the thesis hopes to contribute to practical implementations of multi-level perspective in similar novel technologies and innovation projects, as well as for the development of sustainable healthcare systems. The research is also methodological and pays attention to user practices and thereby tries to respond to Geels's request.

1.4 The role of design

Following system innovation in this thesis was less about the design of a drone and the service it provides, but to investigate which transitions take place when technologies such as drones enter the social context of a healthcare system. Researching views, relationships, and design roles for and within transitions is valuable because it enlarges possible solution spaces from a mere technological tool to new concepts and services [73].

The multi-level perspective presents itself here as a systemic and dynamic tool for the design of multi-level perspective about drone technology, which has recently also been applied in other disciplines, for example, land use policies [74] to expand the innovation potentials. Furthermore, the engagement with a broader range of users may, for example, contribute to the generation of ideas for new drone applications and services, which, in turn, may strengthen their integration into healthcare services, as, for example, Hiebert et al. claim [75].

Design approaches such as system-oriented design or transition design aim to create a new mindset for system innovation [76–78], and in parallel an awareness of designers to be responsible and to address social, economic, and ecological issues [79]. However, although system-oriented and transition designs have a common argument for the necessity of system innovation, they argue differently about design for complexity.

On the one hand, the system-oriented framework uses Gigamaps to visualize complexity and allow the team members to iteratively investigate, learn and adjust the system of interest [80, 81]. Sevaldson, who advocates system-oriented design, described Gigamaps as “information clouds” that try to grasp, embrace and mirror the complexity of problems [80]. Sevaldson recognizes that other fields are also concerned with solving complex problems; however, he believes that designers should use design practice to generate knowledge [79].

On the other hand, transition design draws on approaches from social science to understand the social roots of complex problems [77]. Moreover, Irwin et al., the representatives of transition design, argue that new ways of designing need to be informed by outside design knowledge to gain a deeper understanding of how to design for change/transitions in complex systems [77].

In *The Routledge companion to design research* [82], Daniela Sangiorgi and Kakee Scott argue:

> When designers widen a project’s scope or system boundaries to incorporate broader societal challenges, they must contend with questions of system-level change, even if working on smaller and more manageable manifestations of the wider scale phenomenon. In response, design approaches are undergoing re-tooling to adapt.

According to the authors, this has led to increased interest in design research, which draws on approaches from the social sciences developed over a long history of addressing systemic societal changes. Therefore, this thesis is positioned within design research that may be expanded into transition-scale projects according to Irwin et al. [83]. Design research may take several forms, such as observing what people do in various situations, asking questions, searching for information, making and testing prototypes, and speculating on fictional future visions [82]. In this thesis, the emphasis was placed on user inclusion through user-centered and human-centered design principles, such as understanding socio-technical systems and user needs and thus providing a foundation for a possible future design of the system [84].

1.5 Aims and research questions

By taking real cases and examples from current healthcare systems, the effect of implementing drones and if and how drones contribute to a more sustainable healthcare system can be analyzed. Additionally, the consequences from a socio-technical perspective can be evaluated.

The overall research question for this thesis is as follows: How can drones become a part of the future healthcare transport system?

Based on the background mentioned above and the overall research question, the following three subquestions are formulated:

1. How can current healthcare transport systems be understood as socio-technical systems?
2. What attitudes do healthcare workers have towards drone transport in healthcare?
3. How can drones be implemented in a future healthcare transport system?

1.6 Research papers

This thesis is based on three research papers that have been published in international scientific journals:

Paper 1: H. E. Comtet and K.-A. Johannessen, "A socio-analytical approach to the integration of drones into health care systems," *Information (Basel)*, vol. 13, no. 62, p. 62, 2022. DOI: `10.3390/info13020062`

Paper 2: H. E. Comtet and K.-A. Johannessen, "The moderating role of pro-innovative leadership and gender as an enabler for future drone transports in healthcare systems," eng, *International Journal of Environmental Research and Public Health*, vol. 18, no. 5, pp. 1–15, 2021, ISSN: 1661-7827

Paper 3: H. E. Comtet, M. Keitsch, and K.-A. Johannessen, "Realities of using drones to transport laboratory samples: Insights from attended routes in a mixed-methods study.," eng, *Journal of multidisciplinary healthcare*, vol. 15, pp. 1871–1885, 2022

1.6.1 Contributions of the research papers

The different contributions from the papers to the research questions are presented in Table 1.1.

The intended contributions of these papers are as follows:

(1) The multi-level perspective is analyzed to understand how it can be applied in an innovation project. By applying a broader analytical framework, the papers seek to contribute to an overall understanding of a socio-technical approach to innovation projects. Whether this may lead to increased use of the multi-level perspective in similar innovation projects will undoubtedly depend on the individual settings for a given case.

Research paper	1	2	3
Research question			
1) How can the current healthcare transport systems be understood as socio-technical systems?	•		•
2) What attitudes do healthcare workers have towards drone transport in healthcare?		•	
3) How can drones be implemented in a future healthcare transport system?			•

Table 1.1: Relationships between research papers and research questions

(2) The impact of drones on organizational processes has been scarcely studied and is unknown. The studies in this thesis reveal that although internal hospital transport times often may have delays because they are not being monitored or processed for optimization, a simple reconfiguration of the transport system could easily be obtained without complex organizational processes.

(3) Drones in healthcare are perceived positively and, therefore, may theoretically be valuable to envision future scenarios and improve current processes. Thus, a contribution of this thesis is that technological innovations and system innovation approaches may add value and support continuous improvement by facilitating technological and sustainable change.

The main conclusions are listed below:

1. Socio-technical system theory and the multi-level perspective provide tools for understanding and facilitating innovation processes.
2. In a broader perspective, drones can support the aim of having a healthcare system with good working conditions because they can be used in co-creation sessions to shape how laboratories want to work.
3. Drones allow for developing scenarios that invite user participation.
4. Currently, drones for laboratory logistics are not economically sustainable in an urban environment, but they can advance the sustainable goal of good equipment for transporting laboratory samples.

1.7 Organization of this thesis

Chapter 2 positions this thesis. Chapter 3 describes the research design and strategy for this thesis to answer the research questions. Chapter 4 briefly presents the results of the three research papers. Chapter 5 discusses the main findings concerning the research questions. Chapter 6 provides some remarks and implications. Methodological considerations and implications for validity, ethical considerations of this thesis, and lessons learned and limitations are presented. Finally, Chapter 7 provides some conclusions and suggests future research directions.

Chapter 2

Research position

The following sections position the research in this thesis. First, it discusses methodological awareness and a pragmatic approach. Next, reflexivity issues are discussed, that is, my role as a researcher, insider limitations and challenges, and political and ethical considerations. In the end, the analytical strategy is outlined and the research is described, including its validity.

2.1 Epistemological awareness

This section elaborates on epistemological awareness and provides a design, system, and research perspective on the pragmatic approach taken in this thesis. Epistemology describes the nature and form of knowledge [88] and is concerned with how knowledge can be created, acquired, and communicated [89].

The philosophical conceptualization of knowledge at the levels of ontology, epistemology, methodology, and methods is widely accepted [89–91]. However, there is a philosophical debate about whether the different levels inform each other in a top-down alignment [91, 92], or whether the alignment goes both ways, as Morgan [90] suggested.

In a top-down alignment, the constructivist typically relies on qualitative methods, whereas the positivist uses quantitative methods. Morgan argues that our ontological worldview should not automatically influence the research we do [90]. Instead, we should decide what is essential and appropriate. In that sense, the pragmatic researcher is flexible in selecting the research design and methodology that are most appropriate to address the research question [93].

A pragmatic approach is helpful regarding the multi-level perspective because it includes hard and soft system elements (see the following sections). Geels [51] describe technologies as having a certain “hardness” and consisting of systems of human relations and institutional rules. This is methodologically connected to a pragmatic attitude.

From a design perspective

A practical method that has proven valuable in creating sustainable innovations is to move between divergent and convergent thinking [94]. Convergent thinking is linear, systematic, and analytical, whereas divergent thinking is outward, open-ended, creative, and flexible.

Divergent and convergent thinking can be aligned with the logic of deductive and inductive reasoning. The deductive approach is characterized as a top-down process that provides general statements. On the contrary, inductive reasoning describes an explorative bottom-up approach. Pragmatism is associated with abductive reasoning, moving between deduction and induction [93]. Figure 2.1 illustrates the three described forms of reasoning.

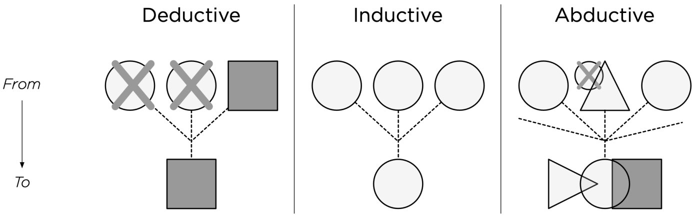

Figure 2.1: Deductive, inductive, and abductive reasoning

From a system perspective

Ison [36] described the hard side of systems as systematic and linear, following step-by-step thinking to name, build, explain, or discover systems and use systemic models as epistemological devices. The soft side of systems is described as systemic thinking in terms of wholes. Continuing along this line, the systemic models used in learning can lead to changes in understanding and practices. The system designer facilitates learning and change based on accommodations between different interests. Ison [36] compared positivistic and constructivist perspectives from a systems point of view and described the thinking traditions associated with hard and soft systems (Table 2.1).

From a research perspective

In research, a deductive process is typically associated with positivism, whereas an inductive process is associated with constructivism [91]. The positivistic perspective is based on the work of Simon [96], in which knowledge is logically connected [97]. Schön [98] criticized this approach because it may solve well-formed problems. However, particularly in design research, researchers and designers may often be confronted with complex or ill-defined problems, sometimes termed wicked problems. Schön suggested a constructivist paradigm that focuses

Hard system thinking traditions	**Soft system thinking traditions**
oriented to goal-seeking	oriented to learning
assumes the world contains systems that can be engineered	assumes the world is problematic, but can be explored by using system models
assumes system models to be models of the world (ontologies)	assumes system models to be intellectual constructs (epistemologies)
talks the language of 'problems' and 'solutions'	talks the language of 'issues' and 'accommodations'
Advantages	**Advantages**
allows the use of powerful techniques	is available to all stakeholders, including professional practitioners; keeps in touch with the human content of problem situations
Disadvantages	**Disadvantages**
may lose touch with aspects beyond the logic of the problem situation	does not produce the final answers; accepts that inquiry is never-ending

Table 2.1: Comparison of hard and soft traditions of system science (Ison [36], adapted from Checkland [95])

on enabling people's creative capabilities through experiential learning. In organizational and management research, systemic thinking can be related to the ability of organizations to learn [99]. Table 2.2 summarizes the different concepts.

	Positivistic	**Constructivist**	**Pragmatic**
Approach	Top-down	Bottom-up	Flexible
Logic	Deductive (convergent)	Inductive (divergent)	Abductive (convergent and divergent)
System knowledge	Name, build, describe, or discover systems and use systemic models as epistemological devices	Used in a process of learning that can lead to changes in understanding and practices	Knowledge useful for problem solving and action
Authors	Simon [96]	Argyris and Schön [100], Schön [98]	Dewey [101, 102], James [103] and Cross [97]

Table 2.2: Ontological and epistemological choices (adapted from Auernhammer [99])

The following section summarizes the influence of the different concepts on this thesis.

Positivistic A positivistic approach for technological and business dimensions lies, e.g., in technological determinism. The idea is that technology is separated from society and is first developed before being tested in society. Therefore, regulation may be necessary to control technology and avoid unintended consequences. For example, although drones and technology, in general, are continuously under development, many technical engineering issues still need to be solved before they can fly autonomously. In addition, logistical models, business values, and technical requirements may be presented objectively and numerically to be measured. From a socio-technical perspective, top-down processes from the landscape into the regime may drive change. In particular, public expectations of healthcare and political guidelines for the use of technology in healthcare actively influence the regime. Such processes can create opportunities for niche developments.

Constructivist The social construction of technology explores the relationship between technology and society. In this process, technology and society shape each other over time. This extended perspective provides the opportunity to develop user-centered services and system innovations, as advocated by the multi-level perspective. The multi-level perspective broadens the analysis from technology and business perspectives to socio-technical systems. Although top-down processes may create tensions in some regimes, the bottom-up process tries to mediate the different regime dimensions. For this thesis, the inductive approach is used to interpret the findings and insights.

Pragmatic The pragmatic focus is located at the regime level in this thesis. In this institutional context, understanding practical performance may lead to the identification of changes. Top-down and bottom-up processes drive changes in system transitions, and identifying which approach offers the best leverage for change during periods of innovation is an essential factor in the ultimate success of any transition [104]. Leverage points are mechanisms by which incremental changes produce more significant changes in complex systems [33].

2.2 Reflexivity

This section discusses my hypothesis and positioning in the research project. I would describe my ontology as being most closely linked to the position of soft system thinking. However, I support the argument of Ison [36] that practicing both soft and hard system thinking gives access to more choices. Furthermore, although I position myself in the constructivist dimension, I firmly believe that sustainable development and interdisciplinary projects need to move from the top-down approach, from ontology to methods, and towards a flexible and pragmatic approach. This is because to be able to work together in interdisciplinary teams, a flexible and pragmatic approach would make it possible to work together towards solutions beyond disciplinary theories and methodologies commonly. However, holding on to your own beliefs and methods may prevent interdisciplinary work because other approaches and methods may be criticized.

The broader design of socio-technical systems considers human, social, and organizational factors alongside technical factors [50]. Socio-technical transitions, i.e., the change from one socio-technical system to another, are multidimensional and can be studied from different angles by different disciplines. The crossover between ontologies may be particularly fruitful for multidimensional phenomena such as socio-technical transitions [105, 106].

The research setting has provided a reward for personal learning on multiple levels. However, time limitations, coursework, and the writing process take time in Ph.D. projects, resulting in not everything being investigated and covered.

2.2.1 Insider limitations and challenges

Conducting research as an insider may often include relations that already exist. However, since I started as an outsider in this research project, the relationships actually needed to be established first. Additionally, because I lack relevant healthcare experience, the initial phase was characterized by learning and building relationships and agreeing with the supervisors on practical knowledge, which can be challenging due to many different opinions and priorities. The HELSEVEL project contained specific requirements and the choice of multi-level perspective as the theoretical framework was questioned. Although research on socio-institutional healthcare systems receives some attention [41], concepts such as the multi-level perspective and system innovation are still relatively unfamiliar.

My doctoral program is rooted in the Department of Design at Norwegian University of Science and Technology (NTNU). The research is rooted in the Intervention Center as an employee at Oslo University Hospital. Although beneficial to my development, the collaboration of both institutions was not strengthened beyond my involvement. One reason may have been that the research project was already initiated and that NTNU was not one of the initial stakeholders in the HELSEVEL research project.

2.2.2 Political considerations

Political considerations describe how organizations are continuously developed to serve their overall societal assignment best. It may need a vision, goals, and values to create a sense of community.

Institutional politics includes the hidden, behind-the-scenes interests and commitments that form part of any institution's social structures. Therefore, researchers need to be conscious of these largely invisible structures [107]. Political disputes may include power differences in the organizational hierarchy, the allocation of space and other resources, gender politics, and who collaborates with whom.

Social structures reflect normative, regulative and cultural cognitive elements [108]. Geels conceptualized the policy rules as one dimension in the socio-technical system (Chapter 2).

Institutions are fundamentally political, and the politics of an institution will undoubtedly influence researchers.

2.2.3 Ethical considerations

Ethical considerations are intended to investigate how to act, how to understand and evaluate the outcomes of actions, and how to act (morality) accordingly. Ethical issues occur in all phases of a research project [109]. However, in this thesis, data collection was the main ethical consideration.

Respecting the particular characteristics of healthcare facilities and disturbing clinical processes as little as possible were essential ethical perspectives. Another issue involved building trust and conveying the extent of anticipated disruption in gaining the necessary access. To avoid disturbing the meetings between patients and providers of clinical services, the research project focused solely on clinical service units.

2.2.4 Research journey

My research journey began with a book on interaction design [110], where I first discovered my interest in socio-technical systems. After my Master's degree in Interaction Design, I worked as a UX designer. Continuing my research journey, I realized the importance of continuous learning and reflexivity to broaden my understanding of socio-technical systems and design processes. As a UX designer turned researcher, I sought to expand my knowledge beyond user interfaces and go deeper into system innovation.

During my PhD project, I had the opportunity to attend the Service Design Conference in Scotland just before the lockdown, where I was exposed to presentations on designing for sustainability without having all the answers. This further piqued my interest in exploring the implications of socio-technical systems on sustainability.

The COVID-19 pandemic, while limiting physical interactions and networking opportunities, surprisingly had minimal impact on data collection for my research. However, it inadvertently encouraged a more theoretical focus, allowing me to read more literature and study the multi-level perspective as a theoretical framework for system innovation design.

In the practical aspect of my research, conducting drone tests proved challenging. We hypothesized that drones could fly and aimed to test a logistical model for Oslo University Hospital [111]. However, logistical issues with drone manufacturers and restrictions on airspace due to emergency helicopter approaches hindered the smooth execution of the experiments [112]. Another time, a drone fell from the air, highlighting the complexities of implementing drones in real-world scenarios.

While more iterations would have been ideal, the lack of access to drones for experimentation and the need to coordinate with external vendors added constraints to the research process. As a designer in the project, my focus was on conceptualization and understanding how drones could contribute to system innovation rather than being directly involved in drone design or defining specific needs and requirements.

Throughout this work, I have appreciated the value of learning, reflexivity, and continuously broadening my understanding. Engaging in a design process when the problem is not clearly defined, the design approach may require a more exploratory and iterative mindset. Therefore, the research in this thesis tried to gather as much information as possible about the problem domain. Reading articles, talking to stakeholders, conducting interviews, and research to gain a deeper understanding of the context and needs of the laboratories.

In conclusion, my research journey has been characterized by a focus on socio-technical systems, system innovation, and the exploration of drones as a potential innovation in the healthcare logistics domain. This has involved navigating the limitations posed by the pandemic, facing challenges in conducting practical experiments, and embracing a theoretical perspective to strengthen the conceptual foundations of the research.

2.3 Analytic strategy and plan

The analytical strategy of this thesis reflects the integration of drones into healthcare systems in a mixed-methods investigation. The analytical plan comprises three research questions. The relationship between the research questions and the multi-level perspective is illustrated in Figure 2.2.

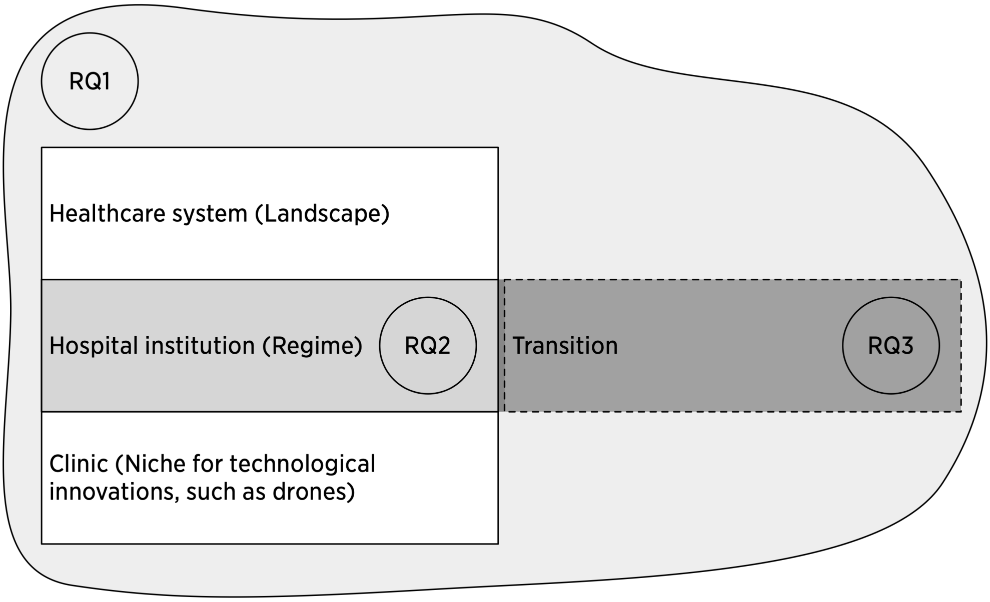

Figure 2.2: Relationship between the research questions and the multi-level perspective

- The first research question asks how the current healthcare transport systems can be understood as a socio-technical system.
- The second research question concerns the attitudes of healthcare workers towards drone transport in healthcare.
- Finally, the third research question examines empirical effects and asks how drones may be implemented in a future healthcare transport system.

The quality of the research is evaluated through evaluation criteria. The validity criteria used in this thesis are described below:

Quantitative and qualitative approaches are validated to verify data quality, results, and the author's interpretation of data results [91]. In this thesis, the concept of validity is inspired by Herr et al. [113], who linked five criteria (dialogic, outcome, catalytic, democratic, and process) to the goals of research as indicators of good research. To this list, I add the criterion of construct validity [114]. Table 2.3 lists the validity criteria and goals, which are described more thoroughly in the next section.

#	**Validity criteria**	**Goals of research**
1	Dialogic validity	Generation of new knowledge
2	Catalytic validity	Education of both researchers and participants
3	Democratic validity	Results that are relevant to the local setting
4	Process validity	Sound and appropriate research methodology
5	Outcome validity	Achievement of valuable outcomes
6	Construct validity	Collection of data

Table 2.3: Validity criteria and goals of research (inspired by Herr [113] with #6 from Yin [114])

2.4 Research description

The previous section described the research strategy and charted six validity criteria. This section outlines the research description and applies the validity criteria. Different research strategies are chosen to contribute to a broader understanding of the integration of drones into healthcare systems. Table 2.4 provides an overview of the purpose, methodology, data, methods, analysis, and results of the three articles:

	Paper 1	**Paper 2**	**Paper 3**
Purpose	To examine the MLP and potential for spin-offs related to the organizational transitions and implementation of drones	To examine variables among employees at the three hospital trusts	To explore the current transport service and identify topics for improvement
Methodology	Qualitative content analysis	Quantitative analysis	Mixed method
Sample and data sources	Review based on 25 articles, supplemented with further publications	Random sampling for a study group of 400 subjects	Purposive sampling of carriers working in the transport department
Research methods	Scoping review, snowballing, and supplement literature	Self-administered questionnaire	Questionnaires, shadowing, interviews and multiple time measures from the transport system
Data analysis	Inductive and deductive process	Descriptive analysis	Convergent design
Conclusion	The MLP is useful for innovation and for understanding the interactions between different system levels. Ethical topics and public acceptance are placed into a socio-technological perspective	Drones are positively perceived. Working in an innovative environment, having experienced technological change, and having leadership that supports new ideas are drivers of beliefs in drones	Suggests experiments and learning from transport by cars and drones in combination

Table 2.4: Overview of the three articles included in the thesis

2.4.1 Dialogic validity

The dialogic validity refers to the generation of new knowledge and the articles published in this research project. Two papers have been published in MDPI journals because of the broader scope, wide readership, rapid turnaround, and relatively high impact factor (>3) of these journals (the impact factor of a journal is calculated in terms of how often other researchers cite articles in the journal). The general success of MDPI and their growth with multiple journals and the treatment that some researchers have experienced from specific journals have been widely debated. The Norwegian National Publication Committee has recently created a new level X for possibly predatory journals and publishers [115, 116]. MDPI, particularly the journal Sustainability, is under investigation and is categorized as level X while the investigation is ongoing.

2.4.2 Catalytic validity

The catalytic validity refers to the spiraling change within the iterative cycle of the plan–act–observe–reflect. Iteration is an accepted characteristic of action research. The overall course of the research for this thesis is depicted in Figure 2.3.

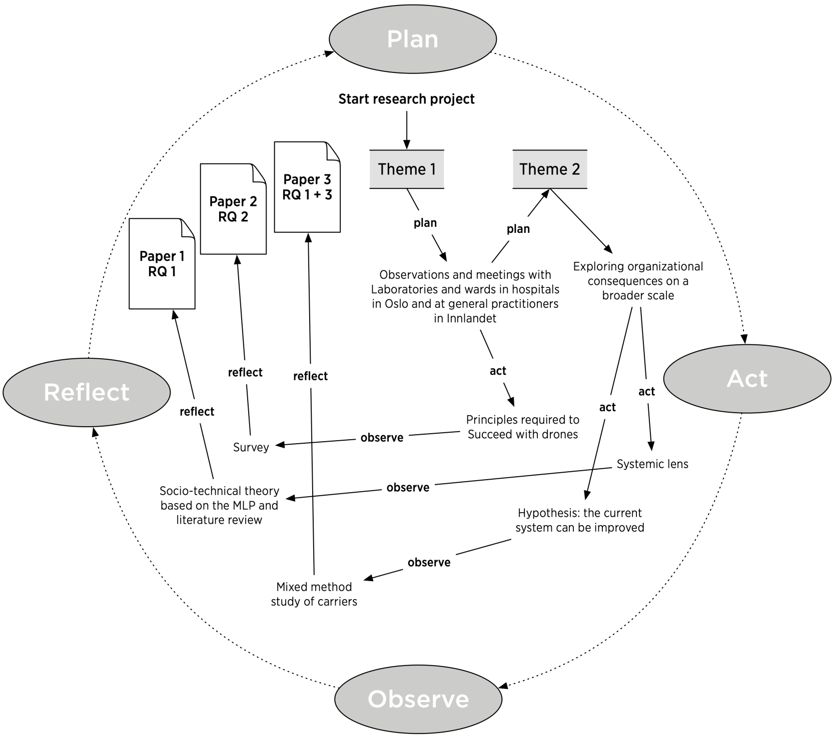

Figure 2.3: Plan–act–observe–reflect cycle

The research project started with extensive observations and subsequent learning. The first article is based on a scoping review. The development of a survey instrument led to the second article. Finally, knowledge of system transitions led to a mixed-method study of carriers that formed the third article.

2.4.3 Democratic validity

Democratic validity refers to the inclusion of involved parties in the investigation and its relevance in the local setting. The research project has focused on healthcare workers and applied qualitative and quantitative methods to assess relevance for the local setting. The system perspective ensured a broad perspective and understanding of multiple factors that may be important for the integration of drones into healthcare systems.

2.4.4 Process validity

Process validity refers to the extent to which ongoing learning is supported. A helpful approach to process validity is to have a hierarchy of themes to guide the production of several outputs on the same topic [117]. For example, the uppermost themes describe what motivated the researcher to become involved, followed by themes more closely related to the actual research project and organizational context.

2.4.5 Outcome validity

Outcome validity is dependent on process validity, described in the previous section. The outcome validity describes the successful outcomes of the research project and includes internal and external validity. Internal validity can be described by the degree to which the results represent the truth in the subject being studied, that is, the strength of the research methods and design. External validity describes to what extent the research outcome can be generalized.

2.4.6 Construct validity

The construct validity requires that correct operational measures are identified for the concept being studied [114]. Trochim [118] conceptualizes this using theoretical and practical dimensions. The theoretical dimension describes how beliefs and theoretical assumptions have been captured and measured, that is, operationalized by the research into the practical dimension.

The validity claims related to the findings in this thesis are discussed in Section 5.7

Chapter 3

Data and methodology

The three articles in this thesis have different data sources and approaches, but are all concerned with integrating drones into healthcare systems. This chapter first outlines the research design in the overall study, then explains the data collection methods and presents methods to determine and assess the research questions in this thesis. Finally, this chapter is summarized.

3.1 Research design

The research reported in this thesis consists of quantitative, qualitative, and mixed-methods. Methodologically, the thesis is grounded in the Ison [36] titled *Systems thinking and practice for action research*. However, as introduced in Chapter 1, the *system thinking* is based on the neutral term *system science*, which Mabry et al. [32] used to describe the conceptualization of a solution space in which the whole system and the interrelated parts can be analyzed. Figure 3.1 illustrates the basic idea of system thinking. An observer has determined the border of a system of interest in a given context. The border differentiates the system of interest from the environment [36].

3.2 Methods of data collection

As described above, in terms of the overall research design, this thesis draws on different methods and data. In this section, the choice of methods is outlined and described.

3.2.1 Mixed-methods

Maxwell [119] describes three purposes for using multiple methods. The first is triangulation, to check whether different methods support a single conclusion. The second purpose is to gain information about different aspects. The third purpose, which is applicable in this thesis, is to provide a more prosperous and better

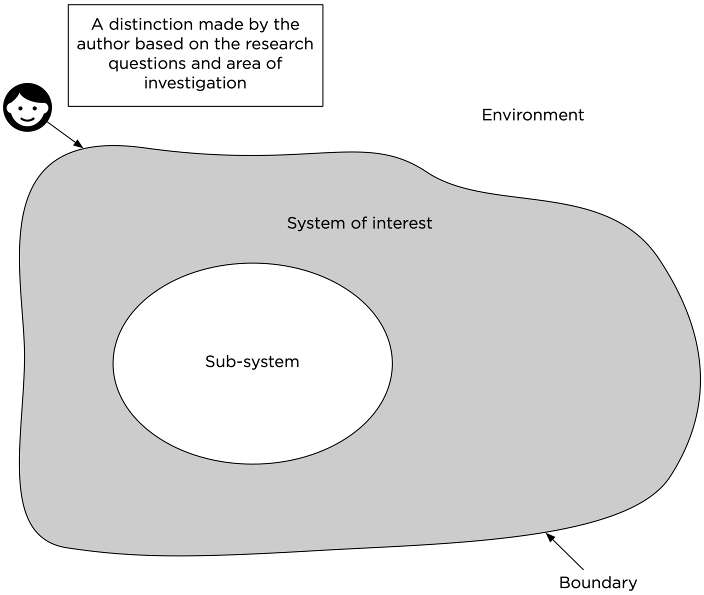

Figure 3.1: Key elements that result from system science (adapted from Ison [36])

understanding of the bigger picture. In addition, using a combination of methods can strengthen the validity of research results.

Statistical analysis and probability calculations help to understand uncertainties and make comparisons straightforward [120]. However, complex and multiscale problems can be challenging to express using purely quantitative data [31]. The combination of methods can improve the depth of understanding [121]. For this, a mixed-method approach should take advantage of qualitative and quantitative methods as complements to each other.

Complementary methods examine different elements of a specific phenomenon [122]. This thesis comprises a quantitative analysis of a questionnaire and data on transport times. The qualitative findings address observations, shadowing, and interviews.

Interpreting qualitative data

The qualitative content analysis describes a development process in which categories emerge through incremental revisions and are enriched while working on the text [123]. First, however, the methodological concept of emergence is discussed [124]. In this thesis, the multi-level perspective is used as a conceptual framework and forms a skeleton for the data. Kelle [124] argued that, in the context of exploratory and interpretative research, such an approach might be beneficial because researchers may otherwise have long processes and generate a lot of data that needs to be analyzed. In contrast, the argument for the emergence of codes is open-mindedness.

However, researchers have always used the existing theoretical knowledge to describe and explain observed phenomena [124]. Researchers should be careful not to force data into specific categories. Furthermore, it is necessary to control whether a chosen theoretical concept leads to the exclusion or neglect of some phenomena [124].

In positivist research, data are considered to be obtained independently of the researcher [125]. However, in qualitative research, the researcher must know his role during the study. Moreover, qualitative research includes personal experience, i.e., the researcher may introduce his knowledge and create individual assessments of the findings. Therefore, qualitative research and its interpretations can never be separated from the researcher's reflexivity or personal views and characterizations. Section 2.2 elaborates on my personal beliefs that I brought with me to this thesis.

Quantitative data and statistical analysis

Quantitative data analysis is a structured process. According to Creswell et al., [91], the data is first evaluated with computer programs such as EXCEL or SPSS. The data are then explored to develop a general understanding of the database. Finally, results may be illustrated in statements, tables, or figures. The process of Creswell et al. applies to the quantitative data analysis in this thesis.

3.2.2 Case study: Oslo University Hospital Trust, Oslo, Norway

Case studies provide valuable insights in the early stages of any research project and can contribute to system design and further investigation.

Oslo University Hospital Trust used as the case in this thesis consists of four main institutions located inside the area of Oslo, and several minor facilities (see Figure 3.2): Rikshospitalet (The National Hospital, offering local, regional, and national services), Ullevål University Hospital (local, regional, and national services), Radiumhospitalet (a specialized cancer hospital), and Aker University Hospital (local and central hospital).

In 2018, Oslo University Hospital had a total patient activity of 94,000 hospitalizations, 45,000 daycare treatments, and 853,000 outpatient consultations. The hospital had 24,000 employees, and patient treatment took place at more than 40 locations within a radius of 20 km. Hence, Oslo University Hospital is a large institution on a European scale and provides services from local hospital treatment to advanced specialized services and transplantations.

With its complete range of medical services in many locations, large-scale economy, and variety of advanced solutions, Oslo University Hospital is a relevant case for the assessment of drone solutions as an extensive service for the time-critical clinical transport of biological samples across large and complex institutions.

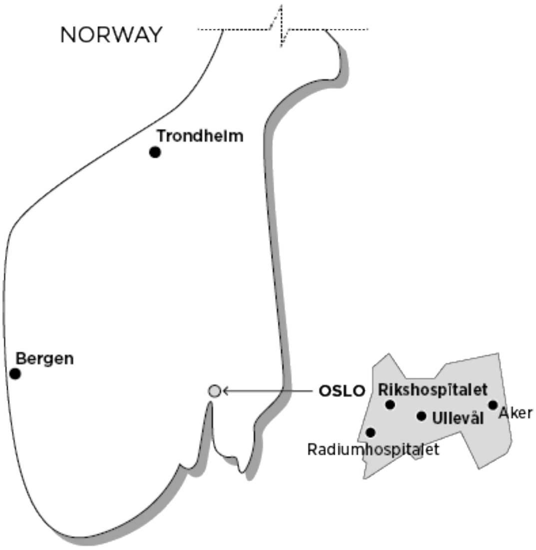

Figure 3.2: Oslo University Hospital Case

At Oslo University Hospital, blood samples are transported across the laboratories at the four locations. Blood samples are taken in different medical subspecialty units (wards, outpatient clinics, centers) that offer various inpatient treatments, day treatments, and outpatient services.

Based on numbers from 2018, the total analysis performed at Oslo University Hospital is more than 22 million analyzes per year. The laboratory at the National Hospital has nearly twelve million analyses. The Ullevål laboratory performs more than six million analyzes. The numbers for the other hospitals are 1,5 million analyses at Radium Hospital and more than 500,000 at Aker Hospital.

The scenario considered in this thesis is an "inner-city project" aiming to ensure that biological material can be transported across the four Oslo University Hospital locations within defined time intervals. This inner-city scenario requires drones to fly over urban areas at high frequency and at all times of the day. If this project proves to be realistic, it may be relevant for other urban hospitals that could benefit from consolidating duplicated services.

The purpose of exploring the drones at Oslo University Hospital was to explore the potential for improved laboratory logistics for the transport of biological material across the four locations based on the hypothesis that transport times could be improved, and as a possible instrument to eliminate duplicated laboratory activities across these laboratories. The thesis aims to explore whether specific organizational topics would have to be considered and modified to obtain the full potential of such solutions.

To broaden our data related to the knowledge and expectations of future drone solutions in Paper 2, we took advantage of the fact that two other hospitals in our region also consider drones as part of future logistics. Both Innlandet Central Hospital and Vestre Viken Central Hospital plan for new centralized hospital structures where drone solutions may improve logistics. Both hospitals have a similar geographical environment with multiple districts and rural areas where biological and other goods are transported by ground vehicles. We got approval to extend our exploratory questionnaire in Paper 2 to these two hospitals.

Today's drones fly with a maximum speed varying from 40–50 km per hour. This represents a limitation of the time difference between cars and drones traveling in parallel. Longer driving distances, particularly when roads have to detour around or bypass natural barriers such as forests, lakes, and mountains, while drones can take shortcuts, drones may still yield some value, and this should be expected to increase in the future with more robust drones having larger load capacities and distance ranger.

3.3 Methods to determine whether current healthcare systems may be understood as socio-technical systems

3.3.1 Observation and shadowing

Ethnography is the combination of observation, interviews, and participation [126]. The purpose of the observations is to observe what people (in this thesis, healthcare workers) say and do when collecting blood samples. Additionally, this understanding can be enriched with photos, notes, and system maps to collect and group information. Finally, shadowing is a common approach to follow group members as they go about their business, the researcher asking questions as needed for clarification and interpretation [126].

Gold [127] described the different roles of observations, ranging from being a *complete participant* to a *participant-as-observer*, then to a *observer-as-participant*, and finally to a *complete observer*. My role during the observations can be described as an observer as a participant. Further, Gold points out that a researcher in this role, compared with a complete participant or a participant-as-observer, is less vulnerable to reminding oneself of the primary role of being an observer. However, contact with the informant is brief compared to the other roles, which can lead to misunderstandings. Applying this method in the present thesis may confirm or reveal gaps in the information gathered through the other data collection methods and aid in identifying questions for future research.

3.3.2 Scoping review

Scoping reviews can be used to identify research gaps and summarize research findings [128]. Similar to systematic reviews, they follow a structured process. However, the review question can have a broader "scope" compared to systematic reviews. Although literature searches may be less defined than systematic reviews, they are intended to provide an overview of a given topic [129].

3.4 Methods to assess the attitudes healthcare workers have toward drones

3.4.1 Questionnaire

According to Salkind [130], questionnaires offer a structured approach to data collection, allowing researchers to efficiently collect large amounts of information from a diverse range of participants in a standardized manner.

Lyu et al. [131] emphasize that questionnaires are often used in innovation studies because questions can be created to ask about information directly.

Questionnaires have several advantages, including their ability to collect data from a large sample size, ease of administration, and the potential for standardized responses [130]. However, there are also drawbacks to consider. For example, Salkind [130] and Dillmann et al. [132] highlight that response bias, low response rates, and the potential for misinterpretation of the questions can limit questionnaires.

Furthermore, questionnaires do not allow the responses to be followed up and are not suitable for a deeper investigation of the responses [133]. Validity of the questionnaire should be ensured through pre-tests and test trials, thus identifying potential issues and allowing further refinement before a wider distribution [134].

Workshops are considered to develop the survey instrument, and the questions are further improved, revised, and categorized to collect information on various topics [135]. The collaborative nature of workshops allows the immediate identification of flaws and biases in the survey questions, leading to iterative improvements and increased validity.

However, there are drawbacks to workshops. For example, time constraints and scheduling challenges in workshops can prevent a thorough exploration of all aspects of the survey instrument. Although workshops provide valuable opportunities for collaboration and refinement of survey instruments [136], it is important to consider efficient use of time to maximize the quality of the survey instrument.

3.5 Methods to assess changes that drones may accelerate in healthcare systems, and how drones may become a part of the future healthcare transport system

3.5.1 Focus group interview

Focus groups are increasingly used, ranging from promotion and marketing to evaluations and social research [137]. One reason might be that individual interviews are considered more cognitive, whereas focus group interviews tend to present spontaneous, expressive, and emotional views [137]. This output can be relevant for marketing research that aims to predict and control consumer behavior [137]. Another benefit may be that focus groups enable an analysis of social interactions that lead to interview statements [138]. Another reason for the popularity of focus groups may be their flexible placement within a research design, for example, front, back, or in parallel.

Excursus: focus group interviews

The planned focus group interviews turned into two sessions with experts and a discussion. The first group included five participants (three laboratory experts, one medical doctor, and one entrepreneur). The second group consisted of 12 experts in health-related logistics. The focus group interviews aimed to generate impressions of the institution and learn how experts talk about drones.

Each session lasted approximately one hour. The author of this thesis first presented the findings from Paper 3, followed by a discussion among the group for 30 min. During the discussion, various questions were asked, covering which institutional elements are considered unnecessary/redundant in the organization of today, which institutional elements are essential, and the ability of drones to contribute to institutional change.

The analysis of the interviews and the focus group meetings followed a simple structure, as suggested by Stewart [139], avoiding the need for a detailed analysis and achieving a faster conclusion. The interviews were transcribed and uploaded to Atlas.ti content analysis software (version 22.0.2).

Four categories emerged from the review: (1) Institutional barriers, (2) Ownership, (3) Support from drones, and (4) Institutional gains. The category most relevant to this thesis that emerged from the review is the support of drones and is discussed in Section 5.3.

Chapter 4

Results

This chapter briefly presents the main findings contained in the three articles underlying this research. Table 4.1 provides a general overview of this chapter.

Research paper	1	**2**	**3**
Research question			
1) How can the current healthcare transport systems be understood as socio-technical systems?	•		•
2) What attitudes do healthcare workers have towards drone transport in healthcare?		•	
3) How can drones be implemented into a future healthcare transport system?			•
Sections	4.1	4.2	4.3

Table 4.1: General overview of the results

The full versions of Papers 1 to 3 are included in this thesis after the bibliography. The remainder of this chapter is based on the three peer-reviewed articles.

4.1 Paper 1

A socio-analytical approach to the integration of drones into healthcare systems

> H. E. Comtet and K.-A. Johannessen, “A socio-analytical approach to the integration of drones into health care systems,” *Information (Basel)*, vol. 13, no. 62, p. 62, 2022. DOI: `10.3390/info13020062`

This study examined what knowledge of socio-technical theories may support the implementation of drones into healthcare systems. The study was built on a scoping literature review of topics related to the multi-level perspective and socio-technical studies from differing arenas, supplemented with studies collected on a broader basis using the snowball effect. The multi-level perspective can provide a framework that can be helpful in understanding system innovations related to drones in healthcare [29, 57, 140–142]. For this paper, the multi-level perspective levels have been translated into a healthcare context and used to organize the literature findings. The study assumes a bottom-up process, starting at the niche level, where drones are first implemented before they generate innovations in a broader perspective. The useful implication of this perspective is that it reveals the dynamics and linkages between the three levels. Furthermore, by reversing the multilevel perspective and starting at the niche level, this study may provide an interesting perspective for niche actors working with innovation and interested in systems innovation.

During the analysis of the documents and the development of the discussion, several additional publications were included to supplement the analysis, following a deductive identification of the relevant articles. The entire process is described in the research article included at the end of this thesis (see Paper 1).

4.1.1 Main findings and conclusion

The multi-level perspective may be useful for innovation and understanding the interaction between different levels of the system. Ethical topics and public acceptance are put into a socio-technological perspective. The articles considered in this study indicate that it is necessary to build a cross-cultural approach and establish a discourse across several stakeholders to develop a future sustainable healthcare system. Information about community needs can guide policymakers and decision-makers in appropriately integrating drones.

4.2 Paper 2

The moderating role of pro-innovative leadership and gender as an enabler for future drone transports in healthcare systems

> H. E. Comtet and K.-A. Johannessen, “The moderating role of pro-innovative leadership and gender as an enabler for future drone transports in healthcare systems,” eng, *International Journal of Environmental Research and Public Health*, vol. 18, no. 5, pp. 1–15, 2021, ISSN: 1661-7827

This study investigated the expectations and beliefs of 400 employees at Oslo University Hospital, Innlandet Hospital, and Vestre Viken Hospital. To extend the study beyond Oslo University Hospital, we included Innlandet Hospital and Vestre Viken Hospital because these two institutions are planning new hospitals and considering drone transports as part of future transport solutions. The study used a self-administered questionnaire and aimed to capture “the overall picture” with respect to the technological interest and competence of individuals, the knowledge and expectations of future drones, and indicators of local culture. The 36 questions in the questionnaire included 16 yes—no questions, 13 multiple-choice questions, and 7 Likert scale questions (rating individuals' agreement with a statement on a scale of 1—5).

The importance of organizational structures and expectations specifically related to the use of drones in hospital systems has been explored by [143] and others [75, 144–146]. These authors agree that this is an important issue that needs further investigation. The study confirmed that factors such as different attitudes by profession and gender might differ in different systems and cultures ([143]). Therefore, this study extends this understanding to a Norwegian setting. Furthermore, the study developed a novel questionnaire that can be used by other researchers to study local settings and systems.

4.2.1 Main findings and conclusion

Drones are perceived positively. Working in an innovative environment, having experienced technological change, and having leadership supporting new ideas drive beliefs in drones. Innovative leadership and culture may strengthen the acceptance and implementation of drone transport in healthcare. Furthermore, it may shape the organizational structure necessary to adapt to technological change. The potential for organizational development was also discussed in Paper 1.

4.3 Paper 3

Realities of Using Drones to Transport Laboratory Samples: Insights from Attended Routes in a Mixed-Methods Study

> H. E. Comtet, M. Keitsch, and K.-A. Johannessen, "Realities of using drones to transport laboratory samples: Insights from attended routes in a mixed-methods study.," eng, *Journal of multidisciplinary healthcare*, vol. 15, pp. 1871–1885, 2022

This article focused on the carriers at Oslo University Hospital who currently transport biological material by car along traditional circular routes.

The study explored how the current transport service is organized, identified areas for improvement, and investigated carriers' perceptions of how drones could be integrated into or substituted for their current services. The findings in this article were based on 16 questionnaires, nine shadowing reports, eight interviews and multiple measurements of transport times. In their review paper, Kellermann et al. [147] argue that current transport problems on the ground should not be the drivers of drone technology development. In our study, we respond to Kellermann et al. call for increased engagement of social sciences. Understanding work practices using novel technologies is emphasized in socio-technical approaches

[148]. Additionally, stakeholders interviews can be conducted in preparation for or as part of a transition process [149].

The involvement of hospital transport service providers as potential stakeholders and resources in the implementation of drone solutions contributed useful knowledge to optimize the existing transport solution. Lessons learned may be relevant to achieving a more innovative transportation system. This study argues that drones may represent a logistics solution with relatively little impact on organizational processes. However, the potential for additional organizational and innovative processes should always be considered when incorporating new technologies. In addition, existing transportation solutions should be carefully analyzed to identify potential improvements before implementing drones. The implications of this study illustrate how existing systems can be improved and how new systems can be created with a combination of old and new technologies.

4.3.1 Main findings and conclusion

New solutions and approaches may challenge the status quo, namely, established work processes and routines. The study revealed that the routes have existed almost unchanged for more than a decade with only minor adjustments. Therefore, the study suggests combining experimentation and learning from transport with cars and drones.

Chapter 5

Discussion

The following sections in this chapter summarize the findings of the three articles in relation to the research questions: (1) How can the current healthcare transport systems be understood as socio-technical systems? (2) What attitudes do healthcare workers have toward drone transport in healthcare? (3) How can drones be implemented into a future healthcare transport system? This will be followed by a broader discussion and evaluation of the overall research. Chapter 6 will discuss the overall contribution of this thesis.

5.1 The current healthcare system as a socio-technical system

Paper 1 and Paper 3 approached the healthcare system as a socio-technical system using the multi-level perspective as a conceptual framework and tool.

Paper 1 discusses the conceptual levels of the multi-level perspective from the dimensions of the niche upward. The multi-level perspective model is often used the other way around. However, assuming that drones are implemented in a “bottom-up” process, the model has been adapted accordingly.

Paper 3 hypothesizes that the current transport options can be improved through a reconfiguration pathway. New solutions and approaches may challenge the status quo, namely established work processes and routines. Existing systems may survive for long periods if traditional modes of operation lock them in. However, in the early phase, new technologies may develop without any consensus on their overall benefits. For example, it may be difficult to comprehend how a new technological tool should be integrated into existing workflows to improve existing processes.

According to the transition management theory, the micro-behaviors that emerge as individuals adapt to innovation may contribute to overall organizational behavior at the system level. For example, a transition perspective might suggest that the transportation department rebrand itself as an innovation hub for logistics, with an open culture for experiments and change (Paper 3). Indeed, in our study

Paper 3, the users said, ”The old structure needs to be cracked to be more innovative.”

Paper 2 suggests that exploring and understanding an organization’s readiness for technology-generated system changes may be crucial in implementing most types of technology and drones. A socio-technical approach might be helpful in this implementation process because it highlights the importance of using technological transformation as an opportunity to improve operations by combining organizational and technical needs [148, 150]. The ability to change and improve existing solutions by implementing technological innovations—in contrast to modifying new solutions to fit existing routines—may be a critical factor in the success of future healthcare organizations.

One possible value of recognizing healthcare systems as socio-technical systems is that new technology can be used to improve existing processes. The socio-technical theory assumes that the implementation of new technology is followed by social change. Furthermore, from a systems perspective, positive feedback loops may be identified and may strengthen the diffusion process of technology implementations and, hypothetically, also for the implementation of drones. The broader perspective of the system can also identify challenges and negative feedback loops that present potential barriers to the integration of drones.

A systems perspective also provides a space to create sustainable service concepts, such as the transport department rebranding itself as an innovation hub for logistics. Furthermore, transitions can be pushed in the desired directions by considering different aspects of the systems perspective. Socio-technical theory recommends that technological acceptance should not be accepted by default, but often asks for thorough management and leadership to be achieved.

The implementation of drones should include an evaluation of the acceptance of drone integration because assuming such approval by default may lead to later rejection (Paper 1). Supporting the more substantial transformation of multiple services beyond logistics offers a space to create sustainable service concepts and ideas with a broad perspective. Therefore, the implementation of drones should include an evaluation of public acceptance. Public acceptance and ethical considerations as part of the system development were identified in the scoping review (Paper 1) as socio-technical issues.

The objective of Paper 1 was to assess the value of taking a socio-technical approach. However, the applied search terms did not identify any studies that used the keyword “socio-technical.” Despite this, my overall interpretation of the findings is that although it is not necessary to operate drones, a socio-technical approach may help achieve a culture open to innovation and change.

In socio-technological terms, ethical considerations and public acceptance are highly relevant to the implementation of drones. The transport routes investigated at Oslo University Hospital are not complex and are not focused mainly on transport times (Paper 3). Substantial improvements should be realistic, with or without drones. Therefore, drones may represent a logistic solution with relatively little impact on organizational processes and may have little effect on other clinical services outside of the transportation service. Although diffusion across technological and medical processes may be somewhat limited, the roles of opinion leaders and change agents in the hospital system may contribute to the emergence of a consensus on various innovations [151]. The multi-level perspective approach makes it easier to find the level of intervention to implement niche technology with the most success.

Even if a socio-technical multi-level perspective combined with transitions research represents a powerful analytical force, it is not the only way to investigate changes. The multi-level perspective conceptualization was intended to broaden the understanding of implementing drones into existing systems. Several future research opportunities, such as the impact of drones on organizational processes and social dynamics in the adoption of drones, may expand the understanding of these questions and nudge transitions in the desired directions. Aspects such as the need to build a cross-cultural approach, cultivate a discourse among several stakeholders (Paper 1), and ensure optimal service design and technology acceptance (Paper 2) may strengthen the innovation process.

Drones in healthcare may have a higher public acceptance than in other domains [146]. However, the recent Australian study by Wiedemann et al. [152] found that, for example, privacy issues are still mentioned as a major concern for the general population. Additionally, emergency drones may be supported, whereas drones for transport may not. For the diffusion and acceptance of drones, the multi-level perspective in this thesis considers lead users, healthcare workers, and the public at the respective niche, regime, and landscape levels. Paper 3 and Paper 2 included healthcare workers and carriers at the regime level. For widespread adoption, public acceptance and support will be essential [147, 152, 153].

5.2 Attitudes of healthcare workers toward drones

An argument from a socio-technical perspective is that technology is never just technology, but that any implementation of new technology also entails social change [34]. Following the argumentation from Paper 2, that technology may be used as a tool to change and improve existing solutions may lead to questions about how much organizational change is desired or needed and to what extent technology can be used to generate change. Unfortunately, such questions probably do not have a general answer because they may differ between different settings.

However, an approach that has shown its usefulness in dealing with them is the multi-level perspective. The multi-level perspective may also be considered a component of transition studies that provide a holistic view of system changes, as the multi-level perspective requires the involvement of different actors and multiple interactions in a system and dynamic alteration at different systemic levels.

Systemic perspectives may facilitate exploring and understanding an organization's readiness before new technologies, such as drones, are implemented. The benefits of this exploration may be that current work practices are improved, in contrast to modifying new solutions to fit existing routines. This ability may be critical for future healthcare organizations to cope with technological change. Moreover, investigating the acceptance of this new technology and including all stakeholders are necessary measures to ensure the full potential of drones in the long run.

Opinion leaders and change agents may contribute to such an innovation journey. However, the improvement process may have to be tailored to the existing organization and culture.

Paper 2 found that the use of drones in healthcare is positively perceived in professional groups, ages, and locations and that the supporting factors for a positive perception of future technological transitions may be related to working in an innovative environment, having a leader who supports new ideas, and having previous experience with technological change. In our study, this was associated with the belief that drones will be used in future healthcare systems.

A possible interpretation of these findings is that to realize the optimal and extensive benefits of implementing drone solutions; the managerial approach should be open-minded, stimulate innovation, encourage experimentation, and support the necessary risk taking. Supported by the harvested literature, Paper 1 discusses how the creation and maintenance of links and networks between clinics, institutions and health systems may contribute to a broader diffusion of drones. Leaders should maintain connections and networks between the different dimensions of the system in such transition processes. It is generally accepted that innovative leadership and culture may possibly strengthen the acceptance and implementation of technology in a manner that shapes the organizational structure necessary to adapt to technological change.

These results confirm previous studies that have suggested that more experience leads to increased familiarity and the ability to learn about technology in general [154]. Furthermore, the experience and knowledge of early adopters/believers can positively contribute to the continued implementation of technology [155].

Although focusing on micro-level innovations may be crucial in the initial implementation phases, a systemic perspective may facilitate the integration of drones into the healthcare system by considering the entire process, encompassing social and technical aspects. This may help improve current work practices and maximize the long-term potential of drones.

5.3 Accelerated changes of drones in healthcare systems

Paper 3 advocates existing solutions being studied and improved. A socio-technical perspective may benefit such analyses because it suggests a broad evaluation of multiple interactions on different systemic levels.

At Oslo University Hospital, the ground transport that was studied was not primarily focused on transport time, but designed to maintain flexibility for laboratories that are carriers' customers. Implementing drones may require strict and timely routings with minimal deviations due to airspace and air traffic regulations. Flexible departures in the current system may violate such regulatory criteria.

From an economic point of view, the willingness to pay for drone solutions may be limited if existing ground transport and loading times are acceptable. Thus, the competitiveness of drones may be related to whether they have lower costs than the current ground transport system for comparable service times or real-time savings.

Paper 1 states that the institutional and clinical contexts in which drones may be a valuable medium for transporting biological material have not been extensively investigated. It is unknown whether the introduction of drones as a transport solution in healthcare will produce significant gains.

Furthermore, whether the implementation of drones for transport in healthcare systems will be primarily based on technical drone requirements alone or whether it will require specific organizational or system-related modifications needs further exploration [156]. For example, few drone studies have addressed the requirements for high-volume transport across larger healthcare institutions or time-critical transportation that requires extreme and regular uptime.

Optimal service design often starts by including stakeholders to shape the best environment for new solutions, thus strengthening the innovation process [157–159]. In this context, attitudes and culture among hospital employees in institutions that plan to implement drones as a future transportation option should accept this new technology.

The interview with the focus group interview with experts in relation to drones served as a means of sharing innovation knowledge [149]. The key point was to implement drones supplementary to conventional transport. This was a valuable add-on. Drones could be used for specific routes, i.e., during the night. Concerning the fact that drones can be expensive to maintain, the participants argued that traditional ground transport at night is also not cheap. Another option for drones outside of regular working hours could involve a collection site where samples could be received from a drone. Additionally, drones could be used for emergency sample analysis, which currently requires taxis.

The above discussions illustrate that drones are perceived as valuable in complementing existing ground transport. However, there is some tension in terms of challenging existing routines. Hospitals seek to improve existing routines that ensure quality through standard procedures and repeatable patterns. Routines in hospitals are at the core of many daily operations [160] and are often difficult to change. However, routines are sustained and evolve through the agency and choice of individuals [160].

Goh et al. [161] conducted an interesting study on incremental changes to work routines in healthcare systems. They found that personal innovation is critical in guiding all change processes in addition to leadership. In particular, users who engage in more exploration have a greater chance of determining which features of the system work most effectively in a given situation. Furthermore, the user experience and sense of control are higher when routine change is perceived volitionally compared to when change is imposed by technology. Technology ownership increases with the agency through innovative behaviors [58].

Based on the aforementioned, strengthening the agency of healthcare workers is an essential first step in creating ownership and increasing the control of technology-initiated change processes. In addition, it may be important to strengthen the understanding that one's own actions contribute to system innovation. Furthermore, insights from system innovation and socio-technical theories illustrate how these innovative healthcare systems can be established and nurtured [68].

5.4 Navigating transitions

Leadership is essential in innovation projects, as is the ability to think holistically and be open to new ideas. Paper 2 found that having a leader who supports new ideas is one of the drivers of the belief that drones will be used in future healthcare systems. However, professional roles during system changes are not well defined. For example, managers at the operational level may need to ensure efficiency, while managers at higher levels may promote the implementation of change and initiate change processes to ensure the legitimacy of the organization [162]. The complexity increases when multiple change contexts run simultaneously, whereby leaders may have multiple roles and be required to juggle operational and strategic goals.

The advantage of governing according to concrete and quantitative goals is the ability to compare, learn from, and compete against other institutions. This paradigm is called new public management. However, although new public management measures relevant goals and provides a helpful tool, it does not necessarily open up new ways of thinking. Instead, the focus is on improving existing solutions.

Networked governance seeks to control not through hierarchy or market incentives, but in a relationship with others and through collective learning [163]. In Norway, the networked governance model is called a trust-based governance paradigm.

Paper 3 considered the question of how much organizational change is desired or needed and to what extent technology can be used to generate change. Leadership needs to address such questions, and some leaders may be better suited to such tasks than others.

Manzini [164] created a mode map for designers that can be adapted to reflect the general relationship between problem, change, knowledge, and doing. The map is illustrated in Figure 5.1. Actors may consider themselves as problem solvers who are aware of the problem. They eventually try to learn from others how to solve the problem and are interested in change or actively working toward change as promoters of social innovation.

Rydland focused on the role of middle managers and developed a typology in which the Market Protector and Executor take a narrow approach to be change

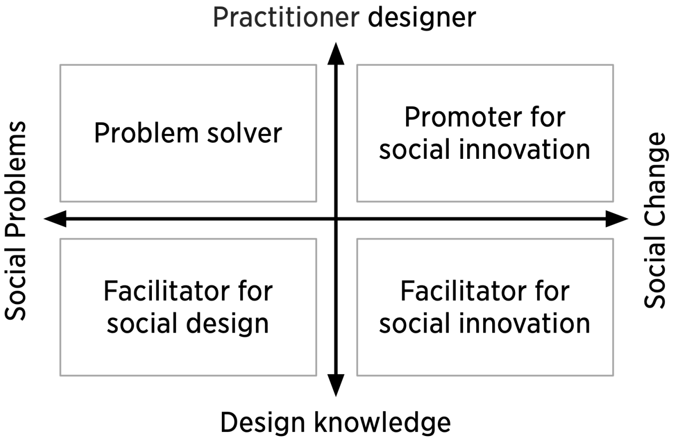

Figure 5.1: Typology of designer (adapted from Manzini [164])

agents, focusing on current customers or their team [162] (Figure 5.2). In contrast, the Renewer and Co-creator take a broader approach and emphasize the entire organization. Rydland argues that the Executor and Co-creator both perceive a need to challenge their mindset in the event of a change, whereas the Market Protector and Renewer do not perceive a similar need.

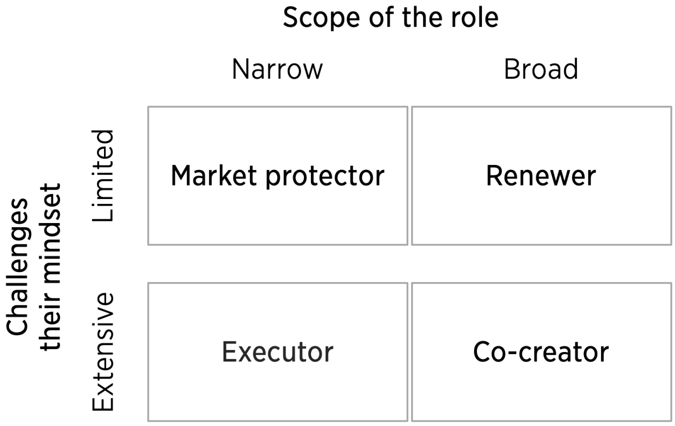

Figure 5.2: Typology of middle managers (adapted from Rydland [162])

As Sosa et al. [165] and Nelson et al. [166] suggest that designers can play an important role in change initiatives because they bring the creative agency to create new products and services or even design new socio-technical systems [29].

However, the agency of designers may still be limited in influencing change at the societal level. According to Gaziulusoy [167], one primary reason for this limitation is that short-term requirements informed by company strategies bound designers.

How much should designers control a design process? Coops et al. raised this question in a discussion among experts working in these fields on how design may evoke sustainability and transitions and transformations [168].

Designers may not be able to solve social challenges by themselves, and transdisciplinary ways of working and competencies are needed [169]. Furthermore, although a general design process may act as an underlay for bringing different practices together, it will not necessarily be the designer who will be in charge of what is being designed. Existing research gaps and transdisciplinary challenges require continuous collaboration and learning from each other.

5.5 Improving work processes

Improving the current work processes instead of modifying technological innovations to fit existing routines has been identified in the literature as a critical success point for sustainable healthcare systems (Paper 2).

From a perspective of technological determinism, technology is responsible for the outcome of a transition, and the existing social context is sometimes seen as a barrier that must be overcome. From a social constructivism perspective, technology is understood as a tool for shaping practices. Additionally, technological tools shape human behaviors and organizations. Therefore, social constructivism suggests being proactive and creating societies by deciding how technology can support humans.

The technological substitution process characterizes transitions as radical innovation [170]. Innovation competes with the existing system and replaces the old solution. Eventually, incumbent actors are replaced by new entrants. According to Berkers et al., [170], this way of conceptualizing innovation is often found in the literature [171–173]. The focus is on technical and business dimensions.

In contrast, the multi-level perspective broadens the analysis from a technological and business perspective to a socio-technical perspective, focusing on the wider processes in system innovation [72].

According to Geels [72], reconfiguration suggests that the institution, actors, and practices change during a sustainable transition, whereby old and new elements are combined to lead to gradual system changes.

Section 1.2.2 introduced the terms positive feedback loops (self-reinforcing) and negative feedback loops (self-correcting). According to most authors, this thesis has studied, positive feedback loops reinforce the direction of change [33].

In a positive feedback loop, innovative and supportive management, together with previous experience of technological change, strengthens the belief in technological innovations, in this thesis, exemplified by drones. Leaders who develop links between the dimensions of the clinic, hospital, and healthcare system can create additional reinforcing cycles, resulting in positive system effects. Facilitating experiments and establishing a culture that is open to change will, over time, generate an environment in which users adjust and accept technology and change. Leaders and change agents are necessary to create and maintain reinforcing cycles.

In a negative feedback cycle, a negative image of a new technology or system can discourage users from modifying their routines to accommodate the system. Lack of involvement and knowledge about the new technology may result in skepticism. Negative cycles ultimately lead to locked-in systems that are resistant to change.

Paper 3 suggests that laboratories are invited to participate in co-creation workshops to influence how the transport service should be designed. Furthermore, Paper 3 revealed that the transport department could rebrand itself as a hub of logistics. The visual observations presented in Paper 3 reveal that the transport boxes could be standardized. Therefore, they may be suitable for drone transportation and could score higher in terms of user experience.

In general, this will contribute to making the department more appealing to applicants. However, it may also mean that some aspects become redundant in the process. The optimized routing model theorized that the reorganization of routes could reduce the number of carriers and cars (Paper 3). In her keynote presentation at IST 2021 (International Sustainability Transitions Conference), Fuenfschilling argued that the “deinstitutionalization” of actors and/or processes could be uncomfortable, exhausting and emotional [174].

Optimizing services provides the opportunity to make them more efficient and streamlined. However, realizing that the technology itself does not determine this is essential. Instead, such processes can be constructed and managed so that they are not experienced as uncomfortable, exhausting, and emotional, but as a chance for improvement. The co-evolution comes from both the social and technical sides. Service design methods may bring people from different functions together and introduce them to new and exploratory learning situations [175]. For example, initial questions may ask, “Can the actors be removed, or their roles changed, to improve the user experience?”

In our studies, drones for medical transport are positively perceived in healthcare professions, ages, and locations (Paper 2). Furthermore, strengthening positive feedback loops and innovation can enable transformative change (Paper 1). In the short term, it is suggested that agency, drone experiments, and learning may facilitate incremental change (reactive change). Radical change may need to be avoided because the various lock-in mechanisms mean that drastic change has too much impact on established work processes. However, in the long term, a more radical fundamental system change may be obtained (Paper 3).

5.6 Contextual understanding

The reconfiguration path described may lead to more sustainable solutions and a more holistic context for future solutions. However, designers cannot force people to make changes they are not ready for, as Shedroff wrote in his book [176]. Instead, designers must understand their biases, preferences, and values. Furthermore, understanding the mission, culture, goals and vision of the organization makes it easier to act on the values and core meanings that enable and support them.

Healthcare systems are diverse. The impact of innovations can be difficult to predict due to the multiple dynamics of professional groups, policies, and opinions that tend to influence and be influenced by the system [25].

The extent to which institutions can recognize the value of new external information and then assimilate and apply this information is an interesting perspective that has been studied in innovation studies (i.e. [177]). Healthcare systems may need to build organizational capacity and the ability to handle change initiatives in addition to daily hospital operations.

Organizational learning can be described as the exploration of new possibilities and the exploitation of old processes. March [178] compared the two approaches and argued that exploring new possibilities is less specific, more distant in time, and more distant from daily operations. On the contrary, the feedback from exploitation is faster and more precise than that from exploration. Innovation journeys (i.e., the process from initiating to implementing an innovation) are, to a large degree, open and uncertain. They may have longer time horizons and more diffuse effects than the further development of existing ones. Therefore, the exploitation processes would appear to be more common [178].

Oslo University Hospital runs a continuous improvement network. This network is driven by change agents, who facilitate change initiatives in addition to their regular health-related work. The network organizes courses on facilitation and problem solving. Continuous improvement follows the cycles of Plan-Do-Study-Act (PDSA) [179]. In contrast, the multi-level perspective promotes system innovation. Continuous improvement compared to system innovation is illustrated in Figure 5.3.

The PDSA model is based on three essential questions: (1) What are we trying to accomplish? (2) How will we know whether a change represents an improvement? (3) What changes can we make that will result in improvement?

The answers to these questions depend on the complexity of the situations and the preferences of those doing the work [179]. In the multi-level perspective, learning is based on Kolb's experimental learning cycle [105, 180]. Cycles of thinking and action are stimulated by reflective thinking through a transformation of experience [180].

According to Matsuo et al. [181], Kolb's learning model corresponds to the Plan-Do-Study-Act (PDSA) cycle. Concrete experiencing is similar to doing, reflectively observing corresponds to studying, abstract conceptualizing resembles

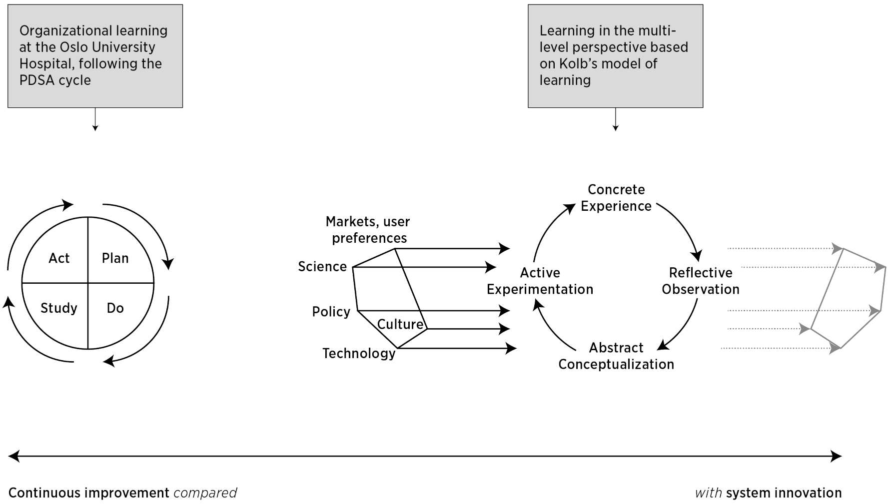

Figure 5.3: Continuous improvement corresponding with system innovation

planning, and actively experimenting parallels acting. The advantage of these similarities is that the process can be more easily understood and applied to facilitate experiential learning.

The size of the solution/learning space may be different in system innovation, and hospitals may not have the luxury of moving too far from daily operations (Figure 5.4).

Inspired by LEAN processes with the goal of creating value with less work, decision grids can be applied to judge ideas and determine which are the most likely to be effective [182]. Problems that make a major improvement and are easy to implement may be favored over wicked problems with the potential for a major improvement but are difficult to implement. Large learning spaces may be more familiar in design. Öztekin et al. argued that system innovation inhabits a similar learning space, in which problem and solution strive to be discovered [183].

Langley et al. [179] distinguished between reactive versus fundamental changes. Reactive changes keep the system of interest running day-to-day at the current level of performance, whereas fundamental changes create a new performance system. However, as Langley et al. argued, it is important to make reactive changes to remove any current problems until suitable fundamental changes can be developed to eliminate them completely.

The scope of a systems innovation project can vary. For example, it can range from a participatory design process to lay the foundations for system design and establish a shared vision to move the project forward [84] to a topic for the disciplines of transportation and urban planning [147]. The scope of this project was to investigate whether and how drones can become part of a future healthcare transport system.

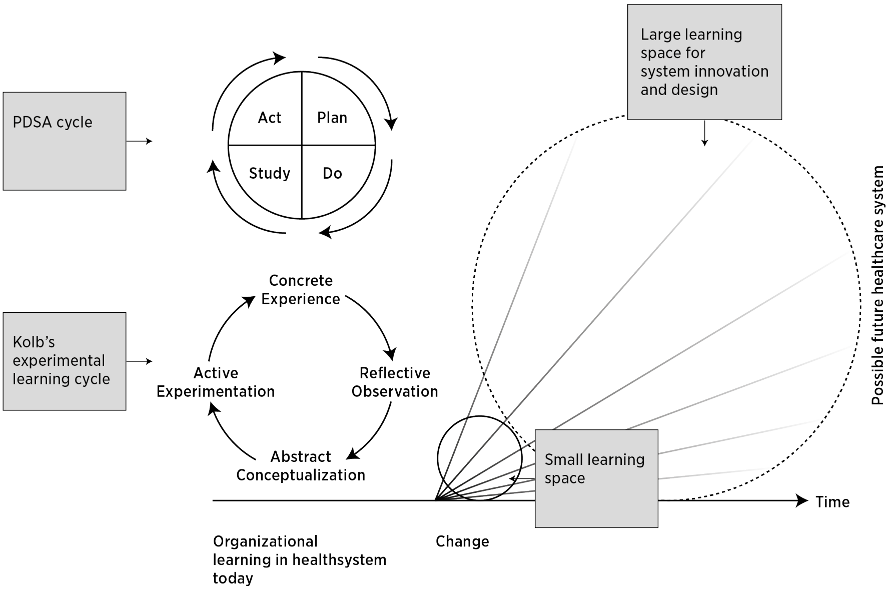

Figure 5.4: Organizational learning versus learning space

However, system change can be difficult because it involves a large number of goals and stakeholders. In addition, Clegg [73] claims that systems thinking is not universally agreed upon or observed in everyday practice. Furthermore, the idea that the designer should have all the answers and skills to solve wicked problem seems unrealistic, according to Thorpe et al. [184].

Shedroff suggests that each time a piece of the system is considered, there is an opportunity to transform that piece into a more integrated whole that meets sustainability goals [176]. For Clegg [73], system innovation needs to be made explicit so that it can be debated, challenged, defended, and improved.

Thorpe et al. [184] refers to DiSalvo et al. [185], Hillgren et al. [186], and Manzini et al. [187] who describe this design for social innovation as both a "process" and a "practice". A process to create networks and interactions of social actors to create and test systemic prototypes and address multiple goals and wicked problems. A practice in which designers apply their skills to the realization of devices and spaces that make it possible to continue collaborating.

Depending on scope and context, multi-level perspective and transition design can provide the tools to understand the process and practice to support system change. A designer may sometimes have a leading role as an expert in the system change, and other times may not have a leading role, but being a team member who can contribute with design knowledge [184]. Regarding self-reflection, a socially responsive designer may act to bring about societal change with the collaborators and resources at hand, settling for the best that can be achieved in a given context, according to Thorpe et al. [184]. However, from my own experience, this can be frustrating at times, but must be accepted when designing for system innovation where different stakeholders and goals need to be unified. On the other hand, the opportunity to define problems and possible solutions and to set the framework for the innovation project also provides a tremendous opportunity to be creative and work toward change with the available resources.

5.7 Research validity

In this section, the overall research is evaluated. Furthermore, the different validity claims introduced in Section 2.4 are discussed in relation to the findings.

5.7.1 Dialogic validity

I am the first author of the three articles included in this thesis and all have been peer-reviewed. All articles are indexed in PubMed. All journals are level 1 scientific journals [188]. Although two of three articles have been published in MDPI journals, I have experienced a well-organized and structured review process with the MDPI journals Information (Paper 1) and International Journal of Environmental Research and Public Health (Paper 2). Overall, this suggests that dialogic validity is high with respect to peer review and professional comments.

5.7.2 Catalytic validity

One limitation of this study is that drones have scarcely been used in practice and that the implementation of drones has mainly been discussed in theory. Additionally, analyzing the theoretical implementation of drones from a broader sociotechnical perspective has led to an analytical focal point. However, the insights of this thesis have generated specific findings that can be used to continue research and development on iterative innovation cycles. This suggests that the catalytic validity is high.

5.7.3 Democratic validity

Laboratories that analyze samples and carriers transporting samples have been included in the research investigation. Furthermore, important variables for integrating drones into healthcare systems among healthcare workers have been examined in the form of interviews and observations. The test flights also confirmed that, technically, the drones could fly efficiently between the National Hospital and Ulleval Hospital. One limitation of this thesis is that the laboratories did not participate in a co-creation workshop to design a drone-based service that would provide them with added value. This lack of involvement, for example, discussing clinical times and the need for flexibility concerning the strict time requirements from scheduled drone flights, shows limitations in terms of democratic validity.

5.7.4 Process validity

Concerning the research project, the initial theme was to ask relevant questions about the integration of drones into healthcare systems and identify how much drones impact institutional organizations. A broader system perspective evolved during the project and allowed the organizational consequences to be explored on a broader scale. Figure 2.3 shows the themes inside the plan–act–observe–reflect cycle.

The broader system perspective ensured that ongoing learning was supported. However, with the danger of moving away from the main interest of investigating the implementation of drones for the transport of laboratory samples, it was difficult to maintain relevance and not drift into other related topics.

An exploratory approach may produce less certain results. However, through collaborative data analysis sessions and discussions, this thesis has maintained a strong degree of relevance. Combining medical and healthcare expertise, design, and system theory with innovation and socio-technical theory was enriching. Furthermore, workshop sessions with bio-engineers, laboratory employees, and healthcare professionals allowed an abductive process that facilitated the creation of new knowledge and insights [189]. This suggests that the process validity is high.

5.7.5 Outcome validity

Internal validity

This thesis shows that minor organizational changes are needed to implement drones. However, the broader discussion in this thesis on innovative mindsets and drivers should be applicable not only to the implementation of drones, but also to technological innovation in general. The systemic perspective and combination of complementary methods suggest high internal validity.

External validity

This thesis has created various outcomes. However, the generalizability of the results is limited. The findings are restricted to a Norwegian setting and may depend on local cultures and environments. Furthermore, compared to other cities, Oslo may have shorter distances between the relevant facilities. In addition, entrepreneurship research has shown that decision-making processes are rarely based on systemic analysis [190]. However, this thesis provides useful information for the ongoing development of drone services as sustainable business models in similar healthcare contexts. This suggests that there are certain limitations to the external validity.

5.7.6 Construct validity

Construct validity in this thesis concerns the multi-level perspective, particularly how it can be applied in an innovation project.

Transitions imagine future system states that are more sustainable than existing systems. Scenarios for future drone-operated societies range from integrated and connected healthcare systems [191, 192] to speculative fiction [193], exploring social and political structures. The drone scenario in this thesis is built on the objective of having a more reliable, efficient, and qualitative transport service. Paper 3 found that the current laboratory system is based on flexibility. Therefore, this thesis has generated relevant questions that need to be answered by laboratories.

The multi-level perspective attempts to solve wicked problems [194], such as climate change, population growth, or inequality, from responsible production to sustainable healthcare systems. The wickedness of sustainable healthcare lies in the difficulty of predicting the implications of technological innovations [23]. However, despite the label “wicked,” such challenges are contextual and may be understood differently as underlying problems [195]. This leads to the dilemma of “solutionism,” i.e., because both a problem and a solution are presented, there is a suspicion that this represents a method trying to legitimize its own existence by constructing problems.

Wang et al. [196] criticized the multi-level perspective for its lack of actors and agency. Although research has addressed this issue, Wang et al. argue that this mainly covers the repositioning of actors. Another review by Kivimaa et al. [197] concluded that insufficient analyses have addressed what intermediaries (facilitators of innovation) do in the different phases of a transition, as well as how their roles change and what happens when a new system is stable and these intermediaries become redundant. Their review concludes that the often idealistic picture of intermediaries requires a more realistic approach and useful strategies for supporting system innovation.

The approach of this thesis has been realistic because concrete boundaries were applied in terms of the technology and system of interest. Although the multi-level perspective applies a wider learning space, this thesis found that learning corresponds to the methods used in healthcare. Overall, this suggests that the construct validity is high.

Chapter 6

Contributions and implications

This chapter summarizes the main contributions of this thesis and outlines its limitations. Although the research findings of this thesis are not generalizable, many of the insights may be applicable in other contexts and settings. Therefore, I conclude with some possible implications for leaders facilitators of change, designers, policymakers, and researchers.

6.1 Contributions

This thesis aimed to elucidate the essential dynamics of innovation on multiple levels and explore how the diffusion of drones could be strengthened. Because sustainable change may arise within systems, coordinating and orchestrating change processes are leadership tasks. This thesis advocates incremental change along a reconfiguration pathway. Furthermore, it advocates for the social construction of change.

The contributions of this thesis are twofold. First, the multi-level perspective was used to understand and learn about its application to an innovation project. Second, this thesis brought together the micro-perspective of drone development in the niche dimension and a broader analytical framework and mindset. The findings of the three articles published during this thesis and the previous chapter's discussion contribute to an increased understanding of a socio-technical approach to innovation projects. Furthermore, this thesis contributes to the more practical use of the multi-level perspective in similar innovation projects. The empirical and theoretical combination of quantitative and qualitative methods with a pragmatic approach has been fruitful in the pursuit of the research questions posed for this study and thesis.

Drones may have a limited direct impact on organizational processes. However, this thesis has revealed that the current ground-based system using cars in Oslo University Hospital is not ultimately based on transport times but on the flexibility required by laboratories. Carriers are asked to wait and postpone a certain departure, although this may cause a delay. Such flexibility is valuable for the requesting site. However, there is limited knowledge of whether this reduces the overall quality of service when all transport legs are considered as a whole.

The overall research question for this thesis is as follows: How can drones become a part of the future healthcare transport system? Drones in healthcare are perceived positively and therefore are valuable for envisioning future scenarios and improving current processes. Another contribution of this thesis is to show that technological innovations and system innovation approaches can be used for continuous improvement, thus facilitating technological and sustainable change.

6.1.1 Socio-technical reflexivity and sustainable change

Operationalizing the multi-level perspective has the potential to push system innovation to the surface. The professional network at Oslo University Hospital may promote transition design to facilitate technological change. Thus, transition design could become another tool of incremental change rather than a tool for radical system change [198]. However, socio-technical thinking is not widespread (Paper 1), and considering system innovation is primarily based on individual preferences. Therefore, identifying who may have a similar mindset may be a valuable first step in innovation journeys.

Paper 2 suggests that incentives for experimentation, learning, network building, and vision building are crucial elements in the push for change [57, 155, 199]. Furthermore, learning from innovation activities and innovation processes can lead to an understanding of how certain barriers may affect innovation activity [200]. Most importantly, Paper 2 found that previous innovation experience is a driver for the belief that drones could be used in hospitals. My results confirm those of earlier studies in suggesting that more experience leads to increased familiarity and the ability to learn about technology, in general, [154]. In addition, the experience and knowledge of early adopters/believers can positively contribute to the further implementation of technology [155].

The concept of sustainability itself is often ambiguous and controversial [105, 201]. Sustainable healthcare was described in the introductory chapter as economically sustainable, in addition to patient satisfaction, having sufficient numbers of health professionals, good equipment and good hospitals. Each of these criteria may be interpreted and weighted differently [22]. Therefore, system innovation for sustainability may be held back by the absence of shared visions [105].

Research on innovation places a greater focus on concretizing challenges. In particular, Schlaile et al. [202] and Uyarra et al. [203] suggest that questions should be addressed relating to directionality (what futures do we want?), legitimacy (why those futures and defined by whom?), and responsibility (transition by and for whom?). Geels and Stirling discuss the need to invest in experiments and learning to stretch existing routines and encourage reflexivity [105, 201]. This may also include critical questions, such as whether the public wants a regular drone transport service and what applications are acceptable in this case. Although critical social services such as healthcare, public transport and postal deliveries can be assumed to be prioritized, a public debate may be necessary [204].

6.1.2 The multi-level perspective as a tool and mindset

Whereas the multi-level perspective usually uses a top-down concept, Paper 1 discusses how the multi-level perspective concept can be applied in bottom-up change processes to produce fundamental change toward more sustainable healthcare systems. The concept is used here for continuous improvement projects. Various types of improvement projects are conducted in different clinical departments. Change agents may facilitate these approaches by initiating new technologies, ideas, or concepts. According to the multi-level perspective, the regime level is a guarantor for stability, characterized by different lock-in mechanisms. People may not commit to change because established technologies or processes are favored. Leaders are essential in explaining why and how these changes are being initiated [179]. The multi-level perspective stresses that a deep involvement is necessary to ensure the successful implementation of innovations.

The requirements created by innovations at the clinical level may spark responses at the regime level. Paper 1 claims that prompt up-front regulation could enhance innovations and actively drive new developments. However, a holistic perspective at the regime or landscape level may need supplementary or broader information than at the specific clinical level to ensure that stakeholders take an extended perspective. The institution may need to engage crucial interdisciplinary teams to provide feedback on consequences beyond the initial perspective.

Although Paper 1 specifically considered drones, a process that cuts across different users and levels in the system may be universal and applicable in terms of continuous and various day-to-day improvements. Leaders are essential in this process, because they create and maintain links between the different dimensions of the system.

Public acceptance and the social benefit of innovations effectively enable health policies. Policymakers have an essential role in recognizing and actively promoting niche innovations by identifying lock-ins and helping to remove them. Kivimaa et al. [197] concluded that policymakers could support change agents in maintaining a broader scope, creating space for niche activities, and simultaneously destabilizing existing regime structures. Creating an environment for trust may contribute an additional nutrient for the diffusion of innovation. Finally, by defining common goals and timely expectations, all stakeholders may work for a shared vision for a future system (Paper 1).

The multi-level perspective allows for social and technical shaping [205]. On this basis, Smirnov et al. [206] argued that a coordinated policy approach should account for social preferences but also support experimental engineering earlier rather than later. Referring to Chapter 1, this is related to bringing together the social and technical sides.

Although focusing on micro-level innovations may be crucial in the initial innovation phases, a systemic perspective may facilitate the integration of drones into the healthcare system by considering the entire process, encompassing social and technical aspects. This would help improve current work practices and realize the full potential of drones in the long run. Socio-technical systems do not work independently, but involve an interaction between technology and the user environment [205].

6.2 Lessons learned and limitations

This thesis was conducted at the point where innovation research intercepts design, technology, and healthcare contexts. The multi-level perspective framework was used as a holistic model to capture the complexity. System innovation can be studied by different disciplines and from multiple perspectives [105]. This adaptability makes the MLP highly flexible [207], but also challenging to find one's position as a PhD researcher. However, multi-level perspective is also very intellectually rewarding because it provides a structure to analyze, understand, and discuss the dynamics of change.

This thesis started with an open question about whether and how drones may disrupt organizational processes. Approaching this research project with a broader analytical perspective was valuable because it allowed us to investigate multiple queries and dimensions. However, drones may only have a limited impact on organizational processes [146], and behaviors may not need to change significantly to implement drones. The scientific articles in our study indicate that building a cross-cultural approach and establishing a dialogue between several stakeholders is necessary to develop a future sustainable healthcare system. It may be essential to note that one may not need the multi-level perspective to generate such a desired behavior. However, because multi-level perspective sets this behavior in the context of system innovation, it can contribute to understanding why this behavior is essential in innovation.

In general, the multi-level perspective may be more relevant in innovation projects that have a broader scope, such as *remote patient monitoring* or the *adoption of telehealth solutions*. However, because this thesis shows how the multi-level perspective can be applied, it may be valuable for other system innovation projects.

Referring to the literature in this Chapter 5, the concept of sustainability can be ambiguous and controversial. Furthermore, sustainability criteria may be interpreted and weighted differently. Although sustainability generally tries to balance economic, social, and environmental factors, the reality for many healthcare institutions may be that they are the first to withhold financial requirements. Oslo University Hospital has decided not to continue drone research because drones are currently not considered economically sustainable.

Most research studies have some degree of methodological shortcomings. Limitations are related to the theoretical and methodological choices made throughout the research process. Although the methodological choices are outlined and discussed in Chapter 3, I now emphasize the research process.

Based on the above evaluation, this thesis has validity limitations in terms of democratic and external outcome validity limitations. The research findings are not generalizable. Furthermore, regarding reliability, i.e., to what extent another researcher could have found similar answers, the interpretation of the data makes the results demonstrable and testable; however, they are not provable. Furthermore, the findings primarily apply to a Norwegian setting. Nevertheless, the general discussion may also be interesting for other structures.

This thesis has addressed contemporary questions that are hotly debated in the media and among healthcare workers. However, the purpose of this thesis was not to present all the arguments, but rather to illustrate the area of tension of which healthcare is a part. Therefore, the argument is that because healthcare is complex, the implementation of technology in healthcare systems is complex (wicked problem).

6.2.1 Implications for researchers

Systems innovation has increased interest in several disciplinary and societal fields to understand innovation systematically. However, there are many research gaps, and Geels has called for more research on the intersection between technical and social innovation and the further development of the reconfiguration pathway [72, 208], i.e., the complementary implementation of technological innovations.

6.2.2 Implications for leaders

Using socio-technical transition theories to understand innovation journeys is fruitful because it highlights the relations and interactions between multiple elements of the system. However, transitions can also happen independently. Systems have multiple feedback loops, and analyzing which relations and interactions influence specific outcomes may be challenging to comprehend.

Empirical contributions highlight that innovative leadership fosters innovation processes that support new ideas and provides space for experiments. Furthermore, this encourages the broader diffusion of drones, because each small interaction can add up to more significant system changes. These issues are highly relevant for leaders and change agents in hospitals in Norway and beyond, that is, how their interactions in the system contribute to overall system innovation.

- Maintain linkages and networks between the multi-level perspective levels parallel to clinic, hospital, and healthcare system
- Be open-minded, stimulate innovation, encourage experimentation, and support risk-taking, thereby
- providing positive effects for the belief in drones and adaptation to technological change

6.2.3 Implications for facilitators of change

System transitions are long-lasting and nonlinear processes; it is unclear who should lead them. Leaders have power, but are rarely neutral in decision-making. Internal or external change agents may be able to facilitate change projects, but roles can change and it is unclear who should be doing what in which phase. For example, when is it a good time to introduce system innovation?

Technical engineers may be occupied with solving specific problems, for example, a code that does not work and needs to be debugged. Designers may include other stakeholders and communicate with others, but do they have enough agency to establish change?

Eventually, innovation may be understood as an organizational commitment. In this form, innovation is defined not only as improvements in price and performance, but also as the creation of new opportunities, disruption of existing systems, generator of public enthusiasm, and builder of social and business coalitions that, in the long run, may support fundamental changes [209]. Recent research on facilitators in healthcare confirmed its importance for improvement work, but also identified a not yet established role that needs to be further strengthened [210–212].

- Improve clinical logistics
- Facilitate long-term processes
- Develop flair for a broader learning space

6.2.4 Implications for designers and niche entrepreneurs

Design plays a major role in the investigation, process, and results of system innovation [213]. New design disciplines, such as systemic design, design for sustainability, and transition design, create a new mindset in designers. Sustainable development implies a reflection on one's behavior, which may lead to reflective practices and responsible innovations [190].

The analytical result of this thesis is based on various findings and insights. Paper 3 suggests improvements to enhance the current transport of laboratory samples. Furthermore, Paper 1 covered the study by Cawthorne et al. [214], who used an ethical framework to design a drone to transport blood samples. Similar studies could be conducted to evaluate public acceptance and ethical considerations. For example, Keitsch [169] concluded that transdisciplinary collaboration could compromise different roles, goals, and responsibilities and that ethics practice could contribute to more transdisciplinary collaboration.

Designers are also experts in the processing of interactions by applying frameworks, methods, and tools. This knowledge and skills may be essential to support and accelerate innovation [215].

- Evaluate public acceptance and ethical considerations
- Reflexive design of products and services

- Application and demonstration of innovation processes that can be used to illustrate and implement innovation processes in society

Overall findings of this thesis reveal that leadership, interdisciplinary work, and collaborative communication are essential factors in innovation processes and that the reconfiguration pathway presents an alternative to technological substitution [216]. System innovation includes many social groups, reconfiguration processes can be difficult to steer, and results can be open and uncertain [72]. However, the reconfiguration pathway is useful for actors in different societal subsystems. Recently, it has been suggested, for example, for policymakers to initiate sociotechnical transitions [208], which indicates that actively promoting niche innovations by identifying lock-ins and helping to remove them seems to be a reasonable task for different stakeholders and professionals working toward sustainable societies.

Chapter 7

Conclusions

This final chapter presents the main conclusion and identifies possibilities for further research.

The primary research question asks if and eventually how drones can become part of a future healthcare transport system. This was carried out by answering three sub-questions:

1. How can current healthcare transport systems be understood as socio-technical systems?
2. What attitudes do healthcare workers have towards drone transport in healthcare?
3. How can drones be implemented in a future healthcare transport system?

The main conclusions are listed below:

1. Socio-technical system theory and the multi-level perspective provide tools for understanding and facilitating innovation processes.
2. In a broader perspective, drones can support the aim of having a healthcare system with good working conditions because they can be used in co-creation sessions to shape how laboratories want to work.
3. Drones allow for developing scenarios that invite user participation.
4. Currently, drones for laboratory logistics are not economically sustainable in an urban environment, but they can advance the sustainable goal of good equipment for transporting laboratory samples.

7.1 State-of-the-art and future outlook

Establishing and maintaining a culture of innovation is hard work. Change agents are important intermediates who work with innovation on a day-to-day basis. The important message in this thesis to healthcare leaders is to strengthen those roles and support this work.

This thesis turned out to be largely theoretical because it was based to a high degree on literature studies, partly due to the conditions and developments described in Section 2.2.4. Therefore, subsequent research efforts should investigate a more practical implementation, such as modeling sustainability transitions [217], designing routines with narrative networks [161, 218], or designing transition pathways [213]. According to Raghunatha et al. [219] especially early research within the theme of adoption is an important subject to address many of the uncertainties in the implementation of drones and system transitions.

The original intention for this thesis was to include a focus group interview. However, due to time limitations, only expert interviews were conducted. Future research efforts should validate the findings of this thesis by conducting focus group interviews. The study by Krigsholm et al. [74] may help plan such a study.

A recently published bibliometric analysis by Wang et al. shows that research efforts on the multi-level perspective are flourishing [196]. This is also the case for research on system innovation in healthcare. Johansen et al. explored transitions in Dutch healthcare [41], a recent study in Finland examined factors that enable innovation activities [25], and Marjanovic et al. [68] examined system innovation based on data from England.

Chapter 1 introduced system science and the holistic conceptualization of a solution space. Although this perspective can be beneficial, the focus on systems and structures may neglect what drives human actions and ignore that people have choices regarding their focus. For this reason, it is important to combine the multi-level perspective with other theories more human-centered. A promising approach combines the multi-level perspective with social approaches to plan and evaluate sustainable transitions [208, 220]. Future studies on drones in healthcare systems should attempt to understand the factors that encourage or prevent such an implementation, thereby understanding the resilience of human-centered healthcare systems and the changes triggered by technological innovations.

The multi-level perspective transferred to design may be a canvas for understanding innovation over time and how transitions could be harnessed to address complex problems [77, 221]. For example, insights from past projects could inform future visions and interventions in the present. Additionally, the multi-level perspective can be applied to analyze complex systems to discover, visualize, and design sustainable solutions.

System innovation does not provide ready-to-use practical guidelines. Therefore, it may not be directly applicable to practitioners involved in innovation projects who do not have an academic background, as Raven et al. points out [59].

An opportunity provided by this PhD project was to learn about the emerging research fields of systems innovation and sustainable transitions. For example, Sustainable Transition Research Network (STRN) was founded in 2009 and has grown from 200 members in 2010 to 1700 members in 2018 [222]. Although design networks and interactions with other disciplines have contributed to these research areas, the contributions of research and practice need to increase [83, 167].

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Paper 1

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Article

A Socio-Analytical Approach to the Integration of Drones into Health Care Systems

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Abstract: The integration of drones into health care as a supplement to existing logistics methods may generate a need for cooperation and involvement across multiple resource areas. It is currently not well understood whether such integrations would merely represent a technical implementation or if they would cause more significant changes to laboratory services. By choosing socio-technical theory as the theoretical lens, this paper intends to harvest knowledge from the literature on various organizational concepts and examine possible synergies between such theories to determine optimal strategies for introducing the use of drones in a health care context. Our particular interest is to examine whether the insights generated from the multi-level perspective (MLP) may have the potential to create dynamic spin-offs related to the organizational transitions associated with the implementation of drones in health services. We built our study on a scoping literature review of topics associated with the MLP and socio-technical studies from differing arenas, supplemented with studies harvested on a broader basis. The scoping review is based on 25 articles that were selected for analysis. As a way of organizing the literature, the niche, regime, and landscape levels of the MLP are translated to the corresponding health care-related terms, i.e., clinic, institution, and health care system. Furthermore, subcategories emerged inductively during the process of analysis. The MLP provides essential knowledge regarding the context for innovation and how the interaction between the different levels can accelerate the diffusion of innovations. Several authors have put both ethical topics and public acceptance into a socio-technological perspective. Although a socio-technical approach is not needed to operate drones, it may help in the long run to invest in a culture that is open to innovation and change.

Keywords: drones; socio-technical theory; scoping review; multi-level perspective; health care

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1. Introduction

As health care costs surge and the need for resources seems to exceed any realistic prospect of supplying them, new technological solutions are being pursued to save costs and reduce the need for specialized resources [1–5]. Among the strategies for reducing the cost curve that several health care systems are considering is improved transport and logistics using drones for multiple purposes.

There are multiple reports on drones in health care, ranging from search and rescue following natural disasters, drug and vaccine delivery in rural districts, the provision of care technology in emergency situations and the transportation of blood samples and organs have been studied [6–15]. Transport of biological samples across laboratories and institutions and of blood samples from remote locations to central laboratories has gained special interest [6,16,17] and promises faster and improved laboratory services by providing service to rural districts and enabling savings.

Drones may be a complete substitute for ground transport in areas where roads are non-existent for large parts of the year. Alternatively, drones may also be relevant as supplements to existing logistics methods, where they can be integrated into existing ground transport systems as an extension to provide last-mile or on-demand services to meet time-critical demands [18–21]. Such integrations may generate a need for cooperation and involvement across multiple resource areas, i.e., across medical, logistical, and transport workforces. How such processes should best be developed and implemented has not yet been studied extensively.

Another interesting topic is whether drones can be implemented in ways that have a broad impact on service and organization models. Creating support for the more substantial transformation of multiple services far beyond logistics offers a space to create sustainable service concepts and ideas with a broad perspective. There is increasing interest in how such extended integrations of drones in health care will interact with the social context of the human ecosystem of stakeholders and executing workforces [22,23].

Whether the implementation of drone transport will transform the laboratory services and logistics operations and health services [24], or if it is merely a technical implementation [25], is currently an unanswered question. However, implementing drones to create sustainability transitions in an extended perspective is a fascinating prospect that may require facilitating interactions between the realms of policy, economics, markets, culture, technology, and possibly public opinion.

Multiple theoretical models have been suggested for approaching such challenges, illustrating the multidimensional nature of sustainability transitions combined with the different aspects of structural change. Transitions for sustainability are goal-oriented with a specific purpose, and combinations of many “sustainable” solutions do not always offer obvious user benefits, as sustainability is a collective benefit. Challenges can present themselves during the process of both cultural and structural change: the existing, unsustainable systems may be fixed in place by various lock-in mechanisms related to the existing infrastructure, current competencies, and benefits for stakeholders, employees, and users, thus creating a dependence trajectory that makes it difficult to replace existing systems. Along with this broader definition of the problem comes a need for broader analytical perspectives [26].

Multiple models have been proposed as approaches to replacing and reconfiguring technological systems. For example, Hekkert et al. [27] described a technological innovation system approach from a multidimensional perspective but did not address structural change. The disruptive innovation approach of Christensen et al. [28] and the technological discontinuity model of Anderson and Tushman [29] are also helpful approaches but are mainly focused on the technology and market dimensions.

In contrast, Geels [30,31] and Geels and Schot [32] processed and refined the multi-level perspective (MLP) framework to explain how changes take place in socio-technical systems. As a follow-up related to drones, Haula et al. [33] suggested that “Interpreting drones through the lens of socio-technical theory, drones cannot be a standalone technological infrastructure but require an ecosystem to function optimally; humans to develop and manage them; regulations to protect the drones as well as people’s freedoms from infringement; and perform the necessary responsibilities they were built for”. This is an interesting hypothesis, although not further justified in their study. In addition, some of the previous statements on these topics may need modifications, for example, because future drones will mainly be autonomous, operated by remote systems with little need for personal attendance.

In our current context, we assume that drones are first implemented at the level of operational units (clinical units performing medical services, laboratory analysis, transport logistics) before generating innovations in a broader perspective at the institutional and health care system levels. The extent to which such use cases will require comprehensive organizational processes for implementation has not been extensively explored or understood. However, in designing the managerial policies related to drone implementations, it may be useful to profit from and build upon the experience of transformative policies in other areas of technology and innovation because drone solutions will combine several technological knowledge areas, such as software and hardware engineering, artificial intelligence, machine learning, internet of things (IoT) and logistical competence [34–36].

Based on a system design approach, we use the MLP [37] because it goes beyond studies of single technologies to focus on the various groups of stakeholders and their strategies, resources, beliefs, and interactions. We apply the MLP's micro (also called niche), meso (regime), and macro (landscape) perspectives and translate them into the health care context, where they parallel the levels of the clinic, hospital institutions, and health care systems in general (Figure 1).

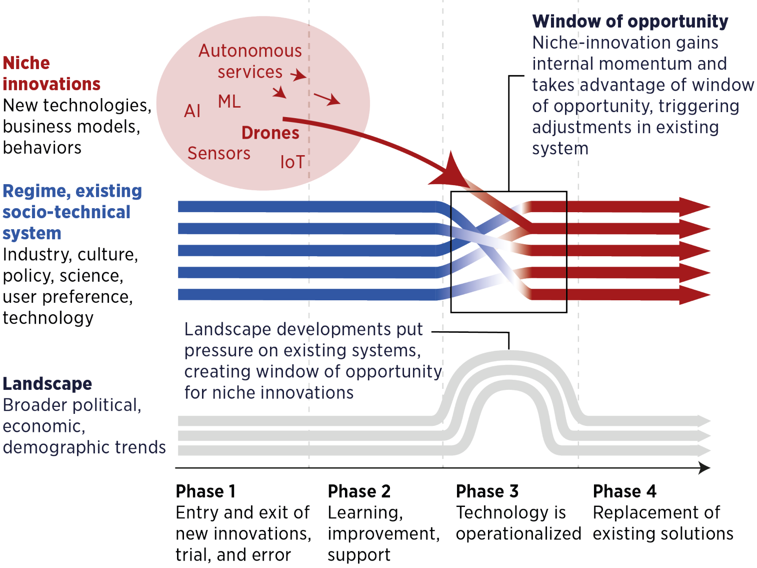

Figure 1. The multi-level perspective on system innovations (adapted from Geels [38]).

In this study, we examine whether the principles of the MLP regarding system innovations as merging transitions from one socio-technical system to another may offer a framework that can be helpful for understanding system innovations related to drones in health care [33,39–42]. By combining the three MLP, i.e., dimensions speed of change, size of change, and period of change [43] and the four MLP phases [42,43], i.e., introduction of technology within the existing environment, exploration of functionalities and user preferences, putting change into practice in daily operations, and gradual replacement of existing solutions, we examine the current knowledge regarding the implementation of drones in health care [42]. As we assume drones to be implemented in a "bottom-up" process, we use the levels in the MLP to sort out the various stages of the implementation of drones in health care systems.

Emerging technologies are usually influenced by the existing institutional solutions (in our context, hospitals), which operate in a stable configuration until a new technology emerges and creates an interplay of multiple technologies [37]. Compliance with legacy systems, as well as ethical standards and standards of clinical and laboratory processes, are crucial in such processes [44].

We believe that drones may be used efficiently for a multitude of purposes in health services, and we intend to harvest knowledge from the literature on various organizational concepts and examine possible synergies between such theories. We built our study on a scoping literature review of topics associated with the MLP and socio-technical studies from differing arenas, supplemented with studies collected on a broader basis. Our particular interest is to examine the potential to create dynamic spin-offs related to the organizational transitions associated with the implementation of drones in health services. The study is based on the following research question:

What knowledge of socio-technical theories may support an extended focus associated with implementing drones into health care systems?

The article proceeds as follows: in the next section, we introduce our scoping review method. In Section 3, we present the results and identify the categories of our research focus. Next, we use the clinic (niche), institution (regime), and health care system (landscape) levels to organize the literature, using a procedure related to the MLP inspired by Prayag and Ozanne [45]. In Section 4, we discuss our findings. Finally, in Section 5, we offer our conclusions.

2. Materials and Methods

Scoping reviews can be used to provide an overview of a given topic [46]. Furthermore, in comparison, for example, with systematic reviews, the review question can have a broader "scope" which is in accordance with the research aim of this study. This scoping review follows the approach set out by Arksey and O'Malley [47]. The framework consists of five stages: (1) identifying research questions and search terms, (2) identifying relevant studies, (3) selecting studies, (4) charting and analyzing data, and (5) collecting, summarizing, and reporting results.

2.1. Research Question and Search Terms

Based on the question "What knowledge of socio-technical theories may support an extended focus associated with implementing drones into health care systems?" we created three search concepts: "Drones, UAV, UAS", "Health care, Health Systems, System Integration", and "Transportation, Logistics, Innovation".

These terms were included in the search strategy because they define the context. Furthermore, "system integration" was included to cover integration from technical, organizational, and social perspectives. The search strategy aimed to identify the relevant literature concerning:

- The integration of drones into existing systems;
- Potential drivers of and barriers to the integration of drones;
- Prerequisites for the integration of drones.

2.2. Identifying the Relevant Literature

The literature search was conducted in March 2021 using the PubMed and Scopus databases and then supplemented with an additional snowball strategy to retrieve other relevant articles. Three strings were created with the operator OR and a combined search with the operator AND for the structured search. The list below displays the search strategy:

1. Drones OR Unmanned Aerial Vehicles OR Unmanned Aerial System;
2. Healthcare OR Health Systems OR Systems Integration;
3. Transportation OR Logistics OR Innovations;
4. 1 AND 2 AND 3.

2.3. Exclusion Criteria for Literature

Based on our primary interest in the use of drones to support laboratory services with a potential to extend such solutions in a broad perspective, articles that described the use of drones to capture images or video footage, their use in humanitarian response, or that focused on algorithms, physical drone parts, energy consumption, or carbon emissions were excluded.

2.4. Analysis and Charting of the Data

The technical process of analyzing the textual content was conducted using coding [48]. The content analysis software Atlas.ti (Version 9.1.3) was used as a tool to organize the data digitally. A first coding scheme was jointly developed by the authors and gradually adapted to the different categories. An inductive process allowed the codes to emerge naturally from the data [49]. Mayring [50] described this category development process as qualitative content analysis, in which categories emerge over incremental revisions and reductions of the categories while working through the text.

3. Results

The search of PubMed with the first, second, and third strings yielded 2101, 1,493,810, and 3,624,067 results, respectively. The combined concept search yielded 51 results from the years 2014 to 2021. After applying the exclusion criteria, a final sample of 29 articles was derived.

The search in Scopus with the three strings yielded 68,376, 504,787, and 1,418,049 results. The combined query yielded 67 search results from the years 2012 to 2021. After applying the exclusion criteria, a final sample of 49 articles was derived.

During the full-text review of the database results, 19 additional articles were identified for inclusion using a snowball strategy.

A total of 97 articles were included for full-text review. First, we scanned the text to identify articles that included the keywords “innovation”, “socio”, “culture”, “leadership”, and/or “integration”. This approach resulted in a sample of 30 articles.

Second, the three MLP levels were chosen to organize the articles. The two authors categorized the papers blinded to each other and finalized the results by consensus when initial disagreement occurred (five papers). The remaining 25 articles are the subject of this results section.

Figure 2 below provides a detailed outline of the document inclusion process from the scoping review.

The earliest article was from 2016, but 16 of the articles were published between 2019 and 2021 (64%).

Table 1 below presents the author keywords from the review sample. The analysis of the 92 keywords shows that 22% of the articles used “drone”, “drones”, “UAV”, “UAS”, “drone integration”, “drone communication” or “drone design”. In addition, 16% used terms referring to technology, 10% to health care, and 8% to logistics and transportation. The remaining 43% of keywords used were only used once. No specific keyword regarding socio-technical systems was identified.

Table 1. Keyword analysis.

Count	Percent	Keyword
20	22%	Drones (including UAV, UAS, integration, communication, design)
16	17%	Technology (including AI, IoT, Machine Learning, Blockchain, 5G, automation, innovation, and disruption)
9	10%	Healthcare (including laboratory, microbiology, health systems, and services)
7	8%	Logistics (including transport, delivery, and supply chains)
40	43%	40 unique keywords: open science; biobanking; iTRANS; bystander CPR RPAS; Canada; prehospital care; throughput; cell phone data; intelligent transportation systems (ITS) platform; learning health care system; community engagement; mobile microbiology; consolidation; policy; Danish public healthcare; remote medicine; surveillance; disasters; battlefield medicine; emergencies; massive open online education; emerging infectious diseases; medium access control; EMS dispatcher; noncommunicable diseases; energy efficiency; out-of-hospital cardiac arrest public access defibrillation AED; epilepsy; portable instruments; ethical framework; public access defibrillation; global health precision medicine; health applications; sudden cardiac arrest; telemedicine; automatic external defibrillation; United States; value-sensitive design (VSD); user experience; values hierarchy
92	100%	

Starting with the three MLP levels, ten subcategories emerged from the analysis. Table 2 displays a list of the articles included in this study, together with the corresponding MLP levels and subcategories.

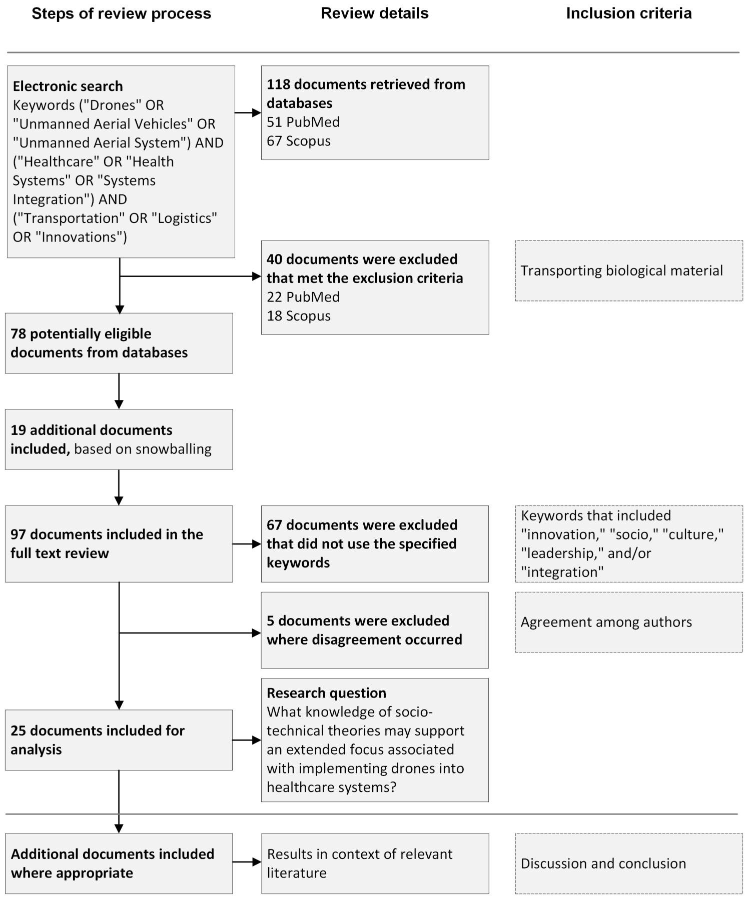

Figure 2. Document inclusion and exclusion process.

Table 2. Included articles.

Dimension	Category	Author
Clinic	Digitalization	Ferreras [51]; Gruson [24]; Vandenberg et al. [52]
	Integration of different technologies and services	Eichleay et al. [25]; Mishra et al. [53]; Ferreras [51]; Khisa et al. [54]; Syed et al. [55]
	Public Acceptance	Mion [56]; Zegre-Hemsey et al. [57]; Poljak et al. [58] Van de Voorde et al. [59]; Shawn et al. [60]
	Regulation/Legislation	Balasingam [61]; Braun et al. [62]; Nentwich et al. [63]
Institution	Integration challenges	Vandenberg et al. [52]; Flahault et al. [64]
	Facilitating innovation processes	Bhavnani et al. [65]; Mishra et al. [53]; Cawthorne et al. [66]; Mion [56]; Johannessen et al. [44]
	Collaboration	Ferreras [51]; Braun et al. [62]; Hiebert et al. [19]; Mion [56]; Truog et al. [67]

Table 2. *Cont.*

Dimension	Category	Author
Health care	Adoption	Mion [56]; Hiebert et al. [19]; Johannessen et al. [44]
	Diffusion/Acceleration	Flahault et al. [64]; Mateen et al. [68]; Mion [56]
	Change and transitions in relation to ethics	Faramondi et al. [69]; Cawthorne et al. [66]; Eichleay et al. [25]; Carrillo-Larco et al. [70]; Mishra et al. [53]; Greaves et al. [71]

3.1. Additional Documents

During our analysis of the documents and development of the discussion, we supplemented our literature review with further publications where appropriate, following a deductive identification of relevant articles. We included five additional recently published review articles [72–76], one essay [77], two online sources [78,79], and five research articles [80–84].

In addition, we identified eight MLP articles of relevance and included them in our discussion [26,30,40,85–89].

Even though the main arguments supporting the use of drones are their promise in terms of cost reductions, their ability to avoid ground traffic congestion, and their ability to maintain services in areas with poor transportation infrastructure and in hard-to-reach areas, only the review article by Hiebert et al. [19], among the articles identified in the scoping review, discussed these topics. We therefore specifically searched for papers dealing with costs and rural services to see if studies discussing perspectives related to our study subject were available and included four more articles [18,90–92] in addition to the study by Hiebert et al.

3.2. Descriptions of Findings

The descriptions of our literature findings are categorized according to whether they are concerned with the clinical, institutional, or health care system levels.

The Clinical Level (Niche)

The important topics discussed in these articles include digitalization as a driver of technological developments in general, the integration of drones related to their acceptance in public space and the role of regulation and legislation as enablers of future drone services.

3.3. Digitalization

Ferreras [51] discussed whether disruptive innovations involving robot vehicles supported by telecommunications or computers may be conducive to more efficient transportation and logistics solutions. From his perspective, drones represent an additional and new element in developing autonomous or semiautonomous vehicles, and there is substantial potential in their independence from heavy ground traffic and congestion.

Gruson [24] and Vandenberg et al. [52] discussed the digitalization and automation of laboratories. They provided an interesting perspective on the impact of technologies on laboratories. Gruson pointed out that integrating big data and real-time management, automation, blockchain, the internet of things (IoT), and the enhancement of the user experience are critical drivers for achieving “smart digital laboratories”. Similar factors may also be relevant to perspectives related to drone solutions. As with Gruson, Vandenberg et al. supported the conclusion that new IT platforms that support integrated datasets across primary and secondary care and measures of outcomes and costs across patient pathways are needed.

3.4. Integration of Different Technologies and Services

Eichleay et al. [25] focused on the implementation of drones in either parallel or integrated setups into existing structures and systems. They pointed out the dilemma that integration into existing structures may take too much time, whereas devising parallel technological systems may fracture health systems and cause informational and operational silos that may result in future inefficiencies. Furthermore, they also concluded that more information on what processes must be changed and how they impact workflows and health outcomes may contribute to the evaluation of sustainability and the actual cost of implementation.

Mishra et al. [53] considered various perspectives on integration synergies between 5G cellular systems and UAV technology. Their survey hypothesized that 5G technologies would enable seamless integration and UAV communication over mobile networks. Furthermore, B5G (so-called "6G") innovations may further enhance the performance and applicability for seamless integration of UAVs into mobile networks.

Ferreras suggested that the full potential of UAVs may be achieved with a combination of several technologies that need to be developed. For example, receiving constant location data provided by autonomous vehicles or autonomous drones in combination with powerful 3D computer visualizations could be used to build future computer interfaces for optimized transportation. In this transition, computer systems would move away from being human control-oriented toward being automated, and self-deciding systems [51].

The integration of UAVs with IoT networks was described as a new direction for research and industry by Khisa et al. [54]. IoT enables things to be connected anywhere, anytime, using any network, thus enabling almost any service. One of the most promising technologies for handling security-related issues in communication is the integration of blockchain with UAV-based IoT. Several studies have been carried out regarding the integration of machine learning mechanisms with IoT and UAV.

The versatility of drones and the potential to support different efficient solutions for smart transport applications were highlighted in the survey by Syed et al. [55]. For example, machine learning (ML) techniques, blockchain, or watermarking may alleviate security concerns regarding drones.

3.5. Public Acceptance

Mion [56] raised an essential question about public acceptance, pointing out that the general acceptance of new technological instruments is usually higher in the health care sector than in other domains, e.g., the application of drones in emergency situations such as the delivery of automated external defibrillators. The fact that drones may save minutes, which can save a life in critical clinical situations (Zegre-Hemsey et al. [57]), is observed as having high value for society and individuals, thus facilitating acceptance.

Based on case studies in Papua New Guinea, Asia, and Africa, a review by Poljak et al. [58] found that drones were generally well accepted. However, they concluded that more research may be needed to understand public acceptance in highly populated environments and high-density traffic airspaces. For example, Zegre-Hemsey et al. [57] suggested that as innovations in drone technology are entering emergency cardiac care [7,93], it may be necessary to explore ways to integrate drones into these environments.

The effect of the combination of purposes and actors involved on public acceptance was also discussed by Van de Voorde et al. [59]. Their article discussed how when police forces use drones for surveillance, regulations for safe and responsible handling of the drones and of the data they provide should not fall outside standard regulations. Relating this example to the transport of biological material, drones in this health care setting may have a higher chance of being accepted. However, at the same time, the proper and secure handling of patient-related data must be guaranteed.

The impact of increasingly demanding patients who expect the same level of innovation, service, and quality from health service providers that they see in other service sectors, such as online shopping, travel, and media, was discussed by Shawn et al. [60]. Consumers profit from being able to choose how their care offering is provided and can pick between different delivery models, including home health, concierge care, and online self-help. These new channels offer consumers qualities they look for from other service providers, such as convenience, thoughtfulness, timeliness, value, and price transparency [94]. Such qualities may contribute to the acceptance of drone services.

Public acceptance and social benefit may act as enablers for policymaking regarding drones [59]. It may, therefore, be essential to understand public acceptance when new environments are being explored.

3.6. Regulation/Legislation

Several authors have discussed the challenge of national legislation. Balasingam [61] argued that the lack of timely legislation often forces organizations to apply for exemptions, hampering the progress of technological innovation. According to Braun et al. [62], the pace of drone design innovation generated by new applications places considerable demands on governmental and local regulatory agencies, which are not always able to keep up with the pace of innovation [95].

Such regulatory lags due to slow adaptation to new technological options were also discussed by Nentwich et al. [63]. The consequences related to new technologies and rapid developments such as drones are that barriers to innovation are created, i.e., autonomous drones could not previously be licensed under existing regulations. As a remedy for this discrepancy in regulatory speed, Balasingam suggested that the stakeholders involved in the medical and drone industries, insurance companies, legislative authorities, and government bodies should work together and develop prompt legislative solutions to integrate drones seamlessly into our communities [61].

It is interesting that although they were published only a few years ago, the findings of several of these papers have fortunately become outdated because proper regulations are being put in place in both the US and the EU [78,79].

The Institutional Level (Regime)

Integrating existing services and collaborations between various stakeholders at the institutional level may be essential to analyze and understand how long-term improvements and value creation should be achieved.

3.7. Integration Challenges

A perspective discussed by Vandenberg et al. [52] is how the introduction of laboratory automation and the linkage of information systems for big(ger) data management, including artificial intelligence (AI), may also strengthen drone implementations. However, they pointed out that the initial optimism associated with these developments has entered a more reality-based phase of reflection on the significant challenges, complexities, and health care benefits posed by these innovations.

Parallels between the integration of different technology systems in general and the implementation of drones were pictured by Flahault et al. [64]. They described the impact of a future health system that connects personal, provider, and population-level health information. This would provide feedback loops on many levels, thus creating computer-supported mechanisms for learning and improving the quality of the overall health system. They describe drones as an exciting example of possible interactions and cooperation between technological sectors both within and outside the health system.

In their scenario, most of the building blocks for learning health care systems exist but are insufficiently connected because of many weak links:

- Integration requires unprecedented levels of interoperability * and standardization;
- Implementation faces many technical and organizational challenges and raises unsolved ethical, legal, and societal issues;
- Impact on health outcomes is difficult to measure and has been poorly addressed so far.

* Interoperability is concerned with the ability of different systems, devices, applications, or products to connect and communicate in a coordinated way without any effort

from the end-user. Functions related to interoperability include data access, data transmission, and cross-organizational collaboration, regardless of developer or origin [54].

3.8. Facilitating Innovation Processes

Facilitating innovation processes may require leaders who know how to combine internal innovations with the capture of new ideas from outside their organizational boundaries. For example, Bhavnani et al. [65] argued that open-access and big data analytics are often developed outside of conventional medical and clinical arenas. To access this knowledge, fundamental changes to clinical teams' internal structures and composition may be necessary. For example, successful research teams should perhaps include clinicians and team members with expertise in big data analytics, bioinformatics, technology, engineering, health care administration, business and entrepreneurship, and health care policy. A cross-cultural, cross-competence process must, therefore, be developed.

Arenas for innovation may give the drone industry and others the potential to learn from each other, as a survey by Mishra et al. [53] suggested from a drone industry perspective. Their survey concluded that manufacturers in the drone industry are not exploring emerging technologies such as IoT, AI, and AR/VR sufficiently. Consequently, they do not fully appreciate which use cases would be interesting to roll out. Mishra et al. hypothesized that the skills needed for the drone industry will include sufficient domain training for equipment providers and technical users because it is necessary to extract users' specifications and requirements to maximize the benefits of the various use cases and generate drone applications.

The extent to which users are enabled to present their needs, specifications, and requirements in early innovation phases is another issue. Cawthorne et al. [66] proposed an ethically based design of drone prototypes to examine the public acceptance of health-related drones. Mion emphasized that organizations that intend to use drones for transport must be open to change and prepared to modify their operations [56].

Johannessen et al. [44] concluded that it would require extensive research to understand how best to engage clinical and laboratory leaders and managers in actively facilitating long-term improvement processes to optimize drone transport solutions. They highlighted the relevance of well-known specialized methods that focus on looking for waste in production processes to improve workflows and create more value with less effort: the LEAN method (originating from the Toyota car manufacturing system) and Six Sigma (originating from Motorola). Although the experience of implementing such organizational processes varies from successful improvements to processes to cases in which implementing LEAN in clinical cultures has sparked challenges that are more demanding than would have been the case with the implementation of the typical methods used in the industry, the generic concepts from the domain of industrial improvement techniques should be considered [96–104].

3.9. Collaborations

The recognition that successful integrations of technology generally require collaboration between professions that need to work together may also apply to drones, as suggested by several researchers [19,51,62,67]. They all recommended that authorities, leaders, and community representatives should be involved in this perspective and pointed out the importance of engaging a broad range of users to promote the development of health-related drone applications.

A review by Hiebert et al. [19] discussed how a range of health and digital proficiencies may support sustainable integration into health care services. Community engagement should include a broad spectrum of activities throughout the design, testing, development, integration, and evaluation stages of new technology program development. This was also supported by a report from a drone project transporting blood and pathology samples between two hospitals in Switzerland [56]; in addition to the public acceptance, regulatory framework, and risk management dimensions, it was concluded that involving the top managerial level is of crucial significance.

The Health Care System Level (Landscape)

On the overall health care level, important topics may include the adoption of technology, the broad diffusion and coordination of innovations, and acknowledgment of the characteristics of change and transition processes in such complex sectors that are subject to regulations, ethical standards, and responsibilities that are far beyond the traditional industrial perspectives.

3.10. Adoption

Regarding health care's implementation of technology in general, Mion [56] suggested that effective implication of new technologies requires careful consideration of whether the solutions improve patients' overall quality of care. They considered both the policy and operational frameworks to be highly significant for adopting new technologies and avoiding obstruction. Furthermore, public acceptance and other sociocultural factors may affect the adoption of most technological innovations.

In their review paper, Hiebert et al. [19] suggested that there may be significant negative implications for the development of health care drone applications if they are driven only by those engaged in computer and software engineering, computer science, and aviation without significant input from health care researchers or professionals. They suggested that representation from the various technical disciplines should be orchestrated in close alliances with nursing, public health, medicine, paramedicine, aviation, kinesiology, and pathology.

A perspective that conceptualizes the interplay within the technology-organizational-environment framework (TOE framework) was depicted by Tornatzky et al. [105]. They described the innovation process as either "developing" or "using", indicating that the innovation generation and adoption processes differ considerably. In some cultures, there may be an ambition to extend new technologies to a broader innovative culture. In contrast, other cultures appear to implement new technologies mainly by fitting them to existing solutions. Therefore, the TOE framework may offer factors affecting the adoption of technologies to improve health care logistics processes when applied in a health care logistics setting. The TOE dimension related to drone implementation was discussed in the context of a logistic drone model by Johannessen et al. [44].

3.11. Diffusion/Acceleration

The MLP argues that a wider diffusion of niche innovations may only be achieved when linked to the ongoing regime and landscape processes [88]. This was the focus of a paper by Flahault et al. [64] regarding precision medicine. They discussed how better targeting of public health interventions, even on a global scale, through innovation and technology should be targeted to maximize the effectiveness and relevance of multiple topics such as the use of remote sensing data to fight vector-borne diseases; the use of large databases of genomic sequences of foodborne pathogens to identify origins of outbreaks; the use of social networks and internet search engines to track communicable diseases; the use of cell phone data in humanitarian actions; and the use of drones to deliver health care services in remote and excluded areas. Moreover, they illustrated how technological solutions may often be spin-offs of inventions initiated from specific targets, showing the value of the expansion from the niche to the landscape level.

A paper by Mateen et al. [68] suggested that education and appropriate training of personnel, instructions to ensure proper maintenance, monitoring in-flight performance, and awareness campaigns are critical factors to consider ensuring that the full potential of drone delivery systems is reached.

This is also in line with an article by Mion [56] that described vital factors from the experience of integrating drones in Switzerland. They focused on the value of integrating such new technologies with organizations' business models, making it the ordinary way of working in the future. However, the impact of drones in the Swiss case had only a limited impact on organizational routines.

Several studies mentioned above may not have considered that future drone solutions will be unmanned autonomous vehicles. This indeed implicates the complex integration of different technology systems, but whether extensive personnel training is needed may be less obvious. The extent to which personnel resources are needed in future extensive drone traffic remains to be studied, and this may influence whether drones as a service will represent a transportation solution that must be delivered as a complete service where the provider operates all parts.

3.12. Change and Transitions in Relation to Ethics

We have hypothesized that a socio-technical approach may be helpful in the process of implementation of technology, as it highlights the importance of using technological transformation as an opportunity to improve processes by combining organizational and technological needs.

Multiple learning points from technological implementations have been described by Faramondi et al. [69] in their discussion of the interplay between different cultures and professional competencies. They argued that the digital transformation of companies is only deemed innovative and useful for creating novel business opportunities and improving efficiency if the company also improves its financial and innovative performance in general, thus illustrating the value of extended implementations of specific solutions.

In laboratory services, methodological concepts, such as sample collection decision support systems, innovations for automated robotic phlebotomy, novel sampling technologies such as fully traceable automated blood tube dispensers, and algorithms that detect sample collection errors, have been proposed to enhance patients' quality of care and the efficiency of the health care system. Whether such solutions result in an improvement of the quality of specimens and minimization of harm is still to be documented [71,80–82].

Although one of the key strategies of the MLP is to stimulate learning processes, it does not explain how to facilitate these processes. Faramondi et al. [69] and Cawthorne et al. [66] proposed different frameworks. Faramondi suggested using a "value proposition canvas" (VPC), a concept initially developed by Osterwalder et al. [106], as a part of a business model canvas. VPC is conceptualized as a framework to ensure that there is a fit between a product and its customers. The VPC is used to highlight the beneficiaries (usually multiple) of a new product/service and the gains and pains provided by the new product/service to each beneficiary or others in general concerning alternative products (if any). By adopting this canvas model, the authors intended to assess the value of a proposed system to multiple beneficiaries, distinguishing between the economic, environmental, and social aspects of the system and their respective implications. Faramondi et al. provided two illustrative examples in the form of a scenario with and without drones where the drone scenario was analyzed using the VPC and summarized in a SWOT analysis.

Cawthorne et al. [66] suggested using an ethical framework for the emerging domain of drones in health care. They assumed that, ideally, drones will be beneficial (in terms of costs, health, jobs, and environmental sustainability), do no harm (in terms of safety and security, privacy, and jobs), enhance human autonomy (trust), be just (fairly distribute benefits and risks), and be easily understandable (explicable). Based on their framework, they proposed that drones conducting transports of biological material should be identifiable in parallel to ambulances and emergency services; for example, they could be marked with a red cross, indicating that they belong to the health services.

The suggestions by Faramondi et al. and Cawthorne et al. to look beyond technology are interesting because both authors propose approaches to learn from stakeholders. The approach by Faramondi et al. presents two well-known tools that can be used to map dimensions and learn from different stakeholders. The design suggested by Cawthorne et al. may be used to build a prototype that can be used to learn about the public acceptance of health-related drones. However, neither suggestion is based on a starting point of a deeper understanding of user and institutional needs.

A potential gap in the understanding of how drones can be integrated into the health system and how long-term sustainability should be achieved was discussed by Eichleay et al. [25]. They suggested five general steps of value in this respect: drones will need to operate within regulations, stakeholders must embrace the drone concept, financial resources need to be available, human resources must be in place, and operational procedures must be developed to work effectively within existing structures.

These steps, although based on interviews in Kenya—and thus possibly reflecting perspectives different from those of systems elsewhere—seem obvious for any system, although their argument that starting conversations about potential UAV integration and interoperability of systems in early phases is key to efficient system design and may have varying degrees of relevance in the drone context.

The topic of ethics has also been discussed by Carillo-Larco et al. [70]. They asked whether the innovative and constantly evolving nature of drone use may spark ethical challenges and suggested that ethics committees need to be aware of what permissions or regulations there are to operate drones in each area to ensure that all requirements are met. This was also discussed by Cawthorne et al. [66] in their reference to Van den Hoven et al. [107] that "technical innovation can entail moral progress . . . (because) it enlarges the opportunity set by changing the world in such a way that we can live by all our values". However, "new options also bring new side-effects and risks", which must be managed.

Mishra et al. [53] also raised social concerns. The operation of UAVs must be adequately regulated to protect the privacy of business organizations and individuals. The existing regulations to protect privacy may not be sufficient due to the rapid evolution of UAV technology and its increasing capabilities; therefore, there is a need to formulate further legislation to protect privacy.

Drones for Remote and Rural Services and Cost Perspectives

Among the rich literature on the cost of drone services and the use of drones for remote and last-mile delivery services, the review paper by Hiebert et al. [19] identified 20 articles that discuss the ability of drones to improve the response time of emergency services due to their ability to fly above roadways, water, and forested areas and 12 reports that discuss how drones may be used to improve access to health services in difficult-to-reach areas. These studies described four overarching topics: health applications; the benefits and costs of drones; the factors influencing use and performance in sociocultural contexts; and community engagement and sociocultural contexts as key factors in tailoring new use of drone technologies to health systems. These studies noted the importance of working with diverse stakeholders (e.g., medical and drone industries, insurance companies, pharmacies, retail outlets, entrepreneurs, legislative authorities, and other policymakers) to successfully integrate drones into health systems and pointed out that there is limited literature on how drone applications may influence patient groups and communities, raising the question of for whom drone applications in health care are being developed.

In a recent review, Nyababa et al. [91] summarized several studies of the socio-technical debate on the drone delivery of medical supplies in Africa. They concluded that in the African context, the implementation of medical drones will revolutionize health care delivery systems, particularly for rural communities that are hard to reach during health emergencies due to poor road infrastructure, thus improving access to health care. Interestingly, they pointed out that the adoption of drones in the medical sector in Africa may be an example of what is known as "leapfrogging", that is, when developing countries skip the gradual process of technological evolution and adoption seen in developed countries and leapfrog over these gradual steps to the rapid adoption of novel devices and systems. However, they noted that the initial cost of implementation of medical drones is usually high, thus implying that the adoption of medical drones in Africa is likely to be a long-term process, as it will take a considerable time for the benefits of drone implementation to make up for the implementation costs, depending on the size of the population that will be served.

Müller et al. [18] did not study health services but discussed the MLP in relation to the mutual interdependence of transport systems during their development and the significance of the interaction of the transport systems' evolution with the socio-economic landscape. They concluded that the landscape comprises deep structural trends such as economic development and social paradigms, where several trends put pressure on the regime, slowly or spontaneously, resulting in the need for the dominant technology regime to adapt to the pressure. This techno-economic pressure is related to disruptive innovations, implying new paradigms that change labor skill profiles, demand patterns, the competitive base for companies' products, and production methods. They concluded that the landscape may generate remarkable pressure to modify the regime's innovation pathway, resulting in the inclusion of techno-economic pressures in the industry regime's incremental innovation pathway.

Zailani et al. [92] compared the costs of drones versus ambulances for transporting blood products to treat maternal obstetric hemorrhages in situations with challenging terrain and traffic flow. Their economic evaluation concluded that although drone transportation of blood products costs more compared to ambulance transport, the significantly reduced travel time offsets the cost. From an economic viewpoint, they concluded that drones are a more cost-effective and viable mode of blood product transportation, particularly during emergencies. The findings of this study add to the body of knowledge pertaining to the cost-effectiveness of drones as a vehicle for health care service delivery where delivery time is of crucial importance.

The review paper by Ling et al. [90] discussed the use of aerial drones for various purposes, such as blood delivery, medical device delivery (automated external defibrillators), and medication delivery, and concluded that aerial drones promise improved health care delivery by providing faster response times, reduced transportation costs, and improved access to medical products/services in remote and/or underserved environments. These are all factors that may be conducive to public acceptance of drones.

4. Discussion

The development of drones in health care will migrate from technological and medical environments into institutional applications for various purposes and may thus have an impact on the entire health care sector. The broad perspective of applications is illustrated by the span ranging from drone delivery of medications [74], emergency transports of blood products in maternal health care [76], and not least the extensive use of drone services to combat the COVID pandemic [75,84]. The scientific articles in our study indicate that it is necessary to build a cross-cultural approach and establish a discourse across several stakeholders to develop a sustainable future health care system. Based on our analysis of the literature, we believe that drone implementations may benefit from considering various organizational and societal topics. Although the extent of the implementation and the value created may differ across various health care systems, geographic localizations, and organizational environments, and the methods for successful implementation may differ from one context to another, we propose that some basic topics should be studied and properly understood regarding the added value that may be achieved if drones are appropriately integrated in an extended perspective.

There seems to be a solid consensus in the literature on the importance of public acceptance. Several researchers have focused on the value of communication between stakeholders across and within systems and have looked at this issue from a socio-technologic perspective, arguing that a holistic understanding of how the adoption of various drone applications may impact a community is necessary. This is a significant concept for the MLP method, which is aimed at building a universal understanding of and implementation approach to disruptive technologies.

Hiebert et al. [19] found the following arguments in favor of community engagement: community understanding and buy-in, ensuring relevance, and increasing sustainability through local control. Furthermore, information about community needs can guide policymakers and decision-makers to properly integrate drones. Agency, understood as the ability of actors to intervene in and change system innovations, is another important concept in understanding the MLP framework [40].

The large diversity of opinions in the public perception of drones is illustrated by the distance between a report by Truog et al. [67] from Malawi, which described how community leaders were afraid that autonomous drones could be perceived as something unnatural and possessed, and our own research at Oslo University Hospital, where we have found that the use of drones in health care is seen positively across professional groups, ages, and locations [83].

Because community perceptions are heavily influenced by culture and prior experience, the response to the use of drones in each local system will reflect the local beliefs, practices, and attitudes of that area. Such responses should not be considered generalizable within or across countries. Governments, drone companies, and implementing partners should assess community perceptions of drones when proposing activities in new areas where attitudes and preferences are poorly understood.

The consideration of ethical questions is essential in this context and has been addressed by several authors. A review by Wang et al. [73] concerning the use of drones for humanitarian services identified several critical areas of concern, with minimizing the risks of harm and protecting privacy appearing to be the most critical points. However, they concluded that ethical conflicts may emerge in the shift from humanitarian drone programs to commercially available drone delivery services. Furthermore, such transitions may reshape issues related to data management and security, control, and responsibility.

4.1. Future Actions: From the Clinical to Institutional Level—The Proof of Concept?

Clinics are one of the most crucial loci for technological innovation. Clinicians and others with innovative mindsets try continuously to solve problems by experimenting, combining, and testing new approaches and tools. In parallel to this, we assume that the process of drone solutions begins with someone launching the idea as a way of transporting biological material. Drones promise a substantial opportunity to interact with other environments, both within and outside the health system [64]. An active innovation policy may enhance such developments, where new knowledge is explored and exploited in a positive feedback loop.

How Does the MLP Concept Apply to This Process?

As we assume drones to be implemented in a "bottom-up" process, we find the three MLP dimensions speed of change, size of the change and the four MLP phases of implementation MLP interesting to guide the process. The MLP argues that landscape pressures create "windows of opportunity" for niche technologies to emerge. However, the starting point of pressure may often come from below, from the niche of "clinical" environments that create innovations in daily practice originating from dynamics in ordinary activities and challenges, such as producing, promoting, adopting, and aligning technologies; cultivating novelties within existing regimes; enlisting users and making them available for integration into practices [89]. Nevertheless, the MLP theory may also be used to understand such processes as the creation of pressures and windows of opportunity at the landscape level.

According to the MLP, innovations are strongly influenced by existing regimes and landscapes. New technologies fit into existing regimes. However, over time, new functionalities, forms, and design options are explored. The co-evolution of form and function may lead to a wider diffusion, adaptation, and new socio-technical regime [30]. However, this process may take time and depend on previous experience with integrating technological knowledge [86]. The MLP suggests that experimental projects help work toward long-term change, fostering learning processes and institutional change. Furthermore, while policymakers can facilitate learning and network building, niche actors may decide the process [87].

An essential element in the MLP is that technologies are introduced into social and economic systems and thus embedded in an "extended universe" where understanding the effects of innovations and changes in systems is necessary. The challenge for innovation not only rests on economic potential but also on the societal changes induced by innovative activity and environmental and social sustainability consequences. Along with this broad framing of the problem comes a need for open-minded analytical perspectives [26].

The institutional level refers to the existing system, which is a guarantor for stability with established structures, rules, and groups of actors. Such systems develop over time, which can make them resistant to change. The MLP refers to such resistance as lock-in mechanisms related to needed changes to established work processes or to the replacement of technical tools or approaches and suggests that technological innovations may divide the audience into enthusiasts and skeptics, early adopters and the fearful, and the curious and the indifferent [56]. However, from a socio-technical perspective, the challenge may lie not in people supporting or opposing the new technology but in a lack of concordance between the requirements of the technologies and the practices that people perform and have developed over time [89].

MPL stresses that the success of an innovation depends substantially on how it becomes integrated into existing systems and technologies and on the extent to which it is approved and fits within regulatory frameworks. Proper integrations developed by deep involvement enforce acceptance by users and society at large [77]. Furthermore, public acceptance and the social benefit of innovations can enable health policies.

Innovations are created through the interactions between technological, social, economic, cultural, and political aspects [77], and technological innovations may be unpredictable for many reasons. Therefore, if and to what extent drones impact structures in laboratories, whether drones in combination with other technologies have the power to transform the health care system, or to what extent in-depth organizational processes are needed to implement drones, is currently unknown and only understood in hypothetical terms.

The aforementioned interactions should also include evaluation of the acceptance of drone integration because assuming such acceptance by default may lead to a later rejection, which in the long run may impact the broader integration process and invalidate all the previous regulatory work done to ensure smooth integration [84].

The requirements created by innovations at the clinical level may spark responses at the regime level, i.e., adaptations or regulations are needed to support further developments. On the one hand, prompt up-front regulation could enhance innovations and actively drive new developments. On the other hand, a holistic perspective at the regime or landscape level may need supplementary or broader information than the specific clinical level to ensure proper interests for an extended perspective. The institution may need to engage interdisciplinary teams crucial for giving feedback on consequences beyond the initial perspective. From such a perspective, the MLP theorizes that the integration of drones and drone-related applications can be strengthened with a process across different users and levels in the system [19].

Based on the MLP principles, leaders become essential in providing arenas for collaboration, both from within and outside health systems [64,65]. Creating and maintaining linkages and networks between clinics, institutions, and health systems may be conducive to a wider diffusion of drones.

In their review of logistics research, Rejeb et al. [72] discussed how IoT in the context of logistics requires the organization to continuously adapt, engage with, and implement new technologies to enhance the performance of logistic systems. With respect to drones, they recommended that managers inspect the technical features to enable them to identify use cases that may integrate economic, social, and environmental considerations into their strategic decision-making processes.

4.2. The Health Care System Level

Health care systems at the overarching level include broader societal processes, such as political, economic, and demographic trends.

The MLP landscape topic assumes that policy forms an integral part of an innovation, either because of directly triggered changes or because policy changes may be a prerequisite for the innovation. The MLP theory assumes that continuous interaction and communication between the MLP levels are crucial to creating the forces that allow the various transitions not to end until changes in the social and technical elements are embedded in the complete system, i.e., at the user level, the production level, and the institutional and system levels. Therefore, it is helpful to understand the potential policy effects at the earliest stage to take the necessary precautions with respect to unforeseen political consequences or to prepare an argument for any policy changes that should occur. In addition, this may help identify specific issues that influence how stakeholders should be addressed to keep their expectations as realistic as possible. Furthermore, understanding the degree to which organizations need to change is essential for developing a realistic concept and ideas of the potentials and limitations of a given domain. Finally, this is an essential platform for identifying where uncertainties remain and which issues need more attention.

The MLP theory points out that policymakers have an essential role in recognizing relevant niche innovations at the earliest possible occasion to identify lock-ins and help remove them. Creating an environment for trust may contribute an additional nutrient for the diffusion of innovation. Finally, by defining common goals and timely expectations, all stakeholders may work for a shared vision for a future system.

Limitations

Our scoping review has several limitations. First, some relevant papers may not have been identified on account of a search concept that may have been too narrow. However, the search results generated in literature studies that use a structured search approach are often limited.

Furthermore, choosing socio-technical theory as our theoretical lens determined our preferences for conducting our search. We conducted searches of the academic literature in the PubMed and Scopus databases. PubMed was chosen as a medical database, Scopus, because of its broad coverage in diverse fields and its quality [72]. Google Scholar was used to snowball relevant articles, which may be a further limitation. Google Scholar's search logic is based on full-text searches and thus generates a high volume of search results. Our search strategy was based on a structured search, which may have needed to be adapted for use with Google Scholar.

Furthermore, articles that were published after we conducted the literature search in March 2021 were not included. It is also possible that more extensive results could have been obtained from the gray literature, but we chose to restrict our search to peer-reviewed scholarly journal articles.

Additionally, the analysis of the literature revealed categories that may have yielded significantly more studies. For example, a search for "public acceptance" may have generated additional relevant studies for inclusion in this review—however, this scoping review intended to provide a more general overview. Thus, although its conclusions cannot be generalized, this review may spark a discussion about the socio-technical considerations for integrating drones.

Our objective in this study was to look for the value of taking a socio-technical approach. However, our search strategy did not identify any studies that used the keyword "socio-technical". This may be because socio-technical thinking is not very widespread. The MLP can be used to address this research gap.

5. Conclusions

This paper is based on our research question regarding how knowledge of socio-technical theory may support an extended focus on implementing drones into health care systems.

Based on a scoping review and supplementing literature, we found evidence in the literature that building a cross-cultural approach and establishing a discourse across several stakeholders is of importance to developing a sustainable future health system. Furthermore, from a socio-technological perspective, ethical considerations and public acceptance are topics highly relevant to the implementation of drones.

Several authors have addressed ethical topics. In the transition from humanitarian drone projects to commercially available service offerings, ethical issues may be seen concerning data management and security, control, and responsibility.

In addition, the topic of public acceptance has been raised by several authors. Community engagement is helpful for buy-in and ensuring the relevance of the innovation. Because acceptance is deeply influenced by culture and prior experience, the acceptance of drones should be evaluated.

Furthermore, addressing community engagement can ensure an agency in terms of the ability of actors to intervene in system change. Experimental projects can cultivate learning processes and institutional change. Policymakers can facilitate learning and network building. An active innovation policy can prompt up-front regulation, enhance innovations, and actively drive new developments.

Systemic knowledge about privacy is needed to obtain a social consensus on the capabilities of drones, thereby also guiding policymakers and decision-makers. Niche actors may decide on the process.

A holistic perspective and the regime or landscape level may need supplementary or broader information than the specific clinical level to ensure that the proper interests are considered in an extended perspective. The institution may need to engage interdisciplinary teams, which are crucial for giving feedback about consequences beyond the initial perspective.

In this process of transition, leaders are essential for creating and maintaining linkages and networks between clinics, institutions, and health systems. The MLP shows that continuous interaction and communication between the multiple levels create forces that secure the various transitions until changes in the social and technical elements are embedded in the complete system. Furthermore, the MLP is helpful for understanding potential policy effects at the earliest stage to take the necessary precautions against unforeseen political consequences and prepare arguments regarding the policy changes that should occur.

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Paper 2

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Article

The Moderating Role of Pro-Innovative Leadership and Gender as an Enabler for Future Drone Transports in Healthcare Systems

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Abstract: Drones have been suggested as an emerging technology that has the potential to disrupt and improve healthcare. The attitude among healthcare workers towards the use of drones is important for its successful implementation. Our aim was to examine individual and institutional variables among employees that may be relevant for the successful implementation of drones. This study used a self-administered questionnaire to investigate the expectations and beliefs among 400 employees at three Norwegian healthcare organizations regarding the future role of drones in the provision of healthcare. The results showed that the use of drones in healthcare is positively perceived across professional groups, age, and location. Working in an innovative environment, having experienced previous technological change in one's working environment, and having leadership that supports new ideas were identified as drivers of individual beliefs regarding the use of drones as an innovative solution in future healthcare services. Men had significantly higher scores than women, and this was associated with reporting innovative leadership. This may indicate that a future implementation of drone usage should focus on local system environments and may depend on the presence of innovative leadership. Our results are harvested from a developed health care system and should be applicable for similar technologically advanced systems where the full potential of drone solutions may benefit from the integration of drones into the overall socio-technical system.

Keywords: drones; unmanned aerial vehicle (UAV); healthcare; transport; socio-technical system; innovation

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1. Introduction

Technological developments are enabling new solutions and challenging how we deliver existing services to an extent that was unimaginable only a few years ago [1]. Healthcare is an area that is facing large changes with respect to new treatment modalities, automatization, robotization, artificial intelligence, and innovations in existing methods aiming to individually tailor services and treatment. Technology has been suggested as one remedy that may alleviate the surging costs of healthcare. Demographic change, increased multimorbidity, and an increasing prevalence of lifestyle-related diseases in developed healthcare systems are all cost-driving factors [2]. It is also expected that technology may enable new solutions for the provision of services in less developed healthcare systems [3,4].

Unmanned aerial vehicles (hereafter referred to as drones) are one of several emerging technologies [5,6] that may contribute to this perspective. In healthcare, possible applications of drones have been investigated and include search-and-rescue operations in natural disasters, the delivery of vaccines and medicines to rural areas and healthcare technology devices in emergency situations, and the rapid transport of blood samples and organs [7–14].

Despite the challenges related to meteorological conditions, transport safety and security, and the short flight range, many researchers foresee drones as a transportation solution that could be viable within a few years [14–18]. The European Union expects that a fleet of 100,000 drones will be used for transport purposes by 2050 [19].

The institutional and clinical context in which drones may be a useful medium for the transport of biological material has not been extensively investigated, and whether the introduction of drones as a transport solution in healthcare will be a significant gain, remains unknown. Extreme demands for safety and uptime should be anticipated, and drones are still in an early innovation phase [20]. The speed of implementation as a transport solution may depend on differing sectors and purposes. Although multiple studies have demonstrated the proof of concept with respect to drone applications for multiple health care purposes [7–14], varying levels of momentum in the implementation of drones for high-volume and time-intensive transport in healthcare may be expected [8,21–23].

Furthermore, whether the implementation of drones for transport in healthcare systems will mainly be based on technical drone requirements alone or whether it will require specific organizational or system-related modifications may need further exploration [24]. As yet, the main focus of drones has been on their potential as airborne vehicles that can bypass ground-based traffic congestion [18] and provide accessibility for services in rural and remote locations [25,26]. It remains unclear whether such benefits and innovations can also be achieved for different transport options related to healthcare. This may concern organizational culture, logistics, and system improvements.

Although the implementation of drone solutions must be initiated and achieved at the local clinical or institutional level, an overall systemic perspective may contribute to understanding the scope of the necessary changes [3,27]. The impact of future regulations and the testing and use of drones [28], as well as interests from various stakeholders [29,30], may be relevant. The successful integration of drones may, therefore, benefit from a holistic socio-technical perspective that is adapted to healthcare cultures and systems [31,32].

The concept of "socio-technical systems" has been used to convey that the success of introducing new technologies does not depend only on the technical product itself, but also on overall policies, user experiences, infrastructure, and existing organizational structures [33]. The relevance of organizational structures and expectations related specifically to the use of drones in hospital systems has been studied by Krey et al. [34] and others [4,35–37]. These authors agree that this is an important issue requiring further investigation.

In particular, there is limited study on whether drone solutions can be achieved in existing logistics and organizational patterns that are found in specific settings, such as high-volume transport across large healthcare institutions or time-critical transport that requires an extremely high and regular uptime. Optimal service design often starts by including stakeholders to shape the best environment for new solutions to strengthen the innovation process [38–40]. In this context, the attitudes and culture among employees in hospitals that are planning to implement drones as a future transport option need to be accepting of this new technology.

This study focused on three Norwegian healthcare organizations that are building new hospitals by 2030 and are considering drone transport as a major part of their future transport logistics.

The largest hospital is Oslo University Hospital (OUS), consisting of four hospitals located throughout the Oslo area: The National Hospital (Rikshospitalet with local, regional, and national services), Ullevål University Hospital (local, regional, and national services), Radiumhospitalet (a specialized cancer hospital), and Aker University Hospital (a local, central hospital). In 2019, OUS had a total patient activity of 94,000 hospitalizations, 45,000 day care treatments, and 874,000 outpatient consultations. The hospital has 24,000 employees, and patient treatment takes place at more than 40 locations within a distance of 20 km. OUS is a large hospital by European standards, providing services that span from local hospital treatment to advanced specialized services and transplantations. The hospital has a structure that is well suited for drone transport across institutional locations.

The Central Hospital of Innlandet services a 52,072 km^2 area (an area slightly larger than Denmark) and covers 42 local communities with a total of 368,000 inhabitants. The hospital has 8700 employees, with patient treatment taking place at 40 primary locations and

25 emergency locations. This organization is planning to have a centralized hospital structure by 2030, with one main central institution and three additional institutional locations. The hospital is currently exploring the use of drone services for conducting primary logistics across its institutional locations and between 80 local healthcare centers (i.e., general practitioners).

The Central Hospital of Vestre Viken is located west of Oslo and provides health services to 26 communities with 500,000 inhabitants. This hospital services a nearly 20,000 km^2 area with a maximum distance of 180 km. The hospital has 9500 employees in total and institutions at five different locations. This organization is planning a new main hospital in the city of Drammen and is considering drone service as a future transport solution.

Our main goal in this study was to examine individual and institutional variables among employees that may be related to the expectations of and positivity towards future drone transport to identify the possible relevance of these variables for the successful implementation of drones.

2. Approach and Research Questions

We applied aspects from the multilevel perspective (MLP) developed by Geels et al. [41,42] related to socio-technical systems. This perspective investigates interlinkages between multiple aspects of an organizational system rather than as isolated phenomena in a local microsystem [43].

MLP distinguishes three levels: micro (niche), meso (regime), and macro (landscape), and these terms can parallel the institutional levels of clinic, hospital, and healthcare, respectively. MLP has the potential to increase our understanding of the dynamics that occur in the innovation phases of technological change in such systems [33,44].

MLP defines the technology itself as the core of the technologic change approach [42,45]. It conceptualizes four phases of technological change [44,46]: (1) Technology is introduced within the existing environment, (2) functionalities and user preferences are explored, (3) the change is put into practice in daily operations, and (4) gradual replacement of existing solutions.

These four phases describe the innovation journey that is characterized by various activities and dynamics. Niche innovations become gradually more specific and stable. The process of implementing niche innovations may benefit from positive feedback mechanisms that add new resources to the iterative development. However, if expectations are not met, then faith in the new technology might diminish and resources for it might be withdrawn [47].

Our current drone study was related to the first two phases. We used a structured questionnaire to obtain information related to organizational and technological topics among 400 employees from the three above-mentioned healthcare organizations.

3. Methods

A self-administered questionnaire containing 36 structured questions (Appendix A) was conveyed by mail, published on the organization's intranet, or presented to randomly contacted employees during workdays (in the case of OUS and Vestre Viken). We received a total of 415 responses: 39 by mail, 234 by intranet, and 142 by random contact. The responders were categorized into professional groups as presented in Table 1.

We chose random sampling for a study group of approximately 400 subjects. Although a representative sample should contain, for example, 80 physicians (based upon the personnel structure in the hospitals), selection of 80 physicians across 45 differing specialties in the hospitals might represent a selection bias using representative sampling, as such a method would need a weighted sampling across small and large specialties. Furthermore, whereas representative sampling minimizes bias from known causes, random samples minimize bias from unknown causes [48]. We had no control of the respondents on the intranet questionnaires, and therefore chose a random sampling method for all questionnaires. This resulted in a fairly representative study group, as the percent of the differing personnel categories in our sample versus relative number of workforce were administration 15%/14%, bioengineer 14%/8%, nurse 31%/39%, other 12%/12%, other patient 14%/10%, and physician 19%/17%.

We had three targets of information in our survey. We aimed at capturing "the overall picture" among healthcare employees regarding the individual digital interest and competence, knowledge, and expectations of future drones, some indicators of the local cultures. Multiple variables might be used as we had no prior knowledge of the status. We also intended to limit the time to perform the response, anticipating that much time for filling in the questionnaire could be negative. The 36 questions consisted of 16 yes–no questions, 13 multiple-choice questions, and a Likert scale (rating of 1–5) questions. We tested the questionnaires before the study using three physicians, three nurses, and two secretaries to assess the time needed to fulfill the questionnaire and solve ambiguous questions.

Information of our study was presented on the intranet of the three hospitals. The survey questions alternated between yes/no, multiple-choice, and Likert-scale response options, intending to make it more interesting and appealing to answer [49]. For the survey that was distributed physically to employees at the hospitals, we addressed the employees by inviting them to participate for an important health-related research, i.e., we asked as insiders. Of course, avoiding some respondents that intentionally reply with wrong answers might be difficult to control for in survey-based studies.

The questions collected demographic and background data of the responders, their knowledge of drones, experience with technological change, and attitudes/expectations for the future. The demographic characteristics included profession, gender, age, self-assessed digital competence, currently working under innovative leaders, and working in a culture resistant to change. The technological perspective of the responders was inquired by asking about their knowledge of drones in general and in healthcare, personal beliefs regarding drones in the future, experience of radical technological change (not specified), and anticipated digital implications for their career. Attitudes/expectations for the future were gathered by asking about their expectations of the new hospital, expectations of upcoming technologies for improving healthcare, and perceived threats to their own career development posed by technological change.

We excluded 15 responses because of missing data. The questionnaire data were transferred into Excel for descriptive analysis. The statistical analyses were performed with SPSS version 27. Differences between groups were examined by two-way analysis of variance, and significant Pearson correlations between single variables were used to perform multivariate analyses. To assess whether the employees believed that drones will be implemented in future healthcare services (yes/no), we used stepwise logistic regression with this dichotomous variable against multiple variables. We used dummy variables for personnel groups and the institution. A grouping variable of gender (man = 0, woman = 1) was applied to assess the differences between men and women. A significance level of $p < 0.05$ was considered to be statistically significant.

4. Results

A summary of the core variable data is presented according to profession in Table 1. There was a majority of women responders (64%), but the physician group had a significantly higher percentage of men (57%) than women. The mean age was lowest in the nurse group ($p < 0.01$ compared with the total sample).

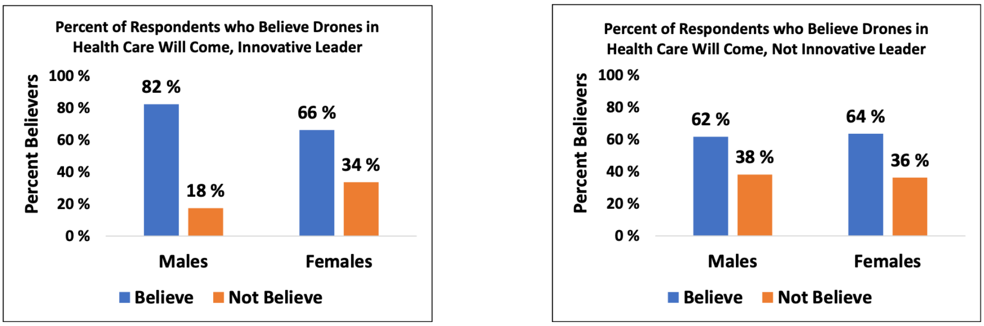
Administrative staff, nurses, and physicians had the highest belief that in the future drones would be used in healthcare ($p < 0.05$); however, there was no such trend related to future drone transport at their own hospital. The personnel groups that are closest to patients, i.e., nurses, other patient-related personnel, and physicians, had the lowest expectations of a new, future hospital with respect to improvements in the patient and employee perspective. Administrative personnel scored the lowest on having experienced radical change, while bioengineers scored significantly higher on this topic ($p < 0.01$).

Table 1. Summary of data by personnel group.

Profession	**Administration (*n* = 59)**		**Bioengineer (*n* = 54)**		**Nurse (*n* = 110)**		**Other (*n* = 47)**		**Other Patient Related (*n* = 55)**		**Physician (*n* = 75)**		**Total Population**	
Category/Variable	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***
Background														
Mean Age (years)	41.2	11.5	39.8	12.4	32.9	12.1	39.1	13.1	39.0	11.4	35.2	12.9	37.30	14.3
Years Worked in Hospital (years)	13.5	9.5	14.8	12.4	9.3	10.2	10.1	10.7	9.3	9.9	7.2	8.3	10.6	9.6
Self Assessed Digital Competence (score 1–5)	3.8	0.7	3.9	0.8	3.7	0.7	3.8	0.9	3.8	0.9	3.6	0.9	3.8	0.64
Positive Culture for Change (% yes)	88%	33%	74%	44%	90%	30%	78%	42%	73%	45%	83%	38%	82%	38%
Innovative Leadership (% yes)	83%	38%	74%	44%	84%	37%	70%	47%	71%	46%	69%	46%	76%	43%
Arena for Innovation (yes)	59%	50%	59%	50%	62%	49%	65%	48%	49%	50%	55%	50%	57%	50%
Knowledge of Drones														
Knowledge of Drones in Health Care (% yes)	73%	45%	76%	43%	56%	70%	72%	62%	55%	63%	49%	62%	62%	63%
General Knowledge of Drones (score 1–5)	2.93	0.92	2.75	0.97	2.32	0.82	3.0	1.20	2.55	1.12	2.64	1.13	2.7	1.0
Believe Drones in Future Health Care (% yes)	81%	39%	67%	48%	73%	45%	54%	50%	60%	49%	77%	42%	70%	45%
Believe Drones in Own Hospital in Future (% yes)	66%	48%	63%	49%	67%	47%	74%	44%	53%	50%	64%	48%	65%	48%
Technological Experience and Expectations														
Experienced Radical Technological Changes (% yes)	32%	47%	59%	50%	39%	49%	33%	47%	47%	50%	49%	50%	43%	49%
Believe New Hospital Positive for Employees (% yes)	68%	47%	65%	48%	66%	55%	70%	47%	64%	73%	53%	55%	57%	49%
Believe New Hospital Positive for Patients (% yes)	75%	44%	69%	47%	69%	52%	76%	48%	58%	66%	56%	55%	61%	48%
Believe Digitalization may improve Health Care (% yes)	97%	18%	98%	14%	98%	19%	98%	15%	98%	13%	99%	12%	98%	15%
Hospital need Change to adapt to Technol. Development (% yes)	92%	28%	87%	34%	83%	38%	65%	48%	80%	40%	75%	44%	82%	38%
Worried Own Work May be removed by Future Technology (%)	16%	39%	9%	32%	29%	39%	19%	46%	12%	37%	16%	36%	17%	37%
Positive Expectations Technology Improve Own Work (scale 1–5)	3.90	0.90	3.87	0.99	3.93	0.82	3.87	1.26	3.62	1.03	3.67	0.93	3.83	0.81

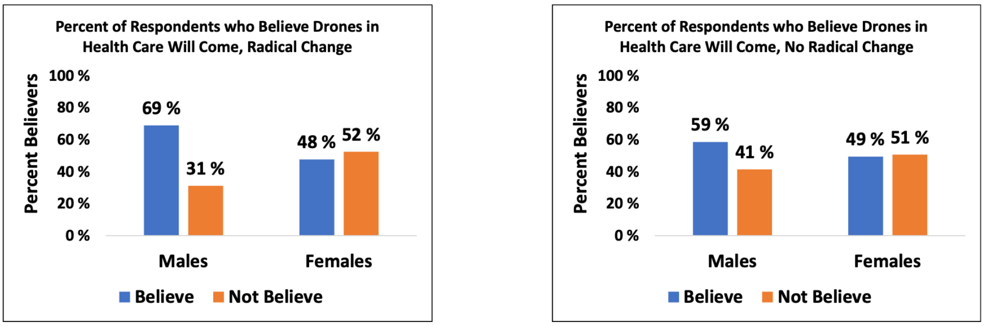
There were some score differences across gender (Table 2). Significantly more men had knowledge of drones in general and an awareness of drones in healthcare; however, the belief that drones would be used in future healthcare services was similar between men and women. The scores of women reflected more skepticism regarding the future risk of general technological development in healthcare.

Several variables had interesting covariations. Having innovative leadership increased one's belief that drones would be used in future healthcare services. This was primarily seen in men, as 82% of men who worked in innovative cultures believed in the use of drones compared with 66% of women ($p < 0.01$). Similarly, for those who experienced radical technological change in one's own work, a significantly higher percentage of men (69%) than women (48%) ($p = 0.015$) believed that drones would be used in healthcare (Figure 1a–d).



(a) Percentage of men and women with an innovative leader who believe in the use of drones in healthcare.

(b) Similar to (a) but for those who do not have an innovative leader.



(c) Percentage of men and women who have experienced radical change and believe in the use of drones in healthcare.

(d) Similar to (c) but for those who have not reported experiencing radical change.

Figure 1. Interesting covariations that show (**a**) percentage of men and women with an innovative leader who believe in the use of drones in healthcare, (**b**) percentage of men and women without an innovative leader who believe in the use of drones in healthcare, (**c**) percentage of men and women who have experienced radical change and believe in the use of drones in healthcare, (**d**) percentage of men and women who have not experienced radical change and believe in the use of drones in healthcare.

A similar but weaker effect was observed in relation to having an arena for innovative communication; in this setting, 80% of men believed that drones would be used in future healthcare compared with 67% of women ($p < 0.05$).

Table 2. Summary of data by gender.

Category/Variable	**Males (n = 138)**		**Females (n = 262)**					
	Mean	***SD***	**Mean**	***SD***	**Mean Male/Female**	**Sig. (2-Tailed)**	**Mean Difference**	**Std. Error Difference**
Background								
Mean Age	40.07	11.68	35.46	12.70	13%	0.01	3.25	1.87
Years Worked in Hospital	10.06	9.72	10.54	10.73	−5%	ns	−0.99	ns
Self Assessed Digital Competence	3.92	0.84	3.67	0.78	7%	0.01	0.25	ns
Positive Culture for Change	82%	39%	83%	38%	−1%	0.05	0.06	<0.05
Innovative Leadership	75%	44%	77%	42%	−3%	ns	−0.02	<0.05
Arena for Innovation	56%	50%	60%	49%	−7%	ns	−0.03	<0.05
Knowledge of Drones								
General Knowledge of Drone	3.08	0.97	2.40	0.99	28%	0.001	0.69	<0.01
Knowledge of Drones in Health Care	67%	51%	59%	65%	15%	0.00	0.20	<0.05
Believe Drones in Future Health Care	78%	42%	66%	47%	17%	0.01	0.02	<0.05
Technological Experience and Expectations								
Experienced Radical Technological Changes	43%	50%	43%	50%	1%	ns	−0.00	ns
Believe New Hospital Positive for Employees	64%	55%	64%	55%	1%	ns	0.04	ns
Believe New Hospital Positive for Patients	67%	52%	67%	54%	−1%	ns	0.03	ns
Believe Digitalization may improve Healthcare	95%	22%	99%	9%	−4%	ns	−0.04	0.02
Hospital need to Change to adapt to Technological Change	1.28	0.36	1.41	0.41	−9%	0.04	−0.18	ns
Worried Own Work May be removed by Future Technology	14%	34%	19%	39%	−26%	0.01	0.01	<0.05
Positive Expectations for own Work	3.80	0.87	3.82	1.02	−1%	ns	−0.08	ns

ns = not significant.

Variables that had significant Pearson correlations were included in a multivariate logistic regression analysis using the belief in drone usage in future healthcare as a dichotomous dependent variable (1: believe, 0: do not believe). The results of the final step in a backward analysis are presented in Table 3.

Table 3. Multivariate logistic regression with a belief in drone usage in future healthcare as the dichotomous dependent variable.

Variable	B	S.E.	Wald	Sig.	Exp(B)
General Knowledge of Drones	0.36	0.14	6.46	0.001	1.44
Knowledge of Drones in Healthcare	0.57	0.22	7.08	0.008	1.773
Experienced Radical Technological Changes	0.66	0.26	6.61	0.010	1.929
Innovative Leadership	0.63	0.31	4.18	0.041	1.872
Believe Digitalization may improve Healthcare	0.60	0.14	18.32	0.000	1.825
Nurse	0.67	0.31	4.69	0.030	1.95
Physician	0.89	0.36	5.97	0.015	2.43
Administration	1.00	0.40	6.32	0.012	2.73
Age	−0.02	0.01	4.27	0.039	0.98
Constant	−1.10	0.98	1.27	0.260	0.33

B = Coefficient (intercept); S.E. = Standard error; Wald = Wald chi-square test; Sig. = *p*-value; Exp(B) = Odds ratio.

Regarding profession, physicians and administrative personnel showed the largest odds ratio for the belief in drone usage in future healthcare, and experience of radical technological change and having an innovative leader were the strongest environmental predictors. Interestingly, increasing age was associated with a lower optimism for the use of drones in healthcare.

5. Discussion

Our results showed that an average of 70% of the participants envisioned drones as a realistic transport solution in future healthcare. This finding was similar across multiple personnel groups, although administrative employees, physicians, and nurses had the highest belief in drone usage. Interestingly, the idea that their own hospital would implement drone solutions was somewhat lower.

The high trust in drones as a future transport solution in health services may be interesting in several aspects. For such subarctic climatic conditions as in Norway, with temperatures varying from −30 to +30 degrees Celsius and wide ranges in wind and precipitation, it has not been proven that the current drone technology may provide near 100% uptime with acceptable quality of biologic specimens. Although a recent study reported that both normal and pathologic blood samples may tolerate exposure to vibration and turbulence [23], multiple challenges, such as icing of drone propellers and wings, and drone range and turbulence around buildings and infrastructures, remain to be studied. We do not believe that our study group has an informed envision based on such topics for their positive assumptions of future drone solutions.

On the other hand, we may interpret our findings as our health care workers have high fidelity in upcoming technologies, that they have heard about and observed drones in general, and therefore have an enthusiastic expectation to drones in the future.

With a socio-technical approach based on individual reported profiles, our study intended to identify possible topics related to technology and local variables in existing systems that may be associated with drone implementation.

Our results demonstrate positive attitudes toward drones among healthcare workers across multiple professions. These workers reported a mean self-assessed digital competence score varying from 3.6 to 3.9 on a 1–5 Likert scale. They had a reasonably high knowledge of drone usage in general and in healthcare, high confidence that technological solutions may improve health services in the future, and high expectations for technology to improve their own work. The employees' concern for their jobs related to future technological change was low across all groups. These observations may, in part, reflect the positive attitude towards technology displayed by the Norwegian population [50].

Experiencing innovation in the local environment, having an innovative leader, and working in an arena that simulated innovation were all positively correlated to the belief in using drone solutions in future healthcare. A similar effect was observed for experiencing radical technology changes in the course of work. However, we cannot conclude whether such individual responses represent local working environments or whether they merely represent individual attitudes. Nevertheless, the significance of such factors with respect to the implementation of drone transport in future health systems should not be ignored, as previous reports have suggested that these topics may be relevant if implementing specific technologies can generate a broader acceptance of general technological innovation [1,3,24]. Our results are in accordance with previous studies that have suggested that greater experience leads to increased familiarity and the ability to learn about technology in general [51] and that the experience and knowledge of early adopters/believers can positively contribute to further technology implementation [52].

The full impact of the gender difference in the current study on the introduction of drones in healthcare is not known. Notably, the effect of working in an innovative culture was a strong factor for men but less for women (Table 2). In contrast, the response profile was quite similar for the two genders in the group that did not report innovative leadership. Whether this may indicate that men are more receptive to innovative cultures than women would need more research. Gender differences related to drones was discussed in a previous report of food drone delivery by Hwang et al. [53]. They found that women who perceived a technology to be innovative were more likely to use the technology than those who did not perceive it to be innovative.

In Norwegian hospitals, 65% of employees are female. With a managerial lens, any gender difference may be of importance related to organizational and innovative developments. If drones are emerging as realistic solutions for the purpose that our hospitals are aiming, understanding possible differences across personnel groups and genders may be useful for the implementation of drones in an extended framework. If we assume that women have a less receptive attitude to innovative cultures than their male colleagues, this should be understood and taken into account.

In our study, administrative personnel, physicians, and nurses showed the largest odds ratios for believing that drones would be used in future healthcare, although they did not stand out with significant higher scores on either digital competence or knowledge of drones. One hypothesis may be that having a higher academic education may be associated with more engagement in future technology. The high score in the administrative group may also be associated with open minded attitude related to managerial positions, although we have no detailed information on their background.

As nurses and physicians are professions close to the clinical activities, they may have more positive experience with the continuous changes in technology and patient treatment over time, although not all changes are observed as radical. As they represent influence on the provision of clinical services, they potentially may be advocates for the introduction of drone solutions, if such solutions are concluded realistic in the future. Further research is needed to fully understand these findings. In a similar study of the Swiss system, Krey et al. [34] reported different attitudes to drones between employees and patients and between healthcare-related personnel and other employee groups. Our results are different from those of Krey et al. because the administrative group had the highest score in our study. This indicates that such factors may vary across different systems and cultures.

The results in Table 3 illustrate several interesting odds ratios Exp(B). The odds ratio for believing in future drone solutions had the largest value in administrative personnel and physicians (2.73 and 2.43, respectively). This is 89.5% and 68% higher than the odds ratio of the general knowledge of drones, and 52.5% and 37% higher than the odds ratio of knowledge of drones in health care. In comparison, the odds ratio of physicians deviated only 25% from that of nurses. These numbers may spark several research questions regarding possible causes as academic background, professional attitudes and cultures, experience from technology, and more.

People's knowledge of emerging technologies may be incomplete and based on their personal values and knowledge constructs [54]. A lack of involvement and knowledge might generate skepticism, whereas positive experiences of radical technological change may build attitudes that are more accepting of change. This idea is consistent with our finding that previous experience with radical change supported a positive attitude toward the use of drones in future healthcare.

Both Mion [36] and Knoblauch et al. [4] discussed the importance of having dedicated project management to support the implementation of drones through the various innovation phases. Change is not driven by the technological solution alone but in combination with the adoption by users, which helps structure the solutions [33,55]. Incentives for experimentation, learning, network building, and vision building have been suggested as crucial elements in the push for change [44,52,56]. These ideas are universal principles, and they correspond to our findings that innovative and supportive management strengthens the belief in future drone solutions.

Negative experiences with a new technology may create acceptance problems whereby people become resistant to subsequent changes [44,57,58]. By contrast, positive experiences and anecdotes may enhance the cultural appeal and social acceptance at the local level [44,52,56]. Users may gradually learn through practical interactions with technology and explore new ways to organize workflows [45].

We found that our study group was receptive to new solutions; however, differing institutional and individual attitudes should be considered by the local leadership and management in future drone implementations. A socio-technical approach might be helpful in this implementation process, as it highlights the importance of using technological transformation as an opportunity to improve processes by combining organizational and technological needs [59,60].

The ability to change and improve existing solutions by implementing technological innovations—in contrast to modifying new solutions to fit existing routines—may become a critical factor for the success of future healthcare organizations.

Drone transport may have the potential to reduce costs by merger of large laboratory services that are traditionally performed at multiple locations with the duplication of infrastructure and 24/7 services. If drones represent a transport system that offers close to 100% uptime with sufficient quality, they may contribute to the centralization of time-critical laboratory services, reducing both operational costs and costs of infrastructure investment. Additionally, drones may also represent decentralization by increasing the pick-up services in rural regions by more frequent and timely transport schedules than current road transport. This may offer both reduced costs for the health care and improved quality for patients.

The full potential of implementing such solutions into existing health care systems may depend on logistics and cooperation across institutional and district systems, thus asking for an extended, socio-technical framework [24,59]. Exploring and understanding the readiness of an organization may therefore be a crucial factor for the implementation of drones. Mion [36] emphasizes that organizations intending to use drones for transport need to be open for change and prepared to modify their operations. Although focusing on the microlevel may be crucial in the initial implementation phases, a systemic perspective may facilitate integrating drones into the healthcare system by considering the entire process, encompassing both social and technical aspects. This would help to improve current work practices and realize the full potential of drones in the long run. Socio-technical systems do not work on their own, but in an interplay between technology and the user environment [42]. Innovative leadership and culture may strengthen the acceptance and implementation of using drone transport in healthcare. Furthermore, it may shape the organizational structure that may be necessary to adapt to technological change.

If drones are emerging as realistic solutions for the involved hospitals, their implementation should attempt to obtain improvements of processes and cultures beyond the primary transport topic. The practical implications of our results may therefore be multiple. The conceptual framework of attitude and knowledge among health care workers defines the framework for decision-makers of how management and leadership should be performed to attain a disrupting technology adoption in an extended healthcare logistic process. Observing that there may be differing attitudes across the professions and possibly across genders, may be of significant importance.

Our data are harvested from hospitals that have declared drones as a future transport strategy. This may imply differing attitudes compared to other systems. Our findings may therefore be influenced by such specific factors. However, we observe hospitals in several health care systems are developing such strategies and give some generality for our results.

No doubt, implementations of drone solutions in less developed systems may have quite differing challenges as those in more developed systems. In our context, all three hospitals intend improve costs by merging large laboratories, but in combination with improvements in decentralized services, as drones may increase service level in rural and remote locations. The latter parallels demand in many lesser health care systems as well. Nevertheless, observing differing attitudes and expectations across employee groups will have general validity. In particular, in a socio-technical analysis, we conclude that gender, innovative leadership, and innovative arenas may be relevant elements to study when implementing any technological innovation.

6. Strengths and Limitations

Our study is subject to some limitations. The findings are limited to a Norwegian setting. Norway is a high-expender, ranked among Organization for Economic Co-operation and Development countries (OECD) from second to fourth in terms of total health expenditure per capita [61]. This may influence attitudes related to economic expectations for new solutions. Furthermore, Norway, along with other Scandinavian countries, is a leader regarding equity policies. Gender differences may diverse from other health care systems.

We did not define the term “drone” but assumed that most Norwegians associate the term drone with a standard multicopter drone which is regularly shown in the media and is owned by half a million Norwegians.

Although this study included more individuals than in similar previous studies and our results may be valid at the individual level, a limitation of our study is related to survivorship bias [62]. Recruiting respondents via the organization’s intranet may have biased the responders towards those who have a special interest in the topic, and they may not be representative of the overall employee population. This may have caused some selection bias in our study group, and we cannot make conclusions on a local clinic or institutional level. Nevertheless, the study group provided interesting perspectives at the individual level across fairly broad personnel groups.

Using a self-administered questionnaire may have introduced errors related to different understandings and interpretations of the questions. Survey questionnaires do not allow for follow-up of the answers and are not suited for a deeper investigation of the responses [63]. Furthermore, our study was carried out in a technologically advanced healthcare system, and the findings may not be as relevant to less developed systems [34]. However, the association between an innovative culture and the successful innovation and implementation of technology has been suggested by others [64] and is supported by our findings.

7. Conclusions

This study suggests that drones are perceived positively across a variety of professions, ages, and locations. A major finding was that working in an innovative environment, having a leader that supports new ideas, and having previous experiences with technological change are drivers for the belief that drones will be used in healthcare and the positive perception of future technology transitions. Our findings require further research related to the impact of the investigated factors on the establishment of drone solutions. However, we believe that to realize the optimal and extensive benefits of implementing drone solutions, the managerial approach should be open minded, stimulate innovation, encourage experimentation, and support the risk-taking that will be necessary.

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Appendix A

Questionnaire

- Your profession? *Physician, Nurse, Bioengineer/laboratory employee, Other patient-related work, Administration, Other*
- How do you rate your digital competence? *Manage—Superuser*
- Do you think digital solutions contribute to more efficient health services? *Yes/No*
- Do you think a new hospital will be beneficial for employees? *Yes/No*
- Do you think a new hospital will be beneficial for patients? *Yes/No*
- What do you know about drones in general? *Very little—Very much*
- Have you heard about drones in healthcare? *Yes/No*
- Do you think a future drone-based transportation of biological material (blood samples, biopsies, other material) is realistic? *Yes/No/Don't know*
- In which area do you think a drone-based transportation can have a positive effect? *Time, Quality, Digital, Collaboration and Communication, Don't know*
- In which situations do you think a drone-based transportation can be an advantage over current transportation methods? *Long distances, Predictability, Possibility for immediate transport, Consolidations of laboratories, Don't know*
- Do you think your hospital will use drones in the future? *Yes/No/Don't know*
- How long do you think it takes to fly a blood sample taken at Rikshospitalet with a drone to Ullevål? *0–15, 15–30, 30–45, 45–60, 60–90 min, Don't know*
- What do you believe are the biggest risks when it comes to drone flights for medical purposes? *Flight safety, Data safety, Biological quality, Sample safety*
- Does your leader support innovative ideas? *Yes/No*
- How does your leader react to innovative ideas? *With rejecting/With doubt/Open/With interest/With support*
- Do you have an arena to discuss and/or test innovative ideas in your unit? *Yes/No*
- Are you leaders active in planning for future change? *Yes/No*
- Are you involved in the planning for future change? *Yes/No*
- Do you think that technological development poses a risk for your hospital? *Yes/No/Don't know*
- From your perspective, does technological development require that the hospital needs to change? *Yes/No/Don't know*
- Are you optimistic that technology can improve your work in the future? *Pessimistic—Optimistic*
- Are you concerned that your work might disappear or that you might lose work as a result of technological development? *Yes/No*
- Have you experienced significant medical-technical change in your area the last 5–10 years? *Yes, radical/Yes, to some degree/Some, but less significant/No*
- If you answered yes to the previous question, did technological development lead to logistical/operational change? *Not relevant/Yes/No*
- How satisfied are you with your work today? *Not satisfied—Very satisfied*

- What gives you most work satisfaction? *Interesting work/Work with patients/Work autonomy/No work-related stress/Nice colleagues/Exciting change projects/Busy and the day goes fast/Good at my work/New challenges*
- Do you experience good collaboration and communication with other professions in your work? *Disagree—Agree*
- Do you have enough time during the day to accomplish your work in a satisfactory way? *Yes/No*
- Will your work be less or more interesting in the future? *Less interesting—More interesting*
- How important is it for you to know what you need to do during the day? *Not important—Very important*
- How often do you have to do unpleasant work? *Never/Rarely/Sometimes/Often*
- What are the reasons for that feeling? *Always behind/Poorly handled organisational change/Delayed work/Too much to do/Poor communication/No support/Inconsistent expectations/Too many patients/Concerned for patients*
- Do you think the hospital needs other then medical competence in the future? *Yes/No*
- What are the biggest challenges for the healthcare system from your perspective? *Shortage of resources/Increasing costs/Increasing unnecessary treatments/Competence/Poor communication/Specialisation*
- Your age? *0–19/20–29/30–39/40–49/50–59/60 years or older*
- Your gender? *Female/Male*

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Paper 3

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ORIGINAL RESEARCH

Realities of Using Drones to Transport Laboratory Samples: Insights from Attended Routes in a Mixed-Methods Study

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Purpose: Drones are an emerging technology with the potential to improve laboratory logistics. This study is based on the hypothesis that the implementation of drones will benefit from an understanding of the current system and that existing transport solutions should be optimized before drone solutions are considered. It focuses on carriers transporting biological material today by car along a traditional circular route. It aims to explore how the current transport service is organized, identify areas for improvement, and investigate carriers' perceptions of how drones could be integrated into or substituted for their services.

Methods: A mixed-methods approach was applied, combining a questionnaire, shadowing of nine transport trips, semi-structured interviews, and time assessments.

Results: The carriers shared insights into how to optimize existing transport solutions in terms of structure, culture, attitudes, and overall functionality. Most carriers expressed in the questionnaire that they were little involved in innovation work. The time assessment revealed that not the driving times, but the loading times had the highest deviations from plans and thus represented the area with the greatest potential for simple improvements. Questions about the use and organizational impact of drones are generated, and their prospects are discussed from a broad sociotechnical perspective.

Conclusion: Our concept was to broaden our understanding of implementing drones into existing systems in a fairly simple setting. Although improved logistics may take place without complex processes, future research opportunities such as the impact of drones on organizational processes and social dynamics in the adoption of drones may be needed if more complex systems are involved. The paper proposes experimenting with, and learning from, transport with "road vehicles" and drones in combination and suggests that improvements should be made to existing transport solutions before drones are implemented.

Keywords: logistics, transportation of laboratory samples, reconfiguration, sociotechnical systems, participation

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Introduction

The healthcare sector is influenced by an increasing stream of new technological solutions that aim to improve medical treatment and care offerings.[1,2] These new technologies promise a variety of possibilities for healthcare but also come with certain technical, functional, and operational challenges.

Such emerging technologies may be enthusiastically welcomed by health professionals. Doctors are eagerly implementing new robots for microsurgeries,[3] radiologists embrace the use of new and improved in-hospital three-dimensional printing,[4] and surgeons implement new features and functionalities in mixed-reality applications.[5]

One area that has a long history of applying automation and technical solutions is clinical laboratories. There are developments in point-of-care analyses (POC) that may revolutionize the sector, both by simplifying hospital analyses and providing access to important analyses in a home care setting for patient follow-ups. An emerging technology that, it has been suggested, could disrupt laboratory services is unmanned aerial vehicles (UAVs, drones).[6–9] Oslo University Hospital plans to construct new hospital buildings by 2030, and considers the use of drones an element of its future

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transport logistics.[10,11] Although the realistic potential and value of drone transport remain unknown, it is well established that both infrastructure for landing and take-off, drone surveillance as well as structures for loading will be needed for efficient and robust drone transport. Few studies have reported on the potential of drone transport to influence hospital logistics from an extended perspective.

The value of the drone services offered by companies such as Zipline[12] and other providers in Africa, where drone transport may provide services to remote and hard-to-reach areas, is easy to appreciate.[13] Even with open roads, delivery by drone transport may be faster and cheaper than ground transport in these areas. Although drone technology is developing quickly, drones will show their full potential only when they are able to fly beyond the line of sight (BVLOS)[14] and fully autonomously for long distances. Nentwich et al[15] predicted that autonomous drones would need to be programmed to reach their targets, to have self-reliant route planning, and to be self-sufficient in averting obstacles. A combination of different technologies may be necessary to reach this level of automation.[16] Although Mion[17] reported in a Swiss case study that the implementation of drones had only minor effects on organizational processes, he also argued that a broader perspective should be taken when integrating drones.

A widespread adoption of telehealth solutions[18] or the acceptance of machine learning applications for clinical laboratories[19] may require taking a broader sociotechnical perspective to fully understand how these technologies can be integrated into existing health care systems. However, whether traditional and existing clinical processes, logistics, and patient care can be adapted to drone solutions taking a similar approach, and if and how drones contribute to sustainable healthcare systems, is currently not completely understood.[20,21]

New solutions and approaches may challenge the status quo, namely, established work processes and routines. Existing systems may survive for long periods if they are locked in by traditional ways of operation. In an early phase, new technologies may develop without consensus being reached on their overall benefits if, for example, it is challenging to comprehend how the new tool can be integrated into existing workflows in a way that takes advantage of the technology to improve existing processes.

Awad et al[22] and Bongomin et al[23] illustrate a future vision of a connected healthcare system, and in their scenarios, drones may play an important role. Although it is not obvious that the future scenarios they sketch out will take place, the combination of multiple future technologies will certainly generate new solutions that we were not able to foresee only a few years ago. In Norway, political guidelines for future patient treatment aim to increase the use of digital patient contacts, enabling digital home treatment for 30% of patients by 2030.[24] This ambition was sparked after the boost of such patient contact during the COVID-19 pandemic. Whether the extensive transitions visioned by Awad et al and Bongomin et al may be enabled by single technologies or will need transformational changes in multiple technologies and between multiple actors,[25–27] remains to be seen. Focusing on the interplay of multiple singular disruptions, with greater attention paid to complete concepts, may be helpful in observing add-ons that may trigger further innovations.[24,27]

One approach that has demonstrated its usefulness in approaches to extensive transformations is the multi-level perspective (MLP). This may be considered a part of transition studies that is useful for providing a holistic perspective on system changes, as the MLP takes into consideration both the involvement of different actors and multiple interactions in a system and dynamic alteration at different systemic levels.

According to Geels, a restricted focus on innovations often ignores in-depth interests in system innovation.[26] In comparison, system innovation has a broader analytical view that may include aligning with more overall ongoing processes or multiple innovations. Together and over time, these innovations may lead to system innovations. This study aims to mitigate this gap by focusing on drones and a reconfiguration pathway of system innovation.

Sociotechnical approaches emphasize understanding the work practices in which technology will be used.[28] Following this argument, this article focuses on the carriers at OUS today who transport biological material by "road vehicles" along a traditional circular route.

The hospital transport services' carriers are employees who should be considered potential stakeholders and resources in implementing drone solutions. Automated transport of drones may influence the carriers' future job positions, and they may represent knowledge of how new solutions should be designed if drones are to be implemented as hybrid solutions that combine existing practices with a new transport modality.

This study is based on the hypothesis that the implementation of drones will benefit from an understanding of the current system, and that existing transport solutions should be examined and possibly optimized before drone solutions are considered.

Our research ambitions are as follows:

1. To explore how the current transport service is organized and identify areas for potential improvement; and
2. To study what the carriers perceive as important factors related to how drones could be integrated into or substituted for their service offerings.

Background

Institutions

Oslo University Hospital (OUS) comprises four hospitals located within Oslo: The National Hospital (providing local, regional, and national services), Ulleval Hospital (providing local, regional, and national services), Radium Hospital (a specialized cancer hospital), and Aker Hospital (a local and central hospital). The current ground transport provides transport of both biological test samples, blood, and other items across differing locations.

Route Organization

Figure 1 shows a map of the institutions. The routes today are mostly organized in a circular design with multi-stop routings except for some on-to-one trips. The different lines indicate the distance between the locations, together with the number of trips.

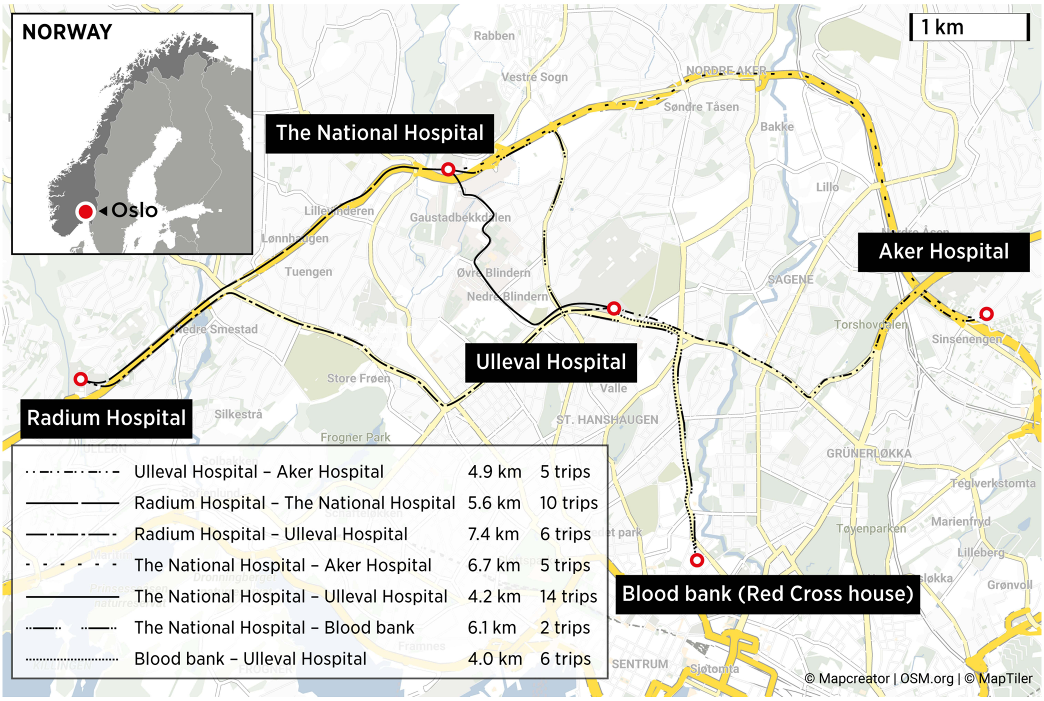

Figure 1 The National Hospital, Ulleval Hospital, Radium Hospital, Aker Hospital, and the Blood Bank in the Red Cross house.

Four routes from the National Hospital to Radium Hospital are served by a bus today that transports patients but also carries payloads of various types. This part of the OUS transport service was not considered in our study.

The article proceeds as follows. The following section introduces the MLP framework and reconfiguration pathways. The next section describes the methods, followed by presenting the results and a discussion. Then, continuing with the limitations of our study, we conclude with our findings.

Is a Reconfiguration Approach Relevant for Drone Implementation?

This paper assumes that drone solutions are initiated by innovators and technologically oriented enthusiasts at the clinical level and that their initiatives will influence the institutional levels of clinics, departments, and institutions. This process may create upstream driving forces in the institution, which in turn may create pressure from above to regulate, adapt, and form the potential implementations and consequences of the innovation. Such processes parallel the hypothesis and sociotechnical approach of the MLP and transition management theory.[29–32]

The potential value of a reconfiguration pathway, as depicted in the MLP, is generated by the method's hypothesis that transitions are not caused by the breakthrough of one technology but by a combination of multiple component innovations.[33] These new components are initially developed in what MLP denotes as "niches", which are equivalent to the clinical units in our system. In the system discussed in this paper, the MLP approach would identify clinics as a protected space for radical innovations that need protection because of their strict regulations regarding medical soundness and documentation.[34] Different forms of subsidies may provide protection. Simultaneously, the more a technology is developed and used, the more is learned about it, and the more it improves.[35] Clinics are also the level that provides space for experimentation and learning processes. Thus, they may also be significant arenas for building socio-technological networks to develop organizational cultures that support innovation.[36]

This requires adequate adoption of the innovations at the clinical department level to solve the challenges caused by unfamiliar innovations at the institutional level, namely, the hospital (equivalent to the regime level in the MLP system).[33,37] To obtain a gradual implementation of innovations at the healthcare level (parallel to the MLP landscape level), deeper structural trends must be triggered to create opportunities and pressure for further change. The expectations and ambitions of political guidelines are examples of such structural trends.

Multiple technologies, including drones, are being continuously developed in combination with each other. Many stepwise changes may add up to reconfigurations that, over time, may create major system changes. Figure 2 illustrates the reconfiguration pathway.

Methods

A mixed-methods approach was applied, combining a questionnaire, shadowing of nine transport trips, semi-structured interviews, and time assessments with carriers from the transport department.

The findings in this article are based on 16 questionnaires, 9 reports from shadowing, 8 interviews, and multiple time measures from the transports. By combining both quantitative and qualitative data, the objective was to picture the current services and the carrier's work.[38,39] Self-administered questionnaires were given directly to the participants.

Ethical Considerations

The study was approved by the hospital's Institutional Review Board and complied with required ethical and legal standards relating to participant anonymity and confidentiality. The data material does not contain any identifying characteristics. Furthermore, data aggregation is only on group-level information. Participation in the survey and interviews was voluntary. All interviewees gave informed consent orally. The actual participation, and the information provided to the participants, imply consent based on conclusive behavior. As the study is conducted anonymously, it is outside the Regional Committees for Medical and Health Research Ethics (REK) mandate. Therefore, ethical approval from REK was not considered necessary.

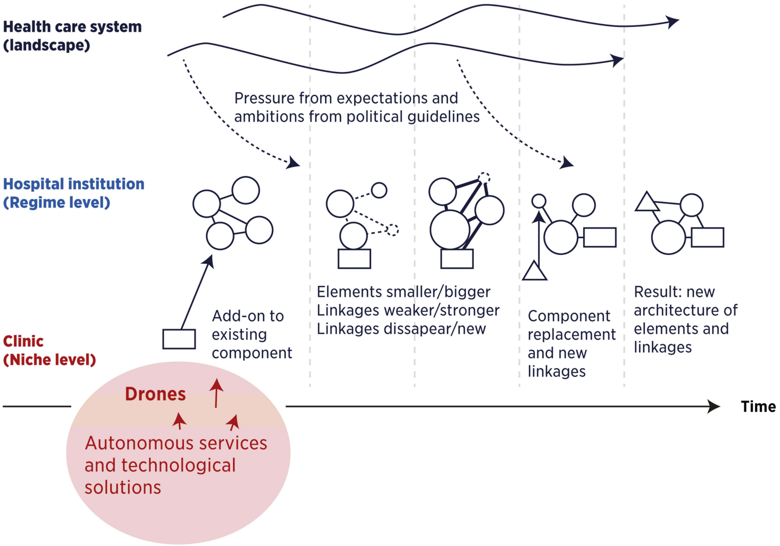

Figure 2 The reconfiguration pathway of the MLP theory translated into a healthcare concept, adapted from Geels FW, Schot J. Typology of sociotechnical transition pathways. Res Policy. 2007;36(3):399–417 Copyright 2007, with permission from Elsevier.[55]

Attended Routes for Observation

Three internal routes were attended three times. Information about arrival and departure times, stops, delays, and disturbances, as well as a general assessment of the transport flow, was gathered by interviewing the driver as well as measuring actual time intervals during the trips.

To ensure that identical questions were presented to all drivers, an interview guide was used to funnel the conversation with the carriers into the questions while accompanying them.

We asked about their opinions of (1) their workday, (2) factors that influence time, (3) changes in routes, (4) barriers and opportunities regarding their work, and (5) their thoughts about the future.

Questionnaire

A self-administered questionnaire containing 36 structured questions was distributed amongst the carriers in the transport department to understand the transport department better. Subsequently, participants were selected using purposive sampling,[40] with the main interest of exploring the range of opinions.[41] As a result, we received a total of 16 responses.

Transport Department, Routes, and Work Process

The transportation department at OUS is organized as part of the OUS Hospital Service Division (OSS). The transportation department is located at Ulleval Hospital, from where carriers drive across the different institutions. The transport department has 20 carriers who operate different routes using “road vehicles”, covering the transport of various biological materials, supplies, clothes, and food. The carpool ranges from normal-sized delivery vans used the most (eg, Renault Kangoo) to trucks (eg, Mercedes 3.5 ton).

The routes cover both internal and external clients. Our study focuses on the internal routes between the National Hospital, Ulleval University Hospital, Radium Hospital, and Aker Hospital.

The carriers are based at Ulleval Hospital, where they start their daily routes for trips across the institutions. The loading is done manually by the carriers, who do both the pick-up and delivery at the different laboratories. The pick-up is organized differently in different locations, and the payload is also stored differently. As we followed the routes, we observed that three major factors influenced the transport time; delays in the traffic, delays when the cars had to wait at the loading site, causing varying and prolonged loading times, and the transfer of delays for the next trip. This sparked the hypothesis that the multi-stop routing with layovers was not always efficient. Furthermore, such multiple routings would not be relevant for future drone services because such serial transports would include legs with multiple drone takeoffs and landings, consuming significant energy for hovering and transport times.[14] We, therefore, intended to consider direct routings, ie, round trip tours between two locations. We measured all time intervals during the shadowing of the tours and also interviewed the drivers about the delays as they occurred. Based on the time measurements, we could experiment with different alternative direct routings, always ensuring that current transport routings were covered to the same extent as in existing routings. Time assessments were analyzed by a simple model using Microsoft EXCEL 2016. Mean, maximum and minimum driving and loading times were calculated.

The current transport system involves a daily driving distance of approximately 290 km. We followed each route three times on weekdays from Monday to Thursday in June 2021. Table 1 below illustrate the current work processes.

Analysis

The analyses followed a convergent design, in which the quantitative and qualitative data were analyzed separately and then merged to combine the results.[40] This design allowed us to link different findings and gain a complete understanding of the transport system.

The interviews were noted, transcribed, and entered into Atlas.ti (www.atlasti.com), which is a qualitative data analysis software package. However, Atlas.ti was not used to analyze the data but primarily to organize the data.

The transcripts were analyzed, and the data was structured into relevant categories.[42,43] The categories emerged from the review and were selected for their relevance to drones.

The round-trip transport times across the locations were assessed, except for the Ulleval–Aker route, which did not have a return trip but was a one-way transport. The measured time intervals in the current routes include driving times (the time from departure from one location to arrive at the next location) and loading times (assessed as the time from arrival to departure for the next leg in the route). The loading time thus includes both the waiting time and the time for delivering/collecting the payloads at each stop. These time intervals were used to assess total transport times in the existing trips across the different locations and to estimate theoretically optimized transport times based on minimal time intervals.

Results

Observations

Six categories emerged from the review of the transcripts, together with the findings and consequences (Table 2).

Table 1 Route Description

Routes	Collected Payload	Approx. Total Length/Day
Ulleval University Hospital, the National Hospital, and Aker University Hospital	Biological material and other goods between 07:30 and 14:30. Transported in bags, Styrofoam boxes, or envelopes. Envelopes are also used for mail between the hospitals.	80 km
Ulleval University Hospital, the National Hospital, and Red Cross	Five trips to the National Hospital. Blood is transported in suitcases, transport bags, or Styrofoam boxes. Mail between the hospitals is transported in a laptop bag.	86 km
Radium Hospital, Aker University Hospital, Ulleval University Hospital, and the National Hospital	Pathologic samples between 08:00 and 16:00. Samples are transported in gray boxes. Mail for the other hospitals is in pink boxes.	124 km

Table 2 Categories That Emerged from the Transcripts

#	Category	Description	Findings	Consequences
1	Change and adjustments of routes	This theme describes changes to the routes and the degree to which the carriers believe they have the power to change and adjust the routes.	The routes have existed almost unchanged over a long time with only minor adjustments. Change is typically initiated top-down. The hospital divisions and laboratories are the gatekeepers of change.	We thus observe that making changes to routes is difficult to accomplish.
2	Customer perspective	The carriers have a service function with respect to the laboratories. This theme describes how the carriers perceive and represent their roles.	The service offering depends on the carriers' attitude and familiarity with the locations. In addition to the transport of samples, the carriers help to place samples, and supply empty racks and containers. They help transport mail, fabrics, garbage, medical equipment, and medicine.	Lack of incentives and influential force to change the system may lead the carriers to become rather passive service workers, ie, not actively trying to change the system.
3	Service Structure	The service structure looked at conditions of how the service is organized today.	Constant delays when picking up samples, because the carriers are asked to wait a few minutes until the samples are ready for transport. The carriers follow a schedule with fixed times, which includes additional time for waiting.	In relation to drones, the delays may be problematic because drones fly according to scheduled times. One carrier pointed out, "following the plan [routing] slavishly also means not being able to wait."
4	Management of change	This theme describes who may be responsible for change and if carriers have areas where they can discuss and exchange ideas.	The carriers suggested that they should be involved in changing routes. Furthermore, the carriers wanted to have leaders who appreciate their meaning, as well as space to experiment and try out new things.	The carriers indicated that greater involvement would result in their being more motivated and satisfied at work. Furthermore, the carriers may have no space for exchanging their concerns or ideas about how to improve the current system.
5	Threats and support by drones	This theme deals with anxiety about possible job loss and how carriers think drones could support their work.	The carriers assessed the use of drones for transport purposes as a threat, because for them drones had been talked about as a replacement for their service offering. However, the carriers also argued that drones could support their work.	The carriers are afraid of being sacrificed for efficiency goals or private companies that overtake the transport. The carriers are convinced that although technology may replace some work, there will always be a need for a backup. Furthermore, they do not believe that drones can replace them in meeting the transport needs to which they cater with "road vehicles" today. Different sizes, weights, and established routines that are difficult to change were mentioned as reasons. However, the carriers are open to using drone support. One carrier argued, "Carriers plus drones can complement each other", while another added, "All of the carriers have additional routes they could give to a drone to make it easier for themselves." Another suggested, "Drones may replace 'road vehicles' for all the taxi trips that the laboratory orders."
6	Miscellaneous	This theme describes the miscellaneous observations that were made while accompanying the carriers.	Transport boxes are not standardized and varying in size and material. Furthermore, carriage issues, such as leaked formol may be dangerous for drone flights.	Transport solutions are not suited for transportation by drone.

Questionnaire

Sample Characteristics

The mean age of the 16 participants was 48.34 years (SD 2.88). The mean number of years worked at OUS was 11.75 years (SD 3.18).

A summary of the most relevant questions in the questionnaire is presented below in Table 3.

Time Measures of the Routings

The routes that we joined were driven daily between 07:30 and 16:30. Table 4 shows the mean, maximum, and minimum driving times and loading times and the estimated total transport times. In the multi-leg routings, the loading times are the sum of all loading times at each site.

Table 4 shows that the loading time represented 33–64% of the total transport times, and the high loading times were often caused by one delay at one of the stations. In our assessments for improvements of the transport routings, we used the mean driving time in direct routes and the shortest loading time, assuming that the latter represented a realistic improvement if better logistics are implemented.

Times from the current and suggested new routings are compared in the upper part of Table 5, the direct routings in the lower part. The most profound gain was observed by transforming the multi-leg routing to direct routings. This is illustrated in Figure 3 for the two most complex routings; the Ulleval-Aker transport with four legs and the Radium-Aker with three legs.

A simple illustration is shown in Figure 3.

Using such modifications to the existing routings, it was theoretically possible to use one less car compared with the current system.

As a summary of our findings, we observed that the carriers had substantial knowledge of how the current transports could be improved, they were interested in how new solutions should be developed, and not least, the timelines of the current ground transport could be substantially improved by simple changes.

Discussion

This study examined basic topics related to logistics, service levels, and personnel involved in an existing ground transport system that it has been suggested could be substituted for by drone transport. Our findings showed that insights

Table 3 Summary of the Most Relevant Questions in the Questionnaire

Category	Scale	Variable
Threats		
Are you concerned that your work might disappear or that you might lose work because of technological development?	Yes/No	5/11 (31/69%)
Are you optimistic that technology can improve your work in the future? Pessimistic—Optimistic	Scale 1–5	3.00 (SD 1.36)
Initiating		
Do you think a future drone-based transportation of biological material (blood samples, biopsies, other material) is realistic?	Yes/No/Do not know	9/2/5 (56/13/31%)
Do you think your hospital will use drones in the future?	Yes/No/Do not know	9/1/6 (56/6/38%)
Involvement		
Does your leader support innovative ideas?	Yes/No	1/15 (6/94%)
Do you have an arena to discuss and/or test innovative ideas in your unit?	Yes/No	2/14 (13/87%)
Are your leaders active in planning for future change?	Yes/No	0/16 (0/100%)
Are you involved in the planning for future change?	Yes/No	1/15 (6/94%)

Table 4 Driving, Loading, and Optimized Times

Existing Routes	Average Driving Time	Average Loading Time	Maximum Loading Time	Minimum Loading Time	Mean Total Transport Time	Loading Time as % of Total Transport Time
UL-AK-RH-UL	40,2	33,6	48,0	25,0	73,8	46%
UL-RA-RH-AK-UL	44,4	43,7	83,0	21,0	88,1	50%
UL-RA-RH-RA-UL	63,0	30,7	43,0	23,0	93,7	33%
UL-RA-RH-UL	39,0	68,0	82,0	55,0	107,0	64%
UL-RH-AK-UL	22,3	24,8	42,0	7,0	47,0	53%
UL-RH-RK-UL	39,0	39,3	45,0	35,0	78,3	50%
UL-RH-UL	19,3	17,5	46,0	8,0	36,7	48%
UL-RK-UL	27,3	28,4	44,0	16,0	55,7	51%
Average All	30,0	27,8	83,0	7,0	57,9	48%

Notes: All times in minutes.
Abbreviations: UL, Ulleval Hospital; AK, Aker Hospital; RH, the National Hospital; RA, Radium Hospital.

Table 5 Current and Direct Route

	Route	Ulleval-Aker (4 Legs)	Radium-Aker (3–4 Legs)
Current Route (Multiple Legs)	Mean driving time	44.3	43.0
	Maximum driving time	59.0	52.0
	Minimum driving time	35.0	35.0
	Mean loading time	23.9	40.2
	Maximum loading time	67.0	83.0
	Minimum loading time	10.0	16.0
	Mean total transport time	**68.2**	**83.2**
	Maximum total transport time	126.0	135.0
	Minimum total transport time	45.0	51.0
Direct Route	Mean Driving Time	14.0	28.0
	Maximum driving time	16.0	40.0
	Minimum driving time	11.0	18.0
	Minimum loading time	10.0	8.0
	Mean Total Transport Time	**24.0**	**36.0**
	Time Saved	**44.2**	**47.2**

Notes: All times in minutes.

from the carriers who perform the current ground transport contributed knowledge helpful in optimizing the existing transport solution concerning the overall functionality. More general, our generated insights on structure, culture, and attitudes may be relevant to obtaining a more innovative transport system. This, in turn, provides information about how drones should be implemented, either as a substitution for or as an integrated part of current ground transport.

The carriers had a somewhat passive attitude toward the system performance, which seemed to be associated with their perception that they had little influence on how the existing system is developed and improved. The current solutions have mostly remained unchanged for 20 years, although the carriers stated that they had presented several ideas for improvement. Their impression was that although the external framework for transport had changed in many ways

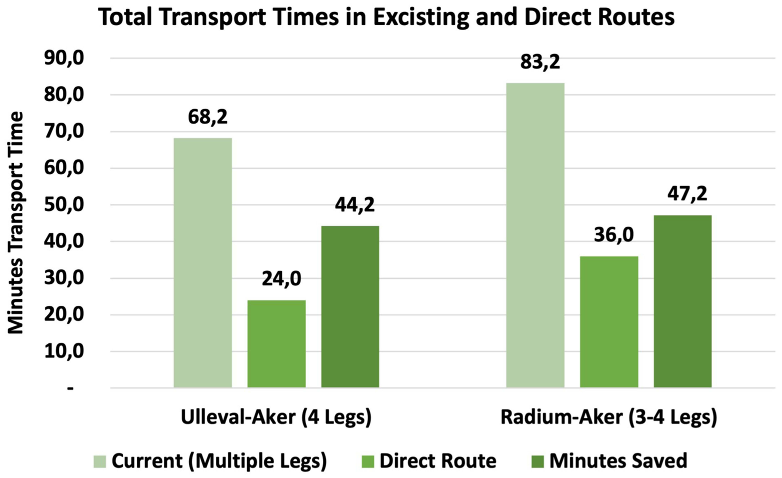

Figure 3 Total transport times in existing and direct routes.

over the period, their proposals for improvements for example HUBs were rarely discussed. The carriers said that they were open-minded regarding involvement in solving problems and improving quality, but that they perceived the institution as having a deficit in open-minded management.

From our interviews, we concluded that the carriers have suggestions regarding how to reduce transport times and improve regularity and how drone transport should be integrated with current solutions in the future. They are motivated to contribute to the implementation of drone services with a positive attitude, but their expectations of being involved are low because they feel that their workplace does not involve in the innovative processes. Although this perception was strong among the carriers, we suspect that this is not representing the actual state of the department and assume that the carriers' statements that none of the leaders are active in planning for future change are considerably biased. Furthermore, the fact that only 31% of the carriers had some worries about their future jobs if drones were implemented is not equivocally telling they are scarcely involved in system development and organization. Nevertheless, we conclude that involvement should be considered because carriers do more than just transport goods; they also significantly influence how this transport works concerning how their customers are acting and the service quality perception of the customers.

We observe that the current ground transport system is not primarily focused on transport times, but rather on maintaining flexibility for the laboratories that are their customers. If the laboratories ask for the transport to wait and postpone a given departure, this is accommodated, despite that this will cause a delay. This flexibility may be part of the explanation for some of the long loading times that we observed. Whereas such flexibility may seem valuable for the actual site requesting elasticity of the transport at an actual time, there is scarce knowledge of whether this reduces the total service when all transport legs are considered as a whole.

This was also reported by the carriers. They had multiple examples of how the flexible departures were often caused by insufficient planning and processes in the laboratories to prepare for the pick-up. This indicates that, whereas the routings are organized as regular trips, the laboratories may act as if the transports are tailored to the laboratories' insufficient preparations. Accordingly, a consequence of their efforts to satisfy their customers is that there are often delays, with consequences for subsequent trips.

We, therefore, conclude that the current transport system is not considered time-critical; that is, the total transport times are not being monitored or processed for standardization or optimization. This, in turn, sparks the question of whether the "timely" demand of the current transport system makes it a good candidate for drone solutions. With the short distances between transport sites, the time savings from drones will be limited. The optimized times in Table 5 show an improvement of 17–38%, calculated in minutes saved; this indicates an improvement between 5.4 and 16.3

minutes. It may be argued that any minutes saved by a drone carrying a cardiac defibrillator could save a life. However, it may be doubted that this is equally crucial to transporting routine blood samples. Some minutes saved may have marginal clinical significance in specific healthcare systems where patients may wait for months for their first contact with healthcare provisions.[14] Furthermore, to what extent faster transport will influence the efficiency of healthcare to any significant degree may be an open research question.

If the variations in the transport times and loading times that we observed are acceptable, this may indicate a limited willingness to pay for drone solutions. The potential competitiveness of drones will therefore be related to whether they have lower costs than the current ground transport system for comparable service times or result in real-time savings.

If large cities have frequent future drone trips and routings for multiple sectors and with many operators, drone transport should be expected to be strictly regulated by time slots and trajectories of unmanned BVLOS flights. This may, in turn, demand strict and timely routings with minimal deviations, and the “flexible departures” in the current ground transport system at OUS may violate such regulatory criteria. This may have a significant impact on how drone solutions are organized in urban locations.

The potential of drones to avoid ground traffic congestion has also been used as an argument for the time savings achieved by drone implementations.[13,44–47] Furthermore, in this context, stricter organization of the routings may be needed. In our system, it was the loading times and not the driving times that caused the highest deviations from plans and may thus represent the area with the greatest need for improvement. The minimum loading times as benchmark times promise considerable potential for time savings. However, whether such improvements, with only minutes, gained per leg, have any clinical value at all remains to be evaluated.

Theoretically, building a revised model with optimized transport times could change the existing route organization. The optimized total transport times show that hourly routings may be a realistic alternative to the current model and that one round-trip leg with one car could handle transport needs with shorter transport times than the existing ones. In our theoretical redesign, one car and carrier could be made redundant, thereby having some gains. Such improvements should be implemented before comparison between drone and ground transport is performed. However, our theoretical model would demand strict loading and departure times; otherwise, substantial delays may occur. The value of strictly regular departures is that missing a specific departure, and thus waiting for the next one, will cause minimal delays.

Will Drone Implementation Need Specific Organizational Processes for Implementation?

The current transport routes are not complex, and they are not focused primarily on transport times. Improvements should be realistic either with or without drones. Drones may therefore represent a logistical solution with relatively little impact on organizational processes and may have little effect on other clinical services apart from the transportation service. This suggests that the implementation of drones may be rather uncomplicated concerning the pure transport topic. Therefore, we conclude that the institutionalization of drones, ie, the process of innovation,[48] may be achieved without many complex processes. This is in accordance with our findings, as only five of 16 carriers expressed concern in the questionnaire.

Our study showed that the current system focuses on flexibility, but although the current solution has not been changed extensively in the last 20 years, there should be a regular assessment of which topics are the most valuable for the laboratories.

An alternative to a simplistic approach to drone implementations in simple models like ours, is the hypothesis that in more complex systems, such solutions should be considered from a broader organizational perspective. The combination of micro-behaviors as individuals adopt an innovation, ongoing regime developments and landscape pressures may, over time, result in more significant system changes. One perspective could be that the transport department rebrands itself as an innovation hub for logistics with an open culture for experiments and change. As a carrier put it, “The old structure needs to be cracked to be more innovative.”

The theory, however, is that socio-technologic transitions require the interplay of technological and social processes that reinforce each other.[25] In our setting, our insights into the technological process are scarce because drone technology solutions are developed externally and not from a hospital perspective. Diffusion across technology and medical processes related to drones may therefore be rather limited. Although drones may seem promising, there is no guarantee for drones to break through and disrupt laboratory transports.

Getting support from drones was discussed as a valuable add-on to the service offering of the transport department. According to the carriers, drones may be used for specific routes, ie, as a replacement for taxi trips that today are used for emergency analysis or outside of regular working hours. However, economic, or technological considerations may strongly influence whether this is realistic, and there are not many scientific data to enlighten this topic.

However, the carriers seemed to have the essential knowledge about logistics and the continuous transport of biological material and other goods and they believed that a combination of drones and the current system may be beneficial. Including them in the introduction of drones may support the acceptance of drones, a topic that has gained much interest in the literature.[49–54]

Limitations of the Study

The small volume of data in the current study may of course be observed as a significant limitation. Small volumes may both challenge the validity of scientific conclusions as well as the soundness for generalization across differing systems. However, our conclusions are not depending on complex scientific deductions but logical conclusions from simple observations and we intended to elaborate on possible ideas for simple approaches. We hypothesize that the generalizability of such findings across differing systems may depend more on systemic differences related to service need and structure, than on the specific findings in each setting.

Although Oslo University Hospital is a large hospital, compared to European standards, the distances between the various locations are short. Furthermore, traffic congestion is probably less than in many larger cities. Therefore, some of our findings may not apply to other locations. Large hospitals in other cities may have quite different structures and transport needs. Nevertheless, involving the workforce in providing transport solutions may reveal important insights.

Our finding that current ground transport could easily be improved is therefore specific to a rather plain model. The interviews were conducted at the OUS transport division and are ultimately not representative of other hospitals or transport departments. Furthermore, the existing ground system with “road vehicles” at Oslo University Hospital is not based on transport times but flexibility for the laboratories. Although these factors may limit the generalization of our actual findings, it may be of value for other transport departments and hospitals to conduct similar research to understand how carriers value drones. Their narratives provided insights and underscore the necessity of open-minded and innovative leadership to facilitate change and acceptance.

This study focused on topics related to current transport solutions and showed that a comparison of drones with optimized ground transport shows close competition. The argument about avoiding ground traffic congestion and the value of time efficiency has been put into perspective. Of course, if drone transport shall be implemented in future transport solutions, multiple infrastructures are needed such as landing sites and automatic solutions for loading and unloading, drone surveillance and drone maintenance. Unfortunately, the study of such topics is currently challenging to perform today because of the immaturity of such solutions. It should also be expected that various types of drones and drone sizes will be used for differing purposes, demanding differing solutions for the mentioned structures. No doubt, such perspectives will be necessary to define in future studies. Nevertheless, the advantages of drones in other settings may be more evident. For example, drone transports in rural districts and on-demand services in emergencies have proven valuable and may have more significant clinical value, resulting in greater willingness to pay, than short-distance transports.

Although a sociotechnical perspective with the MLP and transitions research has a powerful analytical force, transitions do happen without it. The purpose of our conceptualization was to broaden our understanding of how to implement drones into existing systems. We believe that several future research opportunities, such as the impact of drones on organizational processes and social dynamics in the adoption of drones, may extend the understanding of these questions and nudge transitions in the desired directions, and have significant relevance in more complex settings.

Conclusion

The carriers involved in this study had useful knowledge of how future drone solutions should be implemented and were positive about the use of drones as part of their future services. They showed that existing transport solutions should be analyzed carefully to realize possible improvements before drones are implemented. The lesson learned from their input is that drone implementations should be evaluated in context with current ground solutions, either as integrations into or partial substitutions for current services, and that involved personnel should be involved in developing such solutions.

We conclude that in straightforward transport systems such as the one we examined, improvements to current solutions may be obtained without complex processes. This may of course vary between different locations, service demands, and the complexity of the services. Whether an extended organizational perspective of drone implementations is needed in more complex settings needs further research. We also conclude that although improvements may be obtained by unsophisticated changes, the potential for added organizational and innovative processes should always be considered, in particular, if multiple new technologies are included.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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Disclosure

The authors report no conflicts of interest in this work.

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Appendix A

Statements of co-authorship

Statements of co-authorship from:

1. Karl-Arne Johannessen
2. Martina Keitsch

To whom it may concern

Statement of co-authorship on joint publications to be used in the PhD-thesis of
Hans E. Comtet

As co-author on the following joint publications in the PhD-thesis "Drones in Healthcare Systems: Insights from a Multi-Level Perspective" by Hans E. Comtet

Declaration of co-authorship on the following articles:

(1) H. E. Comtet and K. A. Johannessen, "*A Socio-Analytical Approach to the Integration of Drones into Health Care Systems*," Inf., vol. 13, no. 2, p. 62, 2022, doi: 10.3390/info13020062.

The paper was written by Comtet and Johannessen. Comtet created the first draft. The authors jointly created a first coding scheme and followed an inductive process to develop categories.

(2) H. E. Comtet and K.-A. Johannessen, "*The moderating role of pro-innovative leadership and gender as an enabler for future drone transports in healthcare systems*," Int. J. Environ. Res.Public Health, vol. 18, no. 5, pp. 1–15, 2021, doi: 10.3390/ijerph18052637.

The paper was written by both Comtet and Johannessen. Comtet created the first draft, both authors created the questionnaire, Comtet distributed it. Both authors analyzed the data, Johannessen performed the statistical analyses.

(3) Comtet HE, Keitsch M, Johannessen KA. "*Realities of Using Drones to Transport Laboratory Samples: Insights from Attended Routes in a Mixed-Methods Study,*" J Multidiscip Healthc. 2022;15:1871-1885, https://doi.org/10.2147/JMDH.S371957

Comtet wrote a first draft of the paper. Comtet and Johannessen planned the data collection. Comtet collected the data. Johannessen conducted the data analysis and contributed to the writing process. Keitsch provided feedback and comments throughout the writing process.

I declare that his contribution to the papers is correctly identified, and I agree that this work is to be used as part of the thesis.

Oslo 17.12.22
……………………...
Place, date

……………………………………………….
Karl-Arne Johannessen

To whom it may concern

Statement of co-authorship on joint publications to be used in the PhD-thesis of Hans E. Comtet

As co-author on the following joint publications in the PhD-thesis “Drones in Healthcare Systems: Insights from a Multi-Level Perspective” by Hans E. Comtet

Declaration of co-authorship on the following articles:

(1) Comtet HE, Keitsch M, Johannessen KA. “*Realities of Using Drones to Transport Laboratory Samples: Insights from Attended Routes in a Mixed-Methods Study,*” J Multidiscip Healthc. 2022;15:1871-1885, https://doi.org/10.2147/JMDH.S371957

> Comtet wrote a first draft of the paper. Johannessen and Comtet planned the data collection. Comtet collected the data. Johannessen contributed to the writing process. Keitsch provided feedback and comments throughout the writing process.

I declare that his contribution to the papers is correctly identified, and I agree that this work is to be used as part of the thesis.

Trondheim 20.12.2022
……………………….
Place, date

…………………………………
Martina Keitsch

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