Innovation and Digital Global Public Goods

A case study of digital innovation during the Covid-19 pandemic

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Abstract

Digital platforms are known to support innovation by facilitating interactions between the platform and the actors in an ecosystem. However, research on such platforms are often focused on commercially motivated platforms where value is seen as profit. Less is known about digital platforms that support innovation as a digital global public good. Motivated by the context of the Covid-19 pandemic, the importance of digital innovation as response, and the global nature of the situation, this thesis presents a qualitative case study of how a software platform supported digital innovation in two countries as a digital global public good. Two research questions are asked: *How can digital global public good software platforms support digital innovation?*, and 2) *How can our understanding of digital global public goods be informed by digital innovation and software platforms?* The study finds three supporting factors of innovation, namely 1) enabling adoption of software by being freely downloadable, modifiable, and redistributable as open source software, 2) offering existing, customizable and generic software applications in a layered modular architecture, and 3) leveraging on local capacities, efforts and collaborations in the ecosystem. Additionally, this thesis contributes with a discussion of how digital global public goods can be understood by digital innovation and software platforms by arguing 1) that the supporting factors of innovation in the software platform can be linked to its nature of being a DGPG, and 2) seeing the supporting factors of innovation together, a platform ecosystem can generate positive network effects that can benefit all.

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Acronyms

API Application Programming Interface

DGPG Digital Global Public Good

DHIS2 District Health Information Software 2

GPG Global Public Good

HISP Health Information Systems Programme

IS Information Systems

KS The Norwegian Association of Local and Regional Authorities

NIPH The Norwegian Institute of Public Health

SDK Software Development Kit

UiO University of Oslo

WHO World Health Organization

Chapter 1

Introduction

Digital platforms, and especially software platforms, are known to support innovation. The architecture of software platforms enable innovation by being extensible and supporting complementary application innovation (Tiwana, 2013), technical boundary resources of a platform supports third-party innovation by enabling access to digital resources from the platform (Ghazawneh & Henfridsson, 2013), and increased numbers of software developers of different kinds of software in a platform ecosystem produce increased innovation incentives with the platform, which leads to positive network effects (K. J. Boudreau, 2012). However, most of the studies on innovation in software platforms are centered around businesses and commercial platforms (value as profit) (Cenamor & Frishammar, 2021; Gawer & Cusumano, 2002; Parker et al., 2017) and competitive capabilities and opportunities using digital platform technology and strategies (Constantinides et al., 2018). IS researchers has recently called for research on platforms with non-commercial purposes, such as addressing developmental impact (Koskinen et al., 2019; Nicholson, Nielsen, & Saebo, 2021), social goals (Bonina et al., 2021), and ethical and critical goals (Walsham, 2012). Recently, one theoretical concept has tried to address this gap by capturing a notion of how some technologies are able to support global challenges/needs as digital global public goods (DGPG), which are defined as *digital goods designed as non-rivalrous, non-excludable, locally relevant on a global scale*" (Sæbø et al., 2021). These digital technologies are available to be consumed by all, does not reduce the consumption of others, and are locally relevant in use across contextual boundaries. However, the empirical research on this concept is scarce and further conceptualization is needed to gain theoretical legitimacy in the information systems agenda. This thesis is motivated by the real-world problem situation of the Covid-19 pandemic and the role of digital innovation in response to the related challenges. The thesis will contribute to reduce the knowledge gap of platforms with non-commercial goals by presenting a case study of how a software platform supported innovation as a digital global public good during the pandemic. More specifically, the aim of the study is to understand how software platforms as digital global public goods can support innovation, and how the concepts related to software platforms can inform understanding of DGPGs.

1.1 Motivation and research questions

The Covid-19 pandemic has caused major challenges globally. Public health sectors in countries has had to respond to challenges such as developing vaccines, (Calina et al., 2020; Forni & Mantovani, 2021), conducting vaccination (Mills & Salisbury, 2021), digital contact tracing (Ahmed et al., 2020; Chowdhury et al., 2020), data management (Galaitsi et al., 2021), and more. Efforts to mitigate the emerging obstacles has led to forced digitalization efforts in health care services and increasing demands for certain goods and services (Serbulova et al., 2020). Major changes in health care institutions has thus been necessary, and digital technologies has played an essential role in the adaptations to the pandemic (Gundersen et al., 2020; Gundersen et al., 2021).

Digital innovation has been key to address the variety of challenges in public health sectors during the pandemic (Furtner et al., 2022; Woolliscroft, 2020). Adoption of digital technologies has supported health care with everything from diagnosis and patient monitoring (Ciotti et al., 2020), epidemiological surveillance (Budd et al., 2020), contact tracing (Mbunge, 2020), and numerous of other use cases. Likewise, a large set of varied digital technologies has been leveraged to innovate, ranging from artificial intelligence and internet of things (Serbulova et al., 2020) to survey applications and data visualization (Budd et al., 2020).

The importance of digital innovations and information systems for handling various needs related to Covid-19 has been apparent, and the academic field of information systems has responded. Information systems (IS) research has been called for to contribute with knowledge and insight about the role, centrality, value and even negative sides of information systems in times of the Covid-19 pandemic (Ågerfalk et al., 2020), such as how digital technologies and innovations can be leveraged for strengthening public health c apabilities (Rai, 2020). Additionally, IS research has the opportunity to study digital innovation due to less resistance towards technological progress in the pandemic times (Hovestadt et al., 2021).

One digital technology which has had less attention in IS research in relation to the pandemic, and which has significant innovation potential responding to the challenges of Covid-19, is the digital platform. Some types of digital platforms are known for facilitating and enabling digital innovation (Evans & Gawer, 2016; Gawer & Cusumano, 2014; Sun et al., 2021), and digital platforms has indeed played an important role in the response to the pandemic. E.g. India, a country which offers more than 20 digital platforms provided by the Government of India to its citizens, has produced digital innovations for e.g. updating and informing the citizens, telemedicine consultations, and logging of vaccinations (Ghosh, 2021). Digital platforms of mobility services (e.g. ride-sharing services) has also illustrated how the sociotechnical nature of platforms and ecosystems has contributed to resilience against the Covid-19 pandemic by enabling external actors to innovate (Floetgen et al., 2021).

Even though many digital innovations has been developed and/or adopted locally, the pandemic has also sparked international and collaborative innovation efforts (Farrugia & Plutowski, 2020; Lee & Trimi, 2021; McCausland, 2020). Innovation with digital platforms can have global reach and implications and as noted "*(...) we must translate the cooperation that was catalyzed by COVID-19 to a platform for future innovation to benefit people globally. We must continue to activate large networks and resources to solve complex problems simultaneously instead of solving them one at a time in isolation. This will accelerate the digital platform model in health care and help more people*" (Farrugia & Plutowski, 2020, p. 576).

As an effort to recognize the global nature of problems such as pandemics, the notion of *digital global public goods* are increasingly gaining attention in the public discourse on information technology. In June 2020, the United Nations Secretary-General published a The Roadmap for Digital Cooperation recommending to promote digital public goods for a more equitable world (United Nations, Office of the Secretary-General's Envoy on Technology, 2020). There has also been a call for governments to "*provide comprehensive governance and leadership to define globally agreed rules on the sharing of health data for the future of equitable health care*" (The Lancet Digital Health, 2021). Accordingly, some digital platforms show characteristics that accommodate the call for globally oriented and equitable technologies while at the same time supporting local relevance in use (Nicholson, Nielsen, Sahay, et al., 2021; Sæbø et al., 2021).

This thesis is motivated by the real-world problem situation of the Covid-19 pandemic, the importance of digital innovation when responding to the challenges, and the global nature of the problem situation. Accordingly, this thesis studies how global public good software platforms can support innovation. More specifically, this research investigates how an open and globally oriented health software platform supported Sri Lanka and Norway with digital innovations during the Covid-19 pandemic.

This thesis aims to 1) understand how a software platforms as a digital global public good supports innovation, and 2) how we can better understand digital global public goods by studying digital innovation with software platforms. Accordingly, this thesis is centered around the following two research questions:

1. *How can digital global public good software platforms support digital innovation?*
2. *How can our understanding of digital global public goods be informed by digital innovation and software platforms?*

The thesis answers these questions by presenting a qualitative case study of the health software platform, DHIS2, considered as a digital public good by the Digital Public Good Alliance (see digitalpublicgoods.net), and outlining how it supported countries with innovation during the Covid-19 pandemic, and accordingly present how digital global public goods can be understood by studying such software platforms.

Chapter 2

Related research

This chapter presents the theoretical background of this thesis, and aims to account for the theoretical lens which is used to frame the case study when answering the two research questions. Three main theoretical concepts makes up a framework for understanding the studied phenomena, namely *digital innovation*, *digital platforms* and *digital global public goods* (DGPG). The following sections explains how the thesis draws on these concepts and which perspectives of each concept is applied.

2.1 Digital innovation

The phenomena of digital innovation is a central topic in the information systems research agenda (Hund et al., 2021; Nielsen, 2017; Yoo et al., 2010), and has several definitions and perspectives serving different purposes. One common definition is digital innovation "*as the carrying out of new combinations of digital and physical components to produce novel products*" (Yoo et al., 2010, p. 725). This definition presupposes and emphasizes that digital innovation is about recombining digital and physical loosely coupled components. The aim of doing so is to produce new products, and thus is digital innovation realized.

However, digital components differs from physical components in terms of how and why they can be recombined. Digital technology enables recombination by its characteristics of *reprogrammability* (flexible manipulation of digital processing units), *homogenization of data* (all digital contents are processed as bits, and thus being accessible to any digital device), and the *self-referential* nature of digital technologies (digital innovation requires digital technologies)

(Yoo et al., 2010).

Physical technologies are typically designed with an integral architecture (tightly coupled components without a standardized interface between them e.g. a car) or modular architecture (loosely coupled, recombinable components with a standardized interface between them) with product specific components and boundaries (Yoo et al., 2010). Digital products, however, bring forth potential of a new type of product architecture called the *layered modular architecture* (Yoo et al., 2010). This architecture leverage upon the characteristics of digital technologies to create a hybrid of modularity (recombinable components) and layers (device, network, service and contents layer) where innovation can take place at any layer, re-enabling new innovation at and with other layers.

Extending the idea of recombination as digital innovation, the notion of recombination can either refer to *use recombination*, which refers to the "*activity of generating an individual value path by connecting digital resources in use*", or *design recombination*, which refers to the "*activity of generating a value path by connecting digital resources as a value offer to users*" (Henfridsson et al., 2018). In other words, digital innovations materialize when digital resources (or i.e. digital building blocks) are, respectively, either recombined by and for the user to create new value paths (e.g. using Microsoft Word to write a report, and then using e-mail to distribute the report to others, creating a new path of value in use), or firms by connecting different digital offerings to create new value paths (e.g. a travel agency combining both hotel and flight reservation services to create value as a comprehensive service for travelling). In sum, one central characteristic of digital innovation is recombination of digital components/resources.

A similar perspective of digital innovation recombination of digital components, however with different emphasis, is the perspective of digital innovation as dynamic problem-solution design pairing (Nambisan et al., 2017). This notion presupposes that digital artifacts has capabilities that can be matched with socially grounded problems. Digital innovation is thus viewed as the "*matching of the potential (or capabilities) of new/or newly recombined digital technologies with original market offerings*" (Nambisan et al., 2017, p. 226). This definition highlights the fit (or mitigation) between social problems/needs and the capabilities of digital components/resources, indicating that digital innovation is of a sociotechnical nature.

Based on the capabilities of digital technologies to be molded to fit social needs, digital technologies can be generative. Generativity often refers to the capacity of digital technology to "*produce unprompted change driven by large, varied, and uncoordinated audiences*" (Zittrain, 2006, p. 1980). This definition was originally used to explain the nature of the internet as a technology, and emphasizes unpredictable change by unforeseen actors. A more recent and precise definition is generativity as "*a sociotechnical system where social and technical elements interact to facilitate combinatorial innovation*" (Thomas & Tee, 2021). This definition puts emphasis on how social and technical phenomena are intertwined and enables combinatorial innovation, which other empirical research highlights and conceptualizes as sociotechnical generativity (Msiska & Nielsen, 2018). The notion of generativity is thus in line with the aforementioned characteristics of digital innovation as technical capabilities of recombination, and the matching between digital capabilities and social problems.

In summary, digital technology with the characteristics of reprogrammability, homogenization of data, and self-reference, with a layered modular architecture, enables recombination of digital components which produces unanticipated *combinatorial innovations* (Yoo et al., 2012) that can be valuable by being matched with real-life problems. Digital technologies thus have capabilities and potential to gain a *generative* nature (Thomas & Tee, 2021).

Table 2.1: Summary of framework of digital innovation

Characteristic	Explanation
Recombination	Digital innovations occur when digital resources are combined to create new value or products (Henfridsson et al., 2018; Yoo et al., 2010)
Problem-solution design pairing	New value is created when the combination of digital resources are matched with a social problem (Nambisan et al., 2017)
Generativity	The recombinability of digital resources enables innovation in unpredicatable ways and by vast audiences (Yoo et al., 2012; Zittrain, 2006)

2.2 Digital platforms

Research on digital platforms has over the last decade gained a lot of attention in information systems research (Jeyaraj & Zadeh, 2020; Teubner & Stockhinger, 2020), and other domains such as economics (Kenney & Zysman, 2020; Rochet & Tirole, 2003), health (Kickbusch et al., 2021), operations management (Esposito De Falco et al., 2017) and studies within organizational science and business management (K. Boudreau, 2010; K. J. Boudreau, 2012; Thomas et al., 2014; Wareham et al., 2014). The digital platform has also become an important research topic in development studies (Bonina et al., 2021; Heeks, 2020; Koskinen et al., 2019; Nicholson, Nielsen, & Saebo, 2021; Poppe et al., 2021; Russpatrick, 2020) which this thesis will touch upon in the discussion chapter.

There are several definitions the digital platform concept and it largely depends on the perspective and research domain. In information systems research, one common definition is that a digital platform is an "*extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate*" (Ghazawneh & Henfridsson, 2013; Tiwana et al., 2010), or simpler put "*an extensible codebase to which complementary third-party modules can be added*" (de Reuver et al., 2018). This common view outlines a distinct digital technology that provides core functionalities, but also support scalability by enabling addition of new functionality. This scalability (or extensibility) is usually enabled and constrained by the architectural design.

Digital platform architectures are distinct from other digital technology architectures in the way that it "*allows for development of its own computing functionalities and allows the integration of information, computing, and connectivity technology platforms available to an organization*" (Sedera et al., 2016). The digital platform embodies a modular architecture (Gawer & Cusumano, 2014) of some stable/core components which stays unchanged, some flexible components that supports change and variety (Baldwin & Woodard, 2009; Tiwana et al., 2010; Ulrich, 1995) and an interface between them (Gawer, 2009). A simplified example is Apple devices as stable core components, content components (apps) that are flexible by how they can be changed, added and removed, and the Apple Store as the interface between them. Which, why and how components stay fixed or flexible and for what depends largely on the type of digital platform and its purpose.

Digital platforms are commonly distinguished between two types, namly transaction platform and innovation platforms (Bonina et al., 2021; Evans & Gawer, 2016; Gawer, 2014; Koskinen et al., 2019). The *transaction platform* facilitates and generates value from interactions between actors in a multi-sided market (Kenney & Zysman, 2020; Rochet & Tirole, 2003), while the *innovation platform* facilitates actors to develop applications and services on top of a technological foundation as complements to the platform (Bonina et al., 2021; Cusumano et al., 2019; Evans & Gawer, 2016). Whereas transaction platforms seek to create an ecosystem of suppliers and consumers (Kenney & Zysman, 2020), innovations platforms seek to create an ecosystem of complementors (i.e. innovators) that innovate using the platform core resources (Parker et al., 2017). Other similar distinctions has been made by distinguishing between platforms that (for one firm) generate complementary products in the same "product family" (internal platforms), and platforms that opens up the platform components for complementary innovations by many firms (external platforms) (Gawer & Cusumano, 2014). This has implications for innovation because the purpose of the platform can produce different types of innovations (Rocha & Pollock, 2019). This thesis studies a software platform which is considered an innovation platform in the sense that it provides a technological foundation upon which other can innovate, and this perspective is adopted in this thesis.

From a sociotechnical perspective, the digital platform artefact mediates interaction between user groups (de Reuver et al., 2018) where the goal is to innovate and/or compete (Gawer & Cusumano, 2014). The perspective of the dynamics of interaction between platform developers, complementors (users that build on top of the platform) and the digital platform resources is often theorized as an ecosystem (Dittrich, 2014; Jacobides et al., 2018; Wareham et al., 2014) or platform ecosystem. A platform ecosystem has been defined as a "*a platform owner that implements governance mechanisms to facilitate value creating mechanisms on a digital platform between the platform owner and an ecosystem of autonomous complementors and consumers*" (Hein et al., 2020).

One type of value mechanism which is digital platforms are known to create is network effects, and digital platforms are dependent on an ecosystem of actors interacting with the platform's resources to produce the value as network effects (Constantinides et al., 2018; Gawer & Cusumano, 2002). Network effects materializes when the platform finds the right governance mechanisms (Wareham et al., 2014) and boundary resources (Ghazawneh & Henfridsson, 2013) to facilitate self-reinforcing loops in the ecosystem such as 1) more complements (e.g. as applications) leads to 2) more consumers/users leads to 3) more complementors wanting to produce complements to the platform, and repeat. When a platform manages to supports such effects in a favorable way, we refer to it as positive network effects. To understand what enables such effects of value creation, one must understand the complementors's goals and key motivations so that the governance mechanisms can accordingly be orchestrated (Rickmann et al., 2014).

In sum, the digital platform is a distinct information technology artefact (Bonina et al., 2021) that is characterized by layered modular architecture (Yoo et al., 2010) with stable core components and a set of varying complementary components (Gawer, 2009; Tiwana et al., 2010; Ulrich, 1995) that can be recombined (Henfridsson et al., 2018; Øvrelid & Kempton, 2019; Yoo et al., 2010) into leverage as new digital innovations (Thomas et al., 2014). Perspectives on digital platforms focuses often on how technology brings people together around mutually beneficial goals (Rickmann et al., 2014) to innovate (Rocha & Pollock, 2019) and co-create value (Hein et al., 2020) as a phenomena of interest. Digital platform theory highlights how the platform owner facilitates interaction with the platform and how the status and evolution of platforms produce different innovation outcomes (Isckia et al., 2018).

2.3 Digital global public goods

The notion of a *public good* is commonly known to stem from the economist, Paul A. Samuelson who wrote the paper "The Pure Theory of Public Expenditure" in 1954. In this paper, he introduces the term *collection consumption goods* which is explained as goods which " *all enjoy in common in the sense that each individual's consumption of such a good leads to no subtraction from any other individual's consumption of that good*" (Samuelson, 1954, p. 387). This is opposed to *private goods* which are shared to groups of people with attached property rights. A public good expands on the idea of collection consumption good concept by being defined as a good (thing, product, service, condition, etc, which can be consumed/provided by humans (Kaul, 2013)) which is non-exclusive and non-rivalrous. Respectively, this means that that no one can be excluded from the benefits of a good, and when doing so won't have implications for others benefit of it. Notably, a public good can be distinguished from being pure (being both non-exclusive and non-rivalrous, e.g moonlight) or impure (only meeting one of the conditions, e.g. by non-excludable, but rivalrous in consumption like a park) (Kaul, 2013). In this thesis however, the level of analysis of consumption of public goods is global-level, not on individual-level which is often the case.

A *global public good* (GPG) extends the definition by lifting the focus from consumers in restricted environments to consumers in cross-geographical and trans-generational perspective (Kaul, 2013; Kaul et al., 1999), such as countries, highlighting how all countries can benefit from certain goods when provided (Barrett, 2007). In other words, a GPG benefits all countries (non-excludable), and its consumption of one country does not affect another country's consumption (non-rivalrous). Understanding whether, how and why a good is global can be challenging and the the term is often misused (Love, 2020). However, several distinctions of GPG types has been provided as a framework. These types include single best efforts, weakest links and aggregate efforts (Barrett, 2007). A single best effort GPG is one that which only has to be provided once to produce the wished for benefit for all countries, e.g. knowledge about how to conduct lifesaving CPR. A weakest link GPG is when its provision/actualization requires all countries to participate and which depends on the "weakest link". If the weakest link (e.g. a country with scarce medical resources) is unable to e.g. eradicate a lethal pandemic in their country, the efforts of all other countries might be in vain since the spread will continue. And lastly, an aggregate effort GPG depends on all countries to participate no matter which country and with which resources, e.g. protection of the ozone layer.

Recently, papers from IS research has explored of how information technology serves as a global public good (Sahay, 2019) and the notion of *digital global public goods* (DGPG) has emerged, but its conceptualization is lacking coherence and grounding in empirical research. A multi-stakeholder initiative called Digital Public Goods Alliance addresses the sustainability development goals by promoting digital public goods defined as "*open source software, open data, open AI models, open standards and open content that adhere to privacy and other applicable laws and best practices, do no harm by design, and help attain the SDGs*" (Digital Public Goods Alliance, n.d.). This definition steers away from the traditional definition of public goods. This definition is stating explicitly which technologies that is considered digital goods, and sets institutional and value-laden conditions to which digital goods that can attain the DGP status. The condition of being global in this definition is implicit, since the the digital goods must help attain the sustainability goals, which is by definition global goals ("Sustainable Development Goals — United Nations Development Programme", n.d.).

IS researchers has outlined another definition of a DGPG as "*digital goods designed as non-rivalrous, non-excludable, locally relevant on a global scale*" (Sæbø et al., 2021) adhering to the traditional definition of public goods, but extends it to emphasize digital goods and its ability to be relevant for local contexts. The authors behind this definition explain "digital" in line with the characteristics of digital technologies mentioned in previous section on "Digital innovation" by being "reprogrammable, modularized, recombinable", but also adds that digital implies capabilities to being built upon, sharable, appropriated, and modified to gain relevance in multiple contexts (Sæbø et al., 2021). Further, the definition is explicit that digital goods can be purposefully designed for accommodating the three mentioned conditions of being non-excludable, non-rivalrous and locally relevant on a global scale. Another paper extends the definition to highlight how digital goods also "*displays positive network effects*" that are enabled by the characteristics of digital technologies as flexible and generative (Nicholson, Nielsen, Sahay, et al., 2021).

Some other research provides more nuance to understand the nature of a DGPG. A DGPG software platform shows how it actualizes its DGP nature when the right enablers for innovation are supported by the platform (Russpatrick, 2020), however, by seeking to address innovation for macro-level contexts (e.g. countries) can become paradoxical and impede the ability to scale globally because it constrains micro-level (e.g. disctrict) relevance (Nicholson, Nielsen, Sahay, et al., 2021). Other research shows that DGPG not does not comply with the ideal of a GPG simply because it is open source software, but it has to address other sociotechnical factors and gaps to be an effective GPG such as knowledge, governance, procurement, participation, capacity, and financial gaps (Sahay, 2019). Additionally, when a DGPG depends on provision of content by individuals, such as with Wikipedia, some incentives has been evidenced to be more effective to motivate users to contribute, such as when both social and private benefits are apparent (Chen & Yeckehzaare, 2020). Other research on Wikipedia also shows that higher unemployment is associated with increased participation and content generation on the platform (Kummer et al., 2020). An analysis of the public web as a public good sheds light on the complex ways in which consumption of the web can generate different benefits and costs for different private actors by the way users produce data that are captured and used privately (Melgarejo-Heredia et al., 2016). In sum, the nature of a DGPG is complicated. Understanding DGPGs largely depends on the technology type/design, its purpose, how its provided, incentives, and which benefits and costs that are produced (and for whom).

Chapter 3

Research approach

This chapter starts by outlining the contextual background of the study to lay the grounds of the methodological choices later. Then, the chapter continues to explain the philosophical underpinnings, methodology, methods and techniques used for this research.

3.1 Background and context

This study has investigated the health management information system, District Health Information Software 2 (DHIS2). DHIS2 is a web-based, open-source, health software platform (built with Java frameworks) used in 73 low to middle income countries, mainly in the global south [1]. The system is free to use and anyone can redistribute and modfiy it under the BSD-3-Clause license [2]. DHIS2 is abstract and is not designed for a specific or fixed context (Gizaw et al., 2017), but rather designed to meet generic use cases, such as e.g. tracking entities (individuals) through a health program. In order to address the local varieties in use cases, DHIS2 enables the user to easily configure the software in its interface settings, and/or redesigning it by editing or extending the source code enabled by its open source codebase (Gizaw et al., 2017).

Development of the software is primarily managed, coordinated and carried out by the Health Information Systems Programme (HISP). HISP is a global, collaborative network of countries,

[1] https://dhis2.org/about/
[2] https://opensource.org/licenses/BSD-3-Clause

non-government organizations (NGO), donors, 17 partner organizations, or so called HIPS groups, and other actors forming an ecosystem of actors working on designing, implementing, supporting and sustaining DHIS2 as a health information system in developing countries (J. Braa et al., 2004). HISP can also be considered a global action research project aiming at health information system implementation and capacity building by training and education, while also building theoretical knowledge on challenges related to scale and sustainability when implementing health information systems in developing countries (ibid).

HISP started as a post-apartheid project in South Africa in 1995, aiming to provide a health management system which could centralize health data and bring together a fragmented health sector in the country. A collaboration between University of Cape Town, University of Western Cape and University of Oslo eventually led to a successful development and implementation of a health information system, called DHIS, which reached national scale by 2001. This system was a standalone installation based on Microsoft Access and Visual Basic (Adu-Gyamfi et al., 2019). As similar projects was pursued in Mozambique and India, DHIS had to better support scalability of development and maintenance, and did so by transitioning from standalone installations to client-server (or cloud-based) architecture in 2005 enabling distributed development (ibid). This new version was called DHIS2.

Since then, DHIS2 has reached a global scale in terms of use and development. DHIS2 has evolved from a single-country project to a global network of countries and organizations supporting and implementing the software. This scaling has been achieved with development of generic software based on feedback from countries which can be adapted to local contexts while also promoting, supporting and redeveloping local innovations that are transferable and can be recontextualized in other countries, creating a circular innovation cycle between the local and global context (Sahay et al., 2013). The type of circular innovation is enabled by the platform architecture which consist of a stable core and pre-built, customizable applications, and boundary resources such as application programming interfaces and software development kits to support innovation of custom applications (Roland et al., 2017). Other factors has been important in enabling the scalability of DHIS2, such as capacity building through university education programmes and participatory design projects, implementation support by HISP groups, free and open source software (FOSS), support for offline use, and more (J. Braa & Sahay, 2012).

3.2 Philosophical underpinning

The research approach and application of research methods in this thesis is based on the epistemological assumptions of the interpretive research paradigm (Walsham, 2006). Interpretivism presupposes that ”*access to reality is only through social constructions such as language, consciousness, shared meanings and instruments*” (M. D. Myers, 2020, p. 45). Interpretive research aims for capturing social and organizational phenomena and the subjective understandings of humans (M. D. Myers, 2020). Ontologically, interpretive research considers reality as an ”intersubjective construction of the shared human cognitive apparatus” (Walsham, 1995), as opposed to positivist research which considers reality as objective and independent of our understanding of it (M. D. Myers, 2020). Positivist research is thus inappropriate since this research concerns humans and is conducted by interpreting human viewpoints (K. Braa & Vidgen, 1999). The overall research process and application of research methods has been guided by principles and ideas from the interpretive research tradition (Walsham, 2006). This includes sensitivity to participants and contexts in interaction with participants, acknowledging subjectivity in my own understanding of the context and construction of knowledge (Creswell & Poth, 2016, p. 32-33). The knowledge generated through this thesis has thus been drawn from a socially constructivist worldview by how the understanding of the researched context and interactions with participants has been based on subjective meanings from experiences (Creswell & Poth, 2016, p. 24). In sum, the idea of interpretivism is that researching social phenomena, such as in this thesis, is an effort in interpreting the meaning of other human's intepreations of something by what they say and do (M. D. Myers, 2020), exemplified by the french philosopher, Blaise Pascal, “*Words differently arranged have a different meaning, and meanings differently arranged have different effects*”.

In line with the focus on intersubjective human understanding in the interpretive paradigm, the interpretation of the studied context and situations has been done according to hermeneutics as the philosophical standpoint (Klein & Myers, 1999). Hermeneutics is considered a philosophy for *interpreting meaning*, and thus resulting in *understanding* (M. Myers, 2004). The primary idea with hermeneutics is that ”meaning of a part can only be understood if it is related to the whole”(Alvesson & Sköldberg, 2000, p. 53), or i.e. a sentence in a book can only be understood if you construct its meaning based on the whole book and vice versa. This philosophy of gaining understanding is most commonly called the hermeneutic circle. It is called a ”circle” because meaning of a text is constantly being shaped by a iterative/reflective meaning-making from how e.g. parts of a picture related to the whole picture, and the whole picture relates to its parts. This thesis are constructed based on the hermeneutic way of thinking about understanding and meaning-making because it supports the stance as interpretive and socially constructionist research and being a subjective researcher constantly analyzing and understanding a complex social phenomena over a long time period.

3.3 Methodology

This research is based on a qualitative, interpretive case study methodology (Walsham, 1995). The notion of a case study differs based on the academic domain and/or goal of the study, but a case study can in its simplest form be understood as an example of a more general phenomenon (M. D. Myers, 2020). More specifically, a case study can be explained as a bounded study of a phenomenon in its real context (Verne & Bratteteig, 2018), or as more commonly explained as ”an empirical inquiry that investigates a contemporary phenomenon within its real-life context” (Yin, 2003, p. 18). Unlike ”hard case studies” in the positivist realm, interpretive or ”soft case studies” do not aim for generalization based on statistics or predictive power, but rather on ”plausibility and cogency of the logical reasoning used in describing the results from the cases, and in drawing conclusions from them” (Walsham, 1993).

This thesis has studied how a global public good software platform has supported digital innovation, and a case study is suitable to answer this question because it supports empirical investigation of an unfolding phenomena in a real-life context. Case studies are also suitable to answer ”how?” questions (Yin, 2003), and where the aim of the study is to understand, rather than predict or intervene (K. Braa & Vidgen, 1999) which also fits the research questions. The aim is not to provide proof or debunk hypotheses, but rather learn something about a general phenomenon from context-dependent situation (Flyvbjerg, 2006).

The phenomena in this study can simply be put as ”digital innovation with a digital global public good software platform”, and the case is thus the innovation of software applications (in the context of response to Covid-19 pandemic) using the global public good software platform, DHIS2. More specifically, the case follows to countries and shows how DHIS2 was used to innovate software applications for Covid-19. The case as presented in this thesis is bounded by the time period in which the situation has occurred (and is still occurring up until the writing date), by the actors/participants involved and the countries they represent, by the platform an innovations of DHIS2, and the general context and setting of the Covid-19 pandemic. By studying this general phenomena, and analyzing an empirical case study of this phenomena, theoretical contributions can be made by using a suitable theoretical framework gain explanatory weight to the research questions and give insight into the nature of the studied context (Gregor, 2006; Klein & Myers, 1999; Walsham, 2006). The case study relies on so called theoretical interpretive approach, accepting ambiguity in the interpretation of a case, but using the best possible theoretical perspective in order to highlight the empirical questions (Andersen, 2013). Hence, this case study can be seen as a instrumental case study (Stake, 2005) since the goal is to draw insights from the case by using existing theoretical concepts to inform a general phenomena.

In terms of data collection for this case study, this thesis is based on less structured approach (less planning and more pragmatic) of data collection. Structured approaches to data collection is considered best when wanting to differentiate between e.g. people or cases by planning the research approach in detail prior to data collection, and less structured approaches are best suitable when studying a particular phenomena by responding to the situation that is faced (Maxwell, 2013). Three data collection activities has been conducted, but has not been part of an overall plan or structured approach. Also, the selection of methods and techniques has not been part of a preestablished plan, but rather by responding to what has been useful and necessary to gain insight into the phenomena. However, the study has made a trade-off by limiting generalizability as comparability in order to gain internal validity and contextual understanding (Maxwell, 2013). This approach has led to less rigidity in methodological and empirical reproducability, but increased the ability of uncovering local causalities (processes leading to specific outcomes) (Huberman, 1994, as cited in Maxwell, 2013) which fits the research questions. The next section will account for the data collection methods and techniques used in this thesis.

3.4 Data collection methods

This case study research has been developed using a range of qualitative methods. This section will account for these methods and why they are used in this case study.

The most prominent research method used for this thesis is interviews. *Interview* (or more specifically a qualitative interview) is a data collection method where the researcher encourages the participant (or subject) to talk about some topic with the aim of understanding the participant's world and perspective. Interviews enable collection of rich data (M. D. Myers, 2020) and generates knowledge based on language instead of numbers (Kvale & Brinkmann, 2015). Interviews are contextual by its nature since they are conversation-based and cannot be reproduced in another setting at another time (Kvale & Brinkmann, 2015), and produce data which is obtained directly from people or organizations (also called primary data) and "adds richness and credibility to qualitative manuscripts" (M. D. Myers, 2020, p. 147).

The technique used in all interviews for this thesis is semi-structured interviews. Semi-structured interviews uses sets of pre-written questions and/or themes to guide the conversation between the interviewer and interviewee, but also accepts asking questions that are not in the pre-written sets (M. D. Myers, 2020). The advantage of this technique is to use the pre-written questions as an initial guide to explore and uncover some topic of interest, while also enabling the interviewer to ask follow-up questions and explore emerging themes in the conversation. However, generalizability and comparability are reduced, and the freedom which this technique provides can also be counter productive by collecting either too much/little data or data which is irrelevant. Additionally, this form of interview technique relies on the interpersonal skills of the interviewer, e.g. by making the participant feel comfortable, being trustworthy, not asking sensitive questions, not asking leading questions, etc.

The knowledge stemming from interviews starts with a construction of the interactions between the interviewer and the interviewee in the way questions are asked by the interview, new insights are shared by the interviewee, and how the interview evolves through this cycle of interaction (Kvale & Brinkmann, 2015). The continuous back and forth interaction develops a mutual understanding between the interviewer and interviewee which carries on in processing of the material later. This resonates with the philosophical underpinning of interpretivism and construction of understanding through the hermeneutic circle.

Other methods has been for complementing the interviews. Observation has been conducted as a method in this study, but has had less concrete impact than the interviews. Observations are been suitable as a complementary method to interviews by how it enables to compare what people say with what people do by observing actual situations in context (M. D. Myers, 2020). Notions of both indirect observation and participant observation as techniques has been used. Indirect observations has been used on observing video meetings, and participant observations has been used by observing how people use DHIS2 while also interacting with them and conversing (these techniques are mostly used in the third research project explain in the upcoming section on data collection). Review of documents and online resources has also been used as a complementary method to the interviews and observations. These secondary sources has been key to verify information, such as dates and chronological events, and in a general more clarifying understanding of the context and activities that are studied.

3.5 Data collection overview

This section accounts for the qualitative data collection efforts which this thesis is based on. The data collection for this thesis is based on a two-year study (2020-2022) of DHIS2 during the Covid-19 pandemic, and divided by three main data collection activities collaborating with different students and researchers. The first activity was a research project (2020) where interviews were made with key stakeholders in the HISP environment. The second activity was a continuation of the first project (2022), conducting more interviews with key stakeholders within HISP. The third activity was a interview study (2021-2022) with other researchers investigating how DHIS2 was used in Norway for Covid-19. All interview data in this thesis has been collected by me and others, and has been collected for the purpose of using it as part of this thesis. The three activities has also resulted different knowledge outputs during the study which will be mentioned. These activities will be accounted for in the following subsections.

3.5.1 First research project

The first empirical data collection effort started the summer of 2020 with a research project conducted by me and two other students. This project was a part of a student research programme called ”Research Programme Informatics Part 1” with the intention of introducing students to research early in education. Data collected in this project was intended to be used as part of the master's thesis of those contributing, and accordingly this project is the first and introductory phase of data collection for this thesis. This subsection accounts for the project, its research question and output. These outputs are not directly linked to the thesis, but acts as a foundation for which the study has developed further and with this thesis as a result.

The overall goal of this research project was to explore and uncover how the DHIS2 ecosystem responded to the Covid-19 pandemic. We did so by conducting ten semi-structured interviews with various stakeholders involved in the response. The questions revolved around their insights of the pandemic situation, how DHIS2 was relevant for meeting various needs related to Covid-19, and their role in contributing to the process of using/implementing/supporting DHIS2 for Covid-19.

Table 3.1: Interviews from first phase of data collection

Informant role/position	Number of informants
DHIS2 core developer	1
DHIS2 implementer	1
DHIS2 manager	2
HISP Sri Lanka representative	1
Municipality physician	2
Municipality IT manager	1
Municipality contact tracer	1
WHO manager	1

All interviews were recorded, lasted approximately 1 hour, and consent to collect, store, and use the data for research purposes were granted orally or written by email. All interviews were conducted online via Zoom or in person. The material was then processed by transcribing the interview or by writing shorter summaries, depending on the perceived relevance of the interview for our research goal. The data was first analyzed by highlighting data that would fit the research goal of understanding how the DHIS2 ecosystem responded to different needs related to Covid-19. This analysis resulted in a synthesis which illustrated the main activities in the response by various actors in a chronological time order (by date, or time period). Then, in the second iteration of analysis, we reviewed the data once again looking for the enablers of the activities to gain a more neuanced picture of what supported the acitivies in the response. The second iteration of analysis resulted in a updated synthesis of the main activities of the Covid-19 response in the DHIS2 ecosystems and the enablers of the activities. Then, we aggregated the activities by grouping them into similar themes which resulted into four main phases of response. The enablers of the activities was then connected to its respective phase in the response.

The final guiding research question was formulated as followed: *How did a HIS platform and its surrounding ecosystem respond to a rapidly emerging global health crisis, and what were some enabling factors?* The result of the work is summarized in the following table:

Table 3.2: Summary of research project findings

Phase	Enablers
1. Local innovation	Initiative, competence, trust
2. Generification	Teamwork across borders, bottom up development
3. Diffusion	Common spaces for information and communication
4. Adoption	Initiative, unity, sharing knowledge

This thesis builds upon the interview data collected in this project, and further develops using a new theoretical perspective and analyzing the findings by combining data from the following research activities. For this project specifically, the output was a research poster which was accepted to Norwegian Conference for Organizations' Use of IT (NOKOBIT) 2020. See Appendix A.

3.5.2 Second research project

The aforementioned research project continued in 2021 as a second iteration of data collection, analysis and outputs. This subsection similarly accounts for the data collection done, analysis and outputs. This project was building upon the empirical material from the first project, but changing the theoretical perspective. Unlike the first project which accounted for how the DHIS2 ecosystem had responded to the Covid-19 pandemic, this project was about how DHIS2 displayed information system resilience towards the novel challenges as need as related to the pandemic. Two more semi-structured interviews were conducted, aiming for understanding how the DHIS2 system was used to support and aid adaptation to the pandemic.

Table 3.3: Interviews from second phase of data collection

Information role/position	Number of informants
DHIS2 manager	1
DHIS2 developer	1

All interviews were recorded, lasted approximately 1 hour, and consent to collect, store, use the data for research purposes were granted orally or written by email. All interviews were conducted online via Zoom. In this project, the data from the first project and from the two recent semi-structured interviews were analyzed by conducting a thematic analysis (Braun & Clarke, 2006). We conducted two iterations of thematic analysis, both in which we used coding techniques with an online platform called Miro by visually connecting excerpts from the interviews in a large mind map. In the first iteration, the goal was to inductively find similarities in how the interviewees experiences the Covid-19 response with DHIS2. In the second iteration of analysis, we used the codes from the first iterations deductively by applying the theoretical framework of information systems resilience developed by Heeks and Ospina (2019) on the previous codes to see how DHIS2 displayed information system resilience.

In this project we found that DHIS2 mainly showed resilience in terms of its flexibility capabilities, and was thus affirming the theoretical framework used. However, we also saw from the analysis that the stability of the software core components was essential to exercise resilience. More specifically, the way DHIS2 balanced flexibility capabilities and a stable core that emerged from the analysis as key to IS resilience. This project resulted in a forthcoming short research paper, ”Information System Resilience: The Role of Flexibility and Stability” by Johanne Thunes, Andrea Ulshagen, and Vetle Alvenes Utvik (2022). See appendix D.

3.5.3 Third research project

As a global effort to understand how five countries (among them Norway and Sri Lanka) used the Covid-19 Surveillance package of DHIS2, a research project was granted by the Norwegian Research Council (NRC) called ”Emergency Response to the COVID-19 Pandemic: Supporting global and national surveillance” led by researchers at the Institute of Informatics, University of Oslo. This project started in 2020 and ends in 2022, and I contributed to this project by conducting several semi-structured interviews, two field trips, and meeting observations with researchers from this project. All efforts were based in Norway and were conducted by me, a PhD student, and/or other researchers from the Institute of Informatics, depending on who was available. I was participating in all efforts mentioned here.

Table 3.4: Interviews from third phase of data collection

Information role/position	Number of informants
Contact tracer	1
Municipality physician	3
NIPH representative	1
KS representative	2

All interviews were recorded, lasted approximately 1 hour, and consent to collect, store, use the data for research purposes were granted orally or written by email. All interviews were conducted online via Zoom, recorded and transcribed/or processed by writing memos.

In addition to the interviews, two field trips were made to two different municipalities to better understand the context in which DHIS2 was used for contact tracing and by talking to the people using it. In the first field trip, me and two colleagues (DHIS2 implementer, and project manager) went to a contact tracing facility in one municipality and was shown the workplace in which DHIS2 was used. After, we conducted a group interview with two contact tracers and the team lead of the contact tracing center asking about how they used the systems, what were the current challenges and obstacles. The interviewees also illustrated the challenges by displaying a demo of the application on a projector. This group interview was not recorded, but detailed notes were taken and compiled into a memo of combined notes between me and a colleague. The second field trip was with me and the same DHIS2 implementer going to another municipality, this time with focus on understanding challenges in use and receiving feedback on the solution. The participants was two contact tracers, a municipal manager and a municipal physician. Similarly to the first field trip, a demo was shown on a projector with the intention of the participants being able to show examples of challenges and then finding solutions together. The session was not recorded, but detailed notes were taken.

Lastly, several observations of video meetings were conducted of KS and stakeholders involved in providing feedback and prioritization regarding the development of the DHIS2 contact tracing app for Norway (this meeting was called the ”user council” - this will be explained in the case description chapter). Meetings were held once a week, sometimes every other week, and I was observing these meetings ad hoc when I was available to do so. Notes were taken during the meetings when it was useful to do so. The experience of these observations has not played a significant role in the case study other than providing a richer understanding of the function of the meeting and a better understanding of the context around the development and collaboration around the norwegian DHIS2 contact tracing app.

Several other interviews were made by colleagues that were available as recordings and/or transcriptions to me, but is not included in this thesis. However, takeaways from these interviews has been discussed and shared in meetings and has thus affected my interpretation of the context studied.

The analysis of this qualitative data was done by conducting several rounds of collaborative analysis in video meetings with the research colleagues. The main topics of these analysis were related to how contact tracing in Norway had undergone a digital transformation from manual contact tracing procedures to digital driven contact tracing. Additionally, a more thorough analysis was done by deductively coding the interview data and memos based on concepts from institutional theory to understand this digital transformation and its affect on institutional practices of contact tracing. Me and the PhD student was collaborating on this analysis. As a result, two research papers were published, namely "Digital Transformation under a pandemic: A case study of Covid-19 contact tracing in Norway" (2020) and "An Institutional Analysis of Digital Transformation of Covid-19 Contact Tracing During a Pandemic" (2021). See appendix B and C.

3.5.4 Secondary sources

In addition to the three projects, other sources of information related to the context of the case study has been important. These sources are mostly secondary sources, meaning that they are already published information and not directly derived from interaction with other people. These sources include online webinars of the DHIS2 contact tracing solution [3], new paper articles [4] (such as by Dagbladet and Aftenposten, two major newspapers in Norway), web articles from DHIS2 [5], chatting channels in Slack (online conversations between members of the HISP/DHIS2 community, these data are mostly used to confirm dates), the DHIS2 forum website, documents and spreadsheets of information shared internally by DHIS2 stakeholders (such as a spreadsheet of which countries using the covid-19 package, one spreadsheet with a timeline of events related to promotion and diffusion of information about the covid-

[3] https://www.ks.no/fagomrader/digitalisering/felleslosninger/fiks-smittesporing/se-opplaringsvideoer-for-fiks-smittesporing/

[4] such as https://www.dagbladet.no/nyheter/norsk-program-sporer-mulige-baerere-av-skrekkviruset/72098072 and https://www.aftenposten.no/norge/i/pL22qw/norske-smittejegere-brukte-penn-og-papir-i-uganda-og-sri-lanka-foregaar-smittejakten-langt-mer-effektivt

[5] https://dhis2.org/category/covid-success-stories/

19 package, and documents with information about technical documentation of the covid-19 package). These sources of information has not been directly used in the case description as such, but is crucial to the holistic understanding of what has occurred in the context of DHIS2 and Covid-19, how innovations has been made, how information has been shared, communications has been conducted, and other influential ”pieces of the puzzle”. These data sources has been played an essential role by providing triangulation of data and thus strengthening the validity of the study by reducing the misinterpretations and clarifying one or multiple perspectives (Maxwell, 2013; Stake, 2005).

3.6 Analysis

As already explained in the three different projects, the data material used in this thesis has been analyzed in several different ways on several different times including different people and material. Thus, the analysis of this thesis is based on a less structured, but pragmatic approach along the duration of the study. The analysis done for this thesis specifically is an attempt to combine the takeaways from each analysis activity into a holistic understanding to answer the research questions.

The final analysis of this thesis (which is outlined in chapter 5) can be explained as a cyclic process between inductively drawing insights from the data material, and deductively investigating how the insights can be better understood or explained by existing theoretical concepts. Practically, the analysis as such has been conducted by constantly reviewing the data material (transcripts, online resources, notes, memos), conducting literature reviews to develop a better understanding the phenomena of the study, and drawing the combined insights to inform the research questions. Several illustrations and models has been developed by using concepts from information systems literature and then modelling the phenomena according to the concept. Some examples of ideas and theoretical framings that has emerged during the analysis is sociotechnical generativity (Msiska & Nielsen, 2018), disembedding mechanisms and globalization (Eriksen, 2020; Giddens, 1991), generetive mechanisms(Henfridsson & Bygstad, 2013), digital transformation (Vial, 2019), and assemblage theory (DeLanda, 2006; Hanseth & Rodon, 2020). Memos has also been constantly written to capture all emerging ideas, concepts and perspectives as a way to analyze the material (Maxwell, 2013). Discussions with the supervisors, co-students, and collegues has been essential for proposing and getting ideas and critical feedback.This continuously testing of theoretical perspectives on the empirical data led the final theoretical framing of digital innovation, digital platforms, and digital global public good.

These three concepts were in particular useful for shedding light and making sense of the empirical material. *Digital innovation*, because the prominent phenomena in the study is how digital technologies has been used to create novel digital technological solutions. The concept of generativity could have been an alternative approach, but was in this case better understood as an outcome of digital innovation, and not the explanatory factor of what has enabled innovation. Digital innovation as a concept provided better explanatory abilities. The technology used to innovate was a *digital platform*. This framing could also have been of an information infrastructure (Hanseth & Lyytinen, 2010), since this theoretical framing also fits DHIS2, but the framing of a digital platform was more useful because it could better explain the local digital innovation activities than the theory of information infrastructures which has a broader view on innovation as change and evolvability (Aanestad et al., 2017; Grisot et al., 2014; Hanseth et al., 1996). The concept of a digital global public good was a necessary piece in the puzzle to shed light on the innovation phenomena. By learning about DHIS2 as a global public good, understanding what has driven, enabled and promoted the innovation activities and related events in the case, and learning about the notion of digital global public goods through discussions with co-students and colleagues, the perspective gave a nuanced picture of how the platform of DHIS2 is different from traditional digital platforms discussed in the literature. This realization and learning resulted in seeing the connections between the three concepts and how it shed light on how digital innovation happens with a digital platform as a global public good.

Building upon two years of several rounds of analysis in each of the three projects, a constant cyclic iteration between understanding relations between the empirical material, different theoretical perspectives, and constantly discussing and learning from supervisors, co-students and colleagues, the outcome of the methodological approach and analysis has resulted in the thesis as presented and the analysis/discussion in chapter 5. The next chapter will outline the case study by compiling the empirical material into a coherent, interpreted narrative with thick descriptions and quotes, but first I will account for

3.7 Methodological limitations and ethical considerations

This study poses several limitations and ethical considerations which has affected data collection and interpretation of the empirical data. This section will mention three ways in which ethical considerations have been made, and limitations as consequences of the research approach.

First, my role and biases as a researcher. By doing interpretive research, researchers must acknowledge how biases, presumptions, culture, knowledge, political views, and even the physical self can and will affect the interpretations of the studied phenomena and thus affect the analysis and conclusions (Crang & Cook, 2007; Walsham, 2006). Considering some ways I introduce bias and influence to work with this thesis is firstly by being a junior researcher. My lack of experience can have affected the way I conducted interviews, the way the material has been analyzed, and the way the thesis has been written to reflect the findings. Secondly, I study and write about a globally oriented situation, and as a young, Norwegian male, my interpretations of what is considered good, useful or necessary for the global arena is influenced by my culture, knowledge and presumptions about other countries and global conditions. Thirdly, my theoretical framing and conclusions is heavily influenced by my prior knowledge of the information systems field (such as through university courses), by discussions with others, and books/articles which I have coincidentally read. This means that my theoretical framing of the case study might not be the "best" way of objectively explaining the phenomena (as paradigms like critical realism strives for), but, however, can be considered as one of many plausible perspectives of a situation, accepting that several interpretations and theoretical explanations can exist at the same time, as in the interpretive paradigm (Gregor, 2006). This list could go on and on, and these three are examples of ways in which my identity and background can affect the study.

Secondly, relationships with the participants. Conducting qualitative research with human participants is always, to a certain extent, an intrusion into their lives (Maxwell, 2013). However, most interviews in this study has been conducted as online video meetings (due to the pandemic situation). None of the interviews has lasted more than an hour, which limits the intrusion, but many participants has had busy schedules in their work, so appreciating this fact has been important. Therefore, interviews has always been stopped when reached one hour, and participants has always been made aware that their contribution is valuable and appreciated. Additionally, researcher intrusion has been limited since the interviews has been online, but this has also limited the communication by not being able to communicate using body language and not seeing and experiencing the same environment and thus reducing a sense of relationship with the participant.

In the observations of meetings, everyone in the online meeting room was always made aware of my presence by introducing myself, my role as a student, and my intention of observing the meeting. A more thorough consent was given by the meeting host and an email was sent to all participants explaining the research project (the third research project). Everyone was made aware that it would not be recorded, all would be anonymous and the intention was to learn about the process, not about the participants themselves.

During the field work at the municipalities, the relationship with the participants were quite different from the participants in the interviews and online observations. In the case of the field work, we presented our intention of the visit as both collecting information about the use for academic purposes, but also to actually implement changes. The former was my intention, while gaining the practical insights to improve the software was the intention of my colleagues. From my point of view, this approach and intention was received positively by the participants. The participants seemed eager and enthusiastic about being able to express their concerns and challenges, so that we could make changes to improve their work situation. Several of the most crucial challenges raised in these forums were either implemented, raised in the user council as issues which they had to prioritize, or resolved during the sessions by explaining the solution to their challenges. My interpretation of the field work was positive from both our (as researchers) side and their side - both sides got value from the sessions.

Third, how methods and data collection is limiting the study. One central limitation of this study is that most of the participants in the interviews has only been interviewed once. A one hour interview with one person can produce severe limitations and misinterpretations since the conversation is short and is prone to produce gaps of misunderstandings. Also the fact that most interviews was video meetings can also be a factor of unclear communication and thus misunderstandings. The Covid-19 pandemic has thus limited the study significantly. Important pieces of information can have been missed due to the short amount of time spent with each participant, but is made up for by having done a significant amount of interviews, and triangulated using other sources of information sustaining some internal validity.

Chapter 4

Case description

This chapter describes of a case study of digital innovation in a digital platform ecosystem in a narrative form. The case is based on the digital innovations that emerged in the DHIS2 platform ecosystem as responses to the Covid-19 pandemic. More concretely, the case will display how Sri Lanka (one of the HISP partners in the DHIS2 ecosystem) customized existing software in DHIS2 to innovate applications to their specific needs for handling the coronavirus. Then, the case continues by describing how the platform core collaborated with the Sri Lankan HISP partner to adopt and adapt the innovations for sharing it globally as an designated software package. Lastly, the case describes how Norway adopted the contact tracing application made available by the DHIS2 platform core. Before presenting the case description I first describe a central part of the story of digital innovation, namely metadata packages for DHIS2 to provide necessary background.

4.1 DHIS2 and metadata packages

A central offering of the DHIS2 platform is the digital metadata package. A metadata package is a set of pre-configured, downloadable and installable json files that support use cases such as Malaria, HIV or rehabilitation. A metadata package can include data standards, guidance on data analysis, specifications for analytical dashboards, and training material (Poppe et al., 2021). with health indicators, data elements, procedures for data collection, analysis options, visualization and more. A metadata package can be one of three types: dashboard/analytics, aggregate, or tracker. The three types are explained in the following table (retrieved from https://dhis2.org/metadata):

Table 4.1: Types of metadata packages

Type of metadata package	Purpose
Dashboard / Analytics	Core indicators, data visualizations, and dashboards support the standardization of data outputs and strengthen data analysis and use. These packages are typically installed on top of a country's existing DHIS2 configuration, which requires the implementer to map existing data inputs (e.g. data elements, disaggregations via categories combinations) to the standardized outputs in the package.
Aggregate	These packages simulate core health management information system modules for a given health area or use case. In addition to analytical outputs in the Dashboard / Analytics packages, Aggregate packages provide a standardized design for data inputs (data sets, data elements and category combinations) to ensure completeness and precision of systematic routine data capture. Aggregate data entry forms and data elements can be populated by traditional health facility reporting on aggregate data; or they can provide a set of standardized 'target' metadata where individual-level data capture through DHIS2 Tracker or other electronic systems might be in place. Aggregate packages are assured to produce the indicators and dashboards defined by the analytics package.
Tracker	These packages use the DHIS2 Tracker (with registration) and event (without registration) data models to support the systematic capture of individual-level data, uniquely identify and track patients or other entities over space and time, and enhance patient-centered approaches for program management. These packages can be used to support clinical-level decision-making and can generate highly granular data for enhanced analysis. Wherever possible, program indicators are mapped to elements of the corresponding aggregate packages to ensure seamless integration of individual-level data with aggregated outputs for data analysis and use.

4.2 Sri Lanka

4.2.1 Initial response and planning

The news about an outbreak of pneumonia in Wuhan, China was first made official to the global public health community and news media by the WHO on the 5th of January, 2020 (World Health Organization, 2020). The coronavirus was identified not long after. On the 13th of January, the first case of the virus was confirmed in Thailand, and by the next day WHO stated the possibility of human-to-human transmission of the virus, warning about a possible wider outbreak.

In early January of 2020, Sri Lanka was made aware of the Covid-19 disease. Representatives from HISP Sri Lanka, and the Sri Lankan Health Information Unit in the Ministry of Health initiated a discussion in third week of January. The discussion was about the coronavirus and its implications for Sri Lanka in terms of spread and possible outbreak.

> *The medical part is one thing, but information management is another. So we were not kind of ready, because we had DHIS2 in Sri Lanka, but DHIS2 was mostly used by the public health institutes, e.g. mother and child health care, epidemiology, tuberculosis, malaria, things like that, but we were not using DHIS2 or a proper integrated surveillance system we did not have.* (Informant 1, HISP Sri Lanka)

Sri Lanka had a significant number of airborne travelers from China mainly due to tourism and work arrangements with Chinese construction firms. It wasn't a matter of *if* the disease would reach Sri Lanka, but *when* it would eventually reach the island.

> *One major source of income in Sri Lanka comes from tourism. We are a tourist hotspot, so there is a lot of people coming. And the second most common country people come from is from China. So our country must deal with the risk, since this was going on in China, we were really worried when we were going to get it. (...) That is the perception we had back in January* (Informant 1, HISP Sri Lanka)

A presidential task force was established to enable rapid decision-making for handling various needs related to a possible disease outbreak. One of the areas which had to be addressed was to get in place information systems to handle information about suspected cases. The task force acted swiftly and proactively by starting a process of gathering requirements and selecting a suitable digital information system that could aid them in handling needs related to information and communication. The most pressing need was to attain a system which could support registering incoming airborne travelers, their eventual symptoms and their residence in Sri Lanka.

> *For example if you thinking of say an infectious disease like influenza, the patient is in the community, so if somebody is having influenza, the patient is going to be referred to a GP (general practitioner) or a hospital, so likewise we have a designated path how the patient is detected and how the patient is followed up. But in the case of Covid, because the country is not actually having indigenous cases of Covid, at the first instance it has to come from a different country. Unlike a general influenza, the first point we are detecting Covid is maybe the airport* (Informant 1, HISP Sri Lanka)

The team began the work of assessing the situation by setting some essential technical requirements. First, the system had to be customizable and easy to change, because they had yet little knowledge about the characteristics of the disease. The team reasoned they would need flexibility to change the system in parallel with new incoming knowledge and/or changing guidelines about the disease. In other words, they needed to be able to make continuous changes efficiently over an uncertain time period after implementation.

> *What we believed we had to, we don't have to start from scratch, we should use an existing information system, and the thing was we was not really sure about the requirements, because nobody knew, covid-19 was something new to the world, nobody knew how to do this event, because we were not sure how this virus was behaving, how the virus was spreading. The landscape of what we know about COVID is changing. So that is why we wanted to start this system on a platform, which we can change if our requirements change, so the change should not be taking too much time. So if we go for a custom solution, we have to contact the developer and then there may be costing involved, so we didn't have any time for that. So that was one major requirement we had, we wanted to be based on a platform, which is customizable (...)*(Informant 1, HISP Sri Lanka)

Secondly, they prioritized free and open source solutions. The team did not have the financial resources or capacity to develop/order something from scratch – it had to be built based on existing software which could be acquired and customized. They also did not have time to go through a procurement process, and therefore an open-source system could accommodate these challenges.

> *And also we preferred something free and open source where we do not have too much costing and financial processes related to procurement involved.* (Informant 1, HISP Sri Lanka)

Thirdly, health staff should be familiar with the system. Training health staff to use a new system would take too much time and burn too much resources in the implementation stage. By introducing a new system, they would also have to conduct piloting of the system, which they also assessed as taking too much time to conduct.

> *So when all of these [challenges were assessed], what we felt like was: can we do this on an existing platform where most of the health staff are familiar with, which are mostly customizable and were we don't have to hire a developer and things like that? And the number one option we had was DHIS2* (Informant 1, HISP Sri Lanka)

There was one system which health workers in the country were already familiar with, and which met all the essential requirements, and that was the DHIS2 software platform. DHIS2 was already in use in Sri Lanka for other use cases such as maternal and child health, nutrition, malaria and tuberculosis. Many health workers were thus already familiar with the system. Also, the HISP Sri Lanka knew how DHIS2 could be an asset for new use cases and had significant local capacity in terms of expertise in configuring DHIS2. Since the use case were related to tracking information about individuals, the HISP Sri Lanka came up with the idea of using a DHIS2 application called, Tracker, and customize it to meet the needs related to the pandemic.

The DHIS2 tracker application is a case-based (individual-level) data collection, follow-up, analysis, and reporting tool. The tracker application is based on generic data models and flexible metadata configuration to enable customization for any use case related to collection information from individual cases. Several data packages based on WHO standards are available in the Tracker app, e.g. for HIV, Malaria, or maternal and child health. The customization can be done by adapting an existing data package, or create a new program using a designated interface to define what to collect at which stage and which rules should apply for the program.

4.2.2 Implementing a Covid-19 surveillance system

25th of January, three days after the first discussion between HISP Sri Lanka and the Health Information Unit, the HISP Sri Lanka team had configured a basic Tracker application to meet their needs for tracking incoming airborne travelers, and they called it ”the ports of entry program”. The ports of entry application met the need of registering incoming airborne travelers to the country by being able to collect individuals' personal information, residence, and eventual symptoms of Covid-19.

26th of January, the application was presented to the Director General of Health Services in Sri Lanka, and the day after Sri Lanka got their first case of Covid-19. On January 29th, Informant 1 posted a message on the communication platform (Slack) whereby 270 stakeholders in the HISP/DHIS2 community are communicating. The message was this:

> *The Ministry of Health, Sri Lanka, launched a Coronavirus Surveillance System based on DHIS2. This is to be used by the ministry from tomorrow to track suspected travelers from all ports of entry during their stay within the country in the initial stage.* (Informant 1, HISP Sri Lanka)

Figure 4.1: Front page of the ports of entry application for Sri Lanka

This was the first use of DHIS2 for Covid-related use cases. However, after the launch of the ports of entry application in Sri Lanka, the country did not have any more cases of Covid-19 until several weeks later. This would be a beneficial situation while expecting a more profound spread of the disease.

> *From late Januar up until second week of march, we did not have any other cases [of Covid-19]. So we had time to train people and polish the system that we had (...)* (Informant 1, HISP Sri Lanka)

On February 20th, the surveillance system in Sri Lanka was officially described to the DHIS2 Community (CoP). The system at the current time, which was based upon the generic Tracker application, had three program stages and was described in the following way:

Table 4.2: Sri Lankan Surveilllance System described

Program stage	Described purpose
First program stage	Name, DOB, gender, email, passport number, telephone number, and few other sociodemographic factors are captured at the registration as tracked entity attributes. The first programme stage is also captured at the ports of entry along with information for registration. The first which is a compulsory program stage captures information related to immigration, symptoms of COVID-19 disease, possible contacts and the stay in the country.
Second program stage	Second program stage, follow-up (within 14 days) is a non-compulsory repeatable program stage that captures symptoms of COVID-19 disease and any action taken during the surveillance process.
Third program stage	Follow-up (at the end of 14 days), the third program stage is a non-repeatable, compulsory program stage and captures symptoms of COVID-19 disease and any action taken at the end of the surveillance period. This programme stage is the conclusion of the surveillance process.

By the time this was shared with the DHIS2 community, the system was in use at the ports of entry in Sri Lanka, and training was currently being conducted via video conferencing. In addition to the mentioned functionality, unique dashboards (visual reports of certain data groups/indicators) had also been made facilitating aggregation of data to facility, district, province and national levels, strengthening the information overview of the surveillance activities.

4.3 From local innovation to global adaption

From 9th to 16th of march 2020, core developers and implementers from the DHIS2 Tracker team (a team working specifically on issues related the Tracker application) was coincidentally together in Ghana at an DHIS2 Academy event, providing training to health staff and officials there when the efforts to build a globally available package for Covid-19 started. The DHIS2 staff from the Tracker team attending this event had experience with programs for communicable diseases, such as Ebola, Cholera and Malaria. As the technical guidelines for case-based surveillance and contact tracing came in from WHO, the Tracker team realized that this was something which they had done similar works on before. Additionally, Sri Lanka had at this point reached out in the general slack channel and the DHIS2 web forum informing about the ports of entry program they had put together for Covid-19. Usually, creating metadata packages for diseases are usually initated by organizations like WHO who sets the initial requirements, but the tracker team realized the urgency of the situation. Representatives from countries were already messaging the core team asking about specific digital tools/packages for Covid-19, so based on the perceived urgency the teams started to put together a surveillance package for Covid-19.

> *This was kind of pro bono. We followed whatever WHO was saying at the time, some guidelines and such, but we had not contract with them. There were no one who said that we had to do this or that. There was a lot less control from that side, because it was we who chose to do it. So then we finished [the package] pretty quickly.* (Informant 3, DHIS2 implementer)

While the team was working on creating a globally available package for Covid-19, the situation started to change in Sri Lanka, creating new needs and requirements to the system.

4.3.1 Changing needs and new system requirements

> *(...)from mid march we had a huge surge of cases, because there were plenty of Sri Lankans that were returning from countries like Italy and South Korea. By mid march there was a huge surge of patients.* (Informant 1, HISP Sri Lanka)

In around third week of march, as the number of cases of Covid-19 were increasing, the Sri Lankan government implemented quarantine in quarantine centers for all incoming travelers to Sri Lanka. This lead to new requirements to the information systems, and as a result a new tracker application would have to be configured for registering everyone who was sent to quarantine centers. This new tracker application had to be able to register when the persons arrived, when the persons left the center, if the persons had any symptoms and basic socio-demographic information.

As opposed to the first Tracker configuration of the Port of Entry application, this time Sri Lanka had two technical challenges. First, the Tracker module was designed in such a way that when enrolling a person into a tracker program, one need to define which organizational unit the person is getting enrolled to. When people are registered with e.g. dengue fever, the detection occurs at a health facility in a particular district and is thus enrolled into a tracker program with this defined organizational unit. This is mandatory information to register in DHIS2. Every data value has at minimum a defined organizational unit (the where), data element (the what) and period (the when). Organizational unit is also important to capture because it enables data aggregation and better information for decision-making at higher levels in a country. The problem was that people was enrolled in the system at the airports, and in that case, registering people at the airports meant nothing for data aggregation and overview of districts. The people registered at the airport might go to another unknown district, so enrolling them into a particular location would not make sense. They wanted to have a workaround for this challenge, but the DHIS2 core could not be modified based on this single requirement from a single country.

Second, in order to gain a sense of contact tracing between index cases, their contacts, and their residence in the country, they wanted a map visualization of relationships between cases. They wanted to create a tool where one could see geography of residents of known cases of Covid-19 and their contacts. However, this was also something which was not possible to do in DHIS2 at the time.

To accomodate these needs, the governmental ICT Agency in Sri Lanka got involved to discuss what could be done. Since Sri Lanka has a lot of software developers, and the country was in a state of emergency, The ICT Agency suggested to invite software developers to volunteer in a hackathon. The goal of the hackathon was to develop the necessary applications on top of the DHIS2 platform to accomodate the technical barriers. In other words, the goal was to either modify the source code so that the technical challenges could be resolved, or develop web- or android applications which could be integrated with their DHIS2 instance.

However, the HISP Sri Lanka was worried about developing new application which was not according to DHIS2 design principles. So they sought for support from the DHIS2 core team while hosting the hackathon. At the same time, the core team appreciated the work being conducted by Sri Lanka and they understood that the requirements they described would be similar for other countries too.

> *HISP Sri Lanka, early February, said they were working on a contact tracing ap-*

plication, so essentially, in DHIS2 you can get all the information, but we have insufficient analytics tools to be able to visualize the relationships between multiple cases, so you have your index case and then you'd have your multiple generations of cases that come after your index case. And you need to build a relationship between the index and their contacts and the index and the contacts that tested positive and then their contacts and then the subsequent positive cases as it goes down. We didn't have that application. We never had a use case for that application prior to COVID really. Maybe a little bit on the malaria side but nothing nearly as advanced as what covid was requiring. And so Sri Lanka started to put together this application. (Informant 2, DHIS2 core team)

One core developer was assigned to support the developments that were happening during the hackathon. He was available virtually so support the Sri Lankan developers with technical challenges, but also support them in developing programs generically, so that it could be adopted by other countries as well.

It was just really likely that anything they developed was going to get reused in other countries. And they [Sri Lanka] were able to respond to that. You know, they're closer to the use case. They're closer to the requirements. They're able to respond to it much, much more quickly than we would in core. And so appreciating that they were going to be able to move quickly, but also ensuring that anything that they developed needed to be done generically as much as possible, so the countries could adopt it, but also as performant and stable as possible, [A core developer] worked with them throughout the process, so they had the functional requirements they gathered. [Sri Lanka] understood the use case. They started to piece together the kinds of analytics like the mockups, what it actually needs to look like. And then [the core developer] worked with them to actually build the app and support them, which is a a fairly different approach than what we usually do. Usually we allow third party developers on the peripheries too do their own thing. It's very rare that we would assign any of our developer staff to work with someone. But in this particular case, because they're going to be able to respond more quickly than we would. And we wanted it to be as performant and stable and generic as possible, so other countries could adopted it. You know it was worthwhile having [the core developer] work with them and it's a great app now, (...) and quite a lot of countries are using it. Informant 2, DHIS2 core team)

The hackathon was organized and happened from mid March to early April. Sri Lankans living in Sri Lanka, USA or Europe contributed to hackathon around the clock. The challenge of enrolling without an organizational unit was resolved by modifying the source code of the tracker application, and the issue with the map visualization was resolved by creating a web application with integration with DHIS2. A simple application for tracking Intensive Care Unit beds was also developed, and other various functionality.

By mid April, Sri Lanka had several modules incorporated. The Port of Entry application, quarantine center module, suspect cases, a few mobile applications. Various other efforts were also made over time, like an aggregate dataset of cases to get overview of which hospitals that would need medical appliances, and integration with immigration systems of Sri Lanka were set up so that the information about flight passangers to Sri Lanka was pushed into the covid surveillance system. Incoming travelers would fill out health information at the airport, but the rest of the socio-demographic information was obtained from the immigration systems.

Meanwhile these innovations happened, a close collaboration with the core DHIS2 team led to a globally available Covid-19 Surveillance Package with inspiration from the work in Sri Lanka.

> *By the same time there was another countries who were interesting in using [Covid-19 surveillance system]. So what we did was, this is were community of practice comes in, we posted our metadata in the DHIS2 and the core developers and core implemented it in, and they kind of refined them, so that, some specifications we had were very country specific, so they polished it up a bit to make a generic module of Covid-19 that can be used by any other country. This was also happening parallelly, so they prepare it as a metadata package, so if you have a DHIS2 instance in your country, you just have to install that metadata package in your DHIS2 instance, then you can start use the DHIS2 surveillance package for covid-19. So it was made that easy.* (Informant 1, HISP Sri Lanka)

By combining the shared innovations from Sri Lanka, a pre-existing package for generic case-based surveillance, and initial guidelines and standards from WHO, the Tracker team ”scrambled together” a package which was published on 27th of March. The first Covid-19 Surveillance metadata package was ready for any country to download and/or incorporate into their DHIS2 instance. At that time, the following programs were published as part of the package:

1. COVID-19 Case-based surveillance and Contact Tracing programs [tracker]
2. Ports of Entry screening & follow-up program [tracker]
3. COVID-19 Surveillance Event Program [event]

> *And we think you've seen that across the board that various actors have laid the groundwork. And then we made it more publicly available, kind of through our communication channel, and also a little bit more standardized, and then WHO not very long after, just a week or two after, came up with their global standards. And then we just did a little bit of updating and and revising based on that and I think that's one of the very unique things about a platform response to this, and especially like an open platform like DHIS2 is that it allows for that level of community engagement and cooperation and kind of collective content or value generation. And it ultimately results in a much bigger, more useful product than if DHIS2 was like a more closed or proprietary platform.* (Informant 2, DHIS2 core team)

Information about the Covid-19 package was released through various different communication channels, such as in the DHIS2 forum, email newsletters and online meetings, and it was quickly adopted by countries all over the world. However, most of these countries adopting the package was countries already using DHIS2. The next section of the case description will outline how Norway, which has never used DHIS2 (even though the core development is based on Oslo), adopted DHIS2 for contact tracing and how it was adapted to needs in Norway.

4.4 Norway

Before the Covid-19 pandemic, most contact tracing in Norway was conducted using pen and paper, or spreadsheet-based systems. The communicable diseases which has required contact tracing work has usually been diseases like tuberculosis, which is a slow spreading disease and rare in Norway. Since Norway has a decentralized, municipal-based governing structure, each municipality has to acquire their own system(s) for contact tracing and other health related use cases, and there are 356 municipalities in Norway. The first case of Covid-19 was identified in Norway in late february, which woke health officials in municipalities to prepare to respond with necessary measures and tools.

4.4.1 Local adoption and adaptation

One informant (Informant 4) working with epidemiology in a municipality (M1) realized that the current tools for handling contact tracing would be insufficient for the Covid-19 disease. In M1, the existing contact tracing tool were based on paper format (which they used for Covid-19 during the month of March) and it entailed several challenges. The paper based tool did not support sufficient statistical analysis methods, systematic data collection, reporting to other health information systems or stakeholders, or support efficient data security and privacy protocols in compliance with GDPR.

> *In the beginning we worked paper-based, and after some time we felt that it was so complex, so we had the need to digitalize* (Informant 4, municipal physician)

Another municipality (M2) also explained that there was a need to accommodate the necessary reporting requirements of Covid-19 related information.

> *We saw that a lot of the data that needed to be reported to the management, the crisis management and emergency team, and to the various management functions in the municipality had very overlapping needs and we were required to report to NIPH. So there had to be a better way to do this because a lot of the work was done by excel and very manual processes for data synthesis and gathering* (Informant 5, municipal manager)

In the beginning of April, Informant 4 in M1 assessed several digital systems which could potentially meet the needs of effective contact tracing of Covid-19. NIPH, the Norwegian Directorate of E-health and The Norwegian Association of Local and Regional Authorities were contacted to request any recommendations for digital contact tracing systems, but none of the organizations had any recommendations at the time.

> *It was very clear from our side that we had a crucial need. It was urgent, because the number of cases increased every day, and we should digitalize. So no matter what the national guidance were, we had to begin the process. There wasn't any use in waiting for someone to do it for us.* (Informant 4, municipal physician)

M1 then contacted WHO and Centers for Disease Control and Prevention (CDC) to investigate which tools they used. Three different systems emerged from the inquiry, among them DHIS2. DHIS2 had recently published an available application for contact tracing (which Sri Lanka helped build), and not long after, M1 contacted the University of Oslo to adopt a the Covid-19 Contact Tracing package of DHIS2. M1 chose DHIS2 of three reasons 1) open-source because of limited financial resources, 2) customizability so that the system could be adapted to their context, and 3) the expertise and implementation competence was close by and was willing to help to M1 with the customization.

> *I figured DHIS2 was the most attractive which could be adapted. They had a own module for contact tracing based on WHO's recommendations, and at that time I had already translated the validated questionnaire of WHO according to the Norwegian context and adjusted it to our work-flow and with recommendations from FHI. (...) [Here discussing reasons for choosing open source solutions] It principally comes down to costs. Municipalities on our level use a lot of resources to create solutions that we do not have from before. There was a limited financial opportunity to go for private solutions* (Informant 4, municipal physician)

In April, M1 decided to adopt DHIS2 as their contact tracing tool, and started a process with UiO to adapt the system according to their work-flow and requirements. Not long after, M2 started the same kind of investigation looking for a digital system that could support their needs for data gathering and reporting, asking KS, The Department of eHealth, and other municipalities for advice. This is when the information about the process between DHIS2 and M1 started to diffuse to other municipalities and KS.

4.4.2 National adoption and adaption

Concurrently with the work of adapting the Covid-19 Surveillance Package for M1, on 14th of April M1 was invited to present their experiences so far with digital tools for contact tracing of Covid-19 to KS. KS was assessing the possibility to provide an available digital contact tracing tool for all municipalities through an open software-as-a-service platform called FIKS, so that municipalities could avoid having to develop or acquire their own separate system. Several municipalities was involved in the assessment. NIPH was also invited to present their initial assessment of potential contact tracing systems. Both M1 and NIPH had assessed DHIS2 as one of the recommended systems for municipalities. A demo (the system was not in use yet) was shown of how the system was currently being designed for M1.

KS, NIPH and other municipalities that was involved assessed two systems, one of them being DHIS2, and they were convinced that DHIS2 would be the most suitable system for contact tracing.

> *(...) it quickly became evident that one of them [DHIS2] was better for our purpose, meaning how we were rigged and because of [legal] agreements, and there was several things that would be easier to achieve with DHSI2 and simply because the solution was better, more modular. (...)* (Informant 5, municipal manager)

Additionally, informant 5 explained that for M2 it was very beneficial having competence (from UiO) with the system close to their context, DHIS2 being open source project, and having available functionality that matched the best with their most crucial needs, which was registering data.

From there KS took the lead to facilitate a process of adapting DHIS2 to fit the norwegian context. On 5th of May, a pilot introduction started with 5 municipalities (M1 and M2 included) and then was made available to all municipalities on 5th of June through the FIKS platform.

The system which was adopted was the contact tracing application in the Covid-19 Surveillance Package. Since the municipalities had requirements different from how the contact tracing program was designed by default, adaptations had to be made based on the context of norwegian municipalities.

Requirements were collected by municipalities attending what they called a ”user council”. Once a week, municipalities that had been involved in the assessment of DHIS2, been in the pilot project, or otherwise had interest in voicing their concerns and challenges with using the system met in an online meeting to discuss the requirements to the system. Managers and implementers from HISP UiO was attending as well to discuss possible solutions and collect information from the municipalities, and representatives from NIPH attended to voice national-level concerns and perspectives.

The adaptation of the system to the requirements of Norway was done by creating a ”fork”, or copy, of the contact tracing application and hosting it on servers of the FIKS platform.

Adaptations was done either by customizing the program through user interface settings, or by changing the source code. The work was primarily done by implementers from UiO and the HISP Otta, a team of developers working on Tracker.

In the beginning of the work of adapting a DHIS2 contact tracing application, there was lots of changes being made. Both because the generic app had to be adapted to Norwegian circumstances, and because the guidelines from the government was changing relatively often (such as how long a covid-positive person must stay in isolation). Every municipality that adopted the FIKS contact tracing application got the same system, but there was still flexibility in user interface to enable changes on the user level, E.g. one municipality used a dashboard widget (a small graphical interface component) for note-taking which they used as a reporting tool between staff shifts.

> *DHIS2 also helped us with a dashboard in statistics, where you can see real-time map, figures and statistics that are very important with contact tracing work* (Informant 4)

Going forward in time, by March 2021, 125 municipalities was using the system, and a lot of stakeholders was involved in the user council and the continous development of digital solutions for Covid-19 response. At the time of writing, numerous of other information systems has been adopted or developed in Norway for Covid-19 related issues, many of them integrated and interoperable.

4.5 Global reach and implications

Summarizing this case description so far, we first saw how Sri Lanka early on responded to the Covid-19 pandemic by identifing crucial needs, outlining technical requirements, and adapting generic software components in DHIS2 to innovate an information system to address the needs. Then we saw the innovations was shared to the ecosystem of DHIS2 and how core developers of DHIS2 reused the innovations from Sri Lanka to build a generic software metadata package available to all countries. Lastly, we saw how Norway responded to the Covid-19 by undergoing the same activities of Sri Lanka; identifying needs, outlining technical requirements, and adapting generic software components of DHIS2 to innovate information systems to address the needs, however this time adapting software which originated from

Sri Lanka, refined by the DHIS2 core team, and then was made available to countries like Norway.

This case description highlights how an innovation of one country could be beneficial for another through the use of a open software platform. Even though this thesis only focuses on Sri Lanka and Norway, the story of Covid-19 response within the DHIS2 ecosystem and the development of the Covid-19 Surveillance Package was a much more vast response from a global community of countries and organizations pitching in with feedback, commentary, possible solutions, requests and support. This thesis however does not (and cannot possibly) cover this enormous scope. Even though this thesis is limited to the aforementioned story, Informant 2 provides a short summary of the scope of the response to provide piece of context.

> *The unique thing is the global collaboration and the rapid scale of it. So typically these kind of packages, platform responses, is very top down, so it's coming from WHO. They come up with some kind of global standard, which takes years, and then they trickle that down into the platform. So we do the mandate packages and indicators, and we trickle that down to the countries. What was extremely unique about covid was that the initial package development was in Sri Lanka, and then we modified it and approved that, and made it a little bit more generic. But then we had that out even before the WHO got their act together and came out with some real global standards. And when they did, they basically mirrored what we had done since we have been working with them so long and kinda have a sense on how things are done. All the packages we've done, has kind of been initiated by the implementers before WHO got their standards together. It was really just a lot of various actors pouring in to the package development. Nothing was really done in isolation or in silos, it wasn't top down, it was a really incredible community effort. Folks from HISP all over the world, HISP Uganda played a big role in cross border detection, HISP Rwanda did a lot, and [a key developer's] testing. Sri Lanka in the initial package development. And really Norway has by in large consumed what everyone else has done, just translating it to Norwegian. It's probably the biggest effort.* (Informant 2, core developer)

Also, the global effort of developing and sharing innovations with DHIS2 was not new. The ecosystem of countries using and innovating with DHIS2 has embodied these practices for a long time.

In the guidance of the University of Oslo we are sharing knowledge and expertise. Whatever is invented in one of the other countries, in one of the other HISP nodes, is actually shared amongst the others. So that in my country, if there is an issue, unless it is something really new to my country, it is a high chance that I can learn from another country and ask a collegue from another HISP node and without reinventing the wheel I can just fast-track. I can get an efficient solution to answer a particular problem that we are having. So that is how the HISP community usually works. There is this community of practice (Informant 1, HISP Sri Lanka)

This notion is also validated by a DHIS2 implementer:

So every time someone creates something [using DHIS2], they say "hey, look what I have made" on our community of practice [DHIS2 online forum]. Its kind of like, they tell what they have made and they get praise for what they have done, but others also get to copy it and develop it further. (Informant 3, DHIS2 implementer)

Chapter 5

Analysis and discussion

This chapter presents the analysis and discussion of the study. First, the analysis highlights three prominent factors of how the DHIS2 platform supported innovation. Then, I discuss how we can gain a richer understanding of DGPGs by understanding how the DHIS2 software platform supported innovation. Lastly, a summary of how the analysis and discussion contributes to the existing body of knowledge and implications for practice will be accounted for.

5.1 Analysis of supporting factors for innovation

From the empirical case, I identify three prominent ways the DHIS2 platform has supported innovation. These are 1) enabling adoption of software by being freely downloadable, modifiable, and redistributable as open source software, 2) offering existing, customizable and generic software applications in a layered modular architecture, and 3) leveraging on local capacities, efforts and collaborations in the ecosystem. The upcoming subsections will account for the empirical framing whereas these three factors are displayed in all or some of the phases of innovation in the case description.

5.1.1 Innovation in Sri Lanka

The first factor supporting innovation in Sri Lanka was the open source nature of DHIS2. The ability to freely download, use, modify and redistribute the software resolved barriers of having to seek demanding financial resources to acquire a new system. The open source licensing also enabled them to bypass long procurement processes and supporting rapid implementation. Additionally, the open source codebase also enabled Sri Lanka to make necessary changes directly in the source code of the system when addressing novel needs which was not before possible to meet by the standard DHIS2 components. Open technical boundary resources, such as APIs, was also used to create interoperability between separate web application innovations.

The second factor by which DHIS2 supported Sri Lanka with innovation was the DHIS2 platform offerings of existing, flexible and generic software supporting general use cases in health care. In this case, it was the Tracker application, a generic application that supports tracking of an entity throughout different user-defined programs/steps. This was used as the foundation of a digital innovation of an application important for Sri Lanka. The digital innovation was done by customizing the application through user interface settings, or i.e. recombining flexible components of the application to create a problem-solution design matching.

Thirdly, HISP Sri Lanka already had local capacity (i.e. expertise, experience and resources) to both utilize the customization options with DHIS2 and conducting the implementation, and end-user capacity as health workers had experience of using the system for other use cases. Sri Lanka has built health informatics competence through educational programs (whereas DHIS2 has been used in the education) in the country since 2009 (Amarakoon et al., 2021) and had experience with implementing DHIS2 as an open source tool for other use cases prior to the pandemic (Hewapathirana et al., 2017).

The fourth factor for further innovation in Sri Lanka was the collaboration between the team in Sri Lanka and the platform core developers. By sharing their initial innovations with the ecosystem through communication available communication channels in the ecosystem and engaging in other innovations, the core developers provided support by assigning a core developer to support their process and leverage upon their closeness to the use case and local capacities. The collaboration aided Sri Lanka not only with their own innovations, but also innovating with the purpose of sharing it with other countries having the same needs.

5.1.2 Local innovation going global

The first factor of which DHIS2 supported innovation for the core software itself was the local innovations and efforts of Sri Lanka. Innovations of Sri Lanka was either shared, developed collaboratively with the core developers, or as inspiration when putting together a Covid-19 Surveillance package consisting of applications to support various needs in countries related to the pandemic.

The second factor was a collaboration with the local innovators in Sri Lanka. By collaborating with the Sri Lankan team that had capacity to innovate and was close to the use cases, the core development team could participate and aid the process, while also ensuring that the innovations could be adapted generically so that the efforts could benefit other countries too.

Thirdly, communication channels shared with the ecosystem was important for supporting innovation in the core software. Without the communication channels through Slack and the DHIS2 forum, the efforts of Sri Lanka might not have reached the core developers and the sharing of innovations might not have happened. The ecosystem engagement in the these communication channels were important for dissemination of information between the actors and for initiating and sustaining collaboration.

Forth, other global public goods such as health data standards by the WHO was important to innovation in the way that they could be based on existing international standards for contact tracing, and later international standards related to Covid-19 health data. Without proper standards made for global relevance, the innovations shared as core software might not have been relevant for other countries such as Norway (the WHO standards built in the Covid-19 package was one of the reasons DHIS2 was chosen by M1). WHO thus had a indirect supporting role in the ecosystem which the platform could leverage since the standards too were open to be incorporated into the platform software.

5.1.3 Re-embedding and further innovation in Norway

The first factor which contributed to innovation with DHIS2 was the open source nature. M1, as the first municipality to put together a DHIS2 instance for Covid, had limited financial resources, and by adopting open source software these challenges could be resolved. Additionally, being open source was also important because it allowed the software to be customized to the Norwegian context. This was important because Norwegian municipalities had different use cases and work flows that needed to be accommodated. By being open source, it also enabled KS to adopt and redistribute the software through their own software platform, making it available to all municipalities.

Secondly, DHIS2 supported innovation by offering existing, flexible and generic software, but different from Sri Lanka, this time the software was specifically related to Covid-19 as use case. This was crucial for choosing DHIS2 as the system to adopt for the M1 municipality, since existing support was already available and had the ability to be customized to better fit their needs and work flows. Said in other words, the innovation in Norway was enabled by the shared and generically designed innovation of Sri Lanka in the core software of DHIS2 and the efforts that was made by the core team to design and create innovations relevant to other countries.

Thirdly, since Norway had never used DHIS2 prior to the pandemic, the capacity to customize and implement the system was limited. However, implementers and developers from or coordinated from UiO contributed with expertise and development to support the customization process. Arguably, the support from existing capacity provides potential for Norway to build their own capacities and competence. This shows the importance of leveraging upon existing capacity in the ecosystem and collaboration between platform owner and complementors.

5.1.4 Synthesis of how innovations emerged and spread

In summary, bringing these factors of innovation together, the analysis shows that DHIS2 supported innovation by enabling rapid digital innovation through its open source nature, existing, generic software applications with customization abilities (both built in the software, offered boundary resources, and open source codebase), and leveraging upon existing capacities, innovations and collaborations in the ecosystem. These factors are synthesized in the following table.

Table 5.1: Three factors of how the DHIS2 platform supported innovation

#1	Enabling adoption of software by being freely downloadable, modifiable, and redistributable as open source
#2	Offering existing, customizable and generic software applications in a layered modular architecture
#3	Leveraging on capacities, efforts and collaborations in the ecosystem

However, it must be explicitly noted that these factors should not be understood as isolated factors which one by one contributes to increased support of innovation. It is the factors combined which constitutes to the way the DHIS2 platform supports innovation. Removing one of these factors will severely limit support for innovation globally. DHIS2 not being open source would limit rapid adoption, customization, third party development, distribution, and more. Without existing, customizable and generic software, the alternative would obviously be ”no software” or in the best case software that supports specific use cases with no ability to customize the interface. Without leveraging on capacities in the ecosystem, expertise of developing and implementing the software platform would lose a tremendous opportunity of collaborative value creation as innovations in the ecosystem, and new actors would have a cumbersome approach to enter the ecosystem and implementing the software. The factors as presented in table 5.1 should be seen as a combination of supporting factors of innovation in the DHIS2 platform. In the next section, I turn to a discussion of how these factors and developed understanding of innovation with the DHIS2 platform can inform a richer understanding of digital global pubic goods by relating the findings to existing literature.

5.2 Discussion of software platforms and DGPGs

So far, I have stated how the DHIS2 software platform supported innovation during the Covid-19 for mainly two countries. Next, based on the supporting factors for innovation in the DHIS2 software platform, I argue that DHIS2 enacts the traits of a digital global public good. Digital global public goods are digital technologies (Sæbø et al., 2021) designed to be non-excludable and non-rivalrous (Barrett, 2007; Samuelson, 1954) across geographies, social groups and generations (Kaul, 2013). I argue that DHIS2 enacts these traits in several ways which can be drawn from the factors of how the platform supports innovation.

First, DHIS2 enacts being non-excludable and non-rivalrous by being licensed and available as free and open source software (FOSS). This means that in practice, anyone can download the software, modify the software codebase, redistribute it, and by doing so won't affect any other users of the software. This is illustrated in the case both by Sri Lanka and Norway by how being open source enabled them to rapidly adopt the software without the barriers of procurement processes, long requirement- and development processes, and having to deal with the limitations of their financial resources. Both Sri Lanka and Norway modified the codebase to make it better fit their needs, and Norway showed a great example of how the software could be redistributed by the separate software platform of KS.

One current definition of a digital public good is already supporting DHIS2 as being a digital public good by being *open source software (...) that adhere to privacy and other applicable laws and best practices, do no harm by design, and help attain the sustainability development goals*" ("Digital Public Goods Alliance", n.d.). DHIS2 can according to this definition be considered a digital public good. The goal of this study has not been to account for privacy laws/best practices, how it does no harm by design, or how it addresses sustainability goals, but a thorough analysis of the software has been conducted by the Digital Public Good Alliance which points to how DHIS2 complies to these characteristics as well [1]. Even though open source software was a significant supporting factor for innovation, simply open source in itself is not sufficient to explain the way DHIS2 acts as a DGPG when supporting innovation.

Second, by adding the digital notion, DHIS2 is a software platform technology with certain technical characteristics which makes it different from physical goods (such as books) or abstract goods (such as knowledge). DHIS2 embodies a digital nature of a layered modular architecture with a stable core and flexible components. The platform offers generic metadata packages and generic software applications to support a wide range of use cases related to health. The software is open source and supported by knowledge boundary resources, such as open and online documentation and training material, which provides necessary means to e.g. learn how to implement and customize the software. The platform also provides technical boundary resources (such as user interface libraries, APIs, SDKs) which e.g. support data exchange with third party applications. These platform characteristics enhance non-exclusivity by enabling flexibility to any user by providing generic software building blocks supported by the architecture. Additionally, knowledge and technical boundary resources are available to all users which contributes to include those who needs support in implementing the software or needs to create interoperability with existing information systems. E.g. Sri Lanka showed how the technical boundary resources was used to create interoperability with third party

[1] https://digitalpublicgoods.net/registry/dhis2.html

applications.

Thirdly, the richness of how DHIS2 materialize as a digital global public good in the case description comes to show when we look closer into how the software platform addresses on key issue in order to be globally accessible.. Although the case shows how the software is available and can be consumed without affecting other's consumption, which is already enough to consider the platform a GPG according to the traditional definitions (Barrett, 2007; Samuelson, 1954), it leaves out how the software platform is (or is not) effectively leveraged to act as a relevant and effective tool for innovation. Non-excludability and non-rivalry does not take into account that a good can be available to all, but also irrelevant/ineffective to meet particular and contextual needs, e.g. if the user does not have the necessary means (knowledge, expertise, support) to use it as intended, or is designed for particular practices. Following the ideas of Sæbø et.al. (2021) a DGPG needs to be globally available, but also locally relevant. However, achieving local relevance on a global scale is though hardly an easy task.

Software that aims to support work practices is often intentionally or unintentionally built with a prescribed "best practice" of work processes by which the user must obey when using the software (Wagner et al., 2006). Such designs create mismatches between the software tool and the work practices that differ from from the "best practice" built in the system (Gasser, 1986). Even generic software aimed for broad use cases can also become too generic and making it unfit and irrelevant to any local instance (Strong & Volkoff, 2010). These challenges arguably would impede DHIS2 from acting as a global public good because it would exclude groups/contexts that can't comply to the design choices or use the system effectively.

The case description shows how this type of relevance can be achieved. The use case of responding to Covid-19 was the same for both countries, but the particular needs and practices related to covid-19 response were different. The case shows that the DHIS2 had the ability to become relevant to both use contexts by supporting innovation in a *combination* of 1) open source software, 2) existing, generic and customizable software, 3) flexibility of the platform architecture, and 4) an ecosystem that leverages upon existing capacities, efforts and collaborations. In other words, open source, generic and customizable software application has been available in a flexible platform architecture to support initial innovations for unprecedented use cases and necessary flexibility to fit/change the software to address novel requirements/needs in two different country contexts. The software provided has been malleable in such a way that contextual differences can be mediated by taking advantage of the customizability in the generically designed software components. Local innovations has been absorbed into the core software and/or used as inspiration by the core software team, repurposed as generic applications available to all, and incorporated global health standards that increases its default relevance. And lastly, collaborations between core and user organization for leveraging on capacity and expertise, ensuring generic design (as in the case of Sri Lanka), and ensuring relevant adaptations in local contexts (as in the case of Norway).

DHIS2 can be considered a DGPG because it is open and available to all as a flexible platform technology with generic software as it is a stable foundation for innovation which is surrounded by an ecosystem of a platform developer and complementors which contributes with innovations that can be globally relevant. The implications of this is that DGPGs must be understood as more than just open source software available to all, which is how the Digital Public Good Alliance defines a public good. To understand a DGPG one must take into account the capabilities of the software architecture and ecosystem surrounding the technology to fully capture how the technology is non-excludable, non-rivalrous, and locally relevant on a global scale. We see how the notion of a platform ecosystem comes to show by how actors/complementors leverage upon existing platform architecture as technological foundation, get support from the platform core developers, and in turn provide globally relevant digital innovations back to the platform. This brings us to the last phenomea emerging from the case study, which is how the DHIS2 as a DGPG generates positive network effects.

So far I have argued that DHIS2 actualizes itself as a digital global public good by supporting innovation (three factors) which embodies a nature of being non-excludable, non-rivalrous, and locally relevant on a global scale. The case not only shows how these traits materialize, but when seen combined, I argue that DHIS2 as a DPGP software platform platform support innovation in such a way that it generates positive network effects for the whole ecosystem and beyond. As exemplified in the case study, an ecosystem of complementors which use the generic software to innovate, and then contributing back to the generic software, enhances the software for everyone. In essence, Sri Lanka used existing generic software, customized it, which proved to be valuable for other countries. Their efforts was used as a foundation to provide a generic solution in the core software platform, which then Norway could re-adopt and further use to innovate. I argue that DHIS2 as a DGPG software platform supports innovation in such a way that it stays relevant and useful when supporting local innovation and absorbing local innovations that are relevant for all countries. These network effects creates a self-enhancing platform that has the potential of being continuously useful and valuable to countries of the world as new global challenges arise. These positive network effects can be summarized in by this model of a self-reinforcing mechanism:

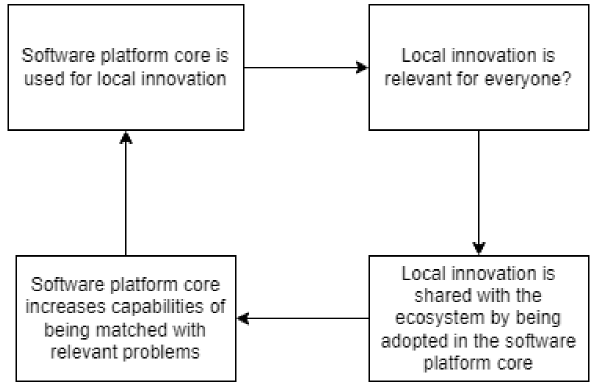

Figure 5.1: Self-reinforcing network effect in the DHIS2 ecosystem

Other research also shows how the software platform and the Covid-19 metadata package has contributed to similar innovation in ten lusophone and francophone countries in Africa (Poppe et al., 2020). Norway is a great example to study in detail because DHIS2 has never been implemented or used in Norway prior to the pandemic, showing that countries without prior expertise with DHIS2 can implement it successfully as a result from network effects and capacities in the ecosystem.

In sum, DHIS2 is not a digital global public good simply because it is a digital open source technology. DHIS2 materializes as a digital global public good when framed as both as technology with certain capabilities supported by its architecture, and an ecosystem of contributors of complementary innovation. The core platform software is developed, maintained and provided by the UiO, but as a global public good, it is also provided by the actors of the ecosystem when re-embedding local innovations back to the platform which can make it available and relevant for all. This is a clear difference between traditional public goods where its usually provided by a government or a company. In this case, the platform owner and its ecosystem of complementors are mutual providers of the DGPG because the available and relevant software is provided by the platform owner and complementors in a dynamic network of innovators.

5.3 Theoretical contribution and implications for practice

This thesis has theoretical contributions and implications for practice. First, the study contributes the existing body of knowledge on digital global public goods. It does so by providing a qualitative case study that shows how three supporting factors for digital innovation in a software platform can materialize as the means to provide a software platform as a digital global public good. Earlier research has provided conceptualizations of DGPGs (non-excludable, non-rivalrous, locally relevant on a global scale) which this thesis finds fitting for understanding the broader characteristics of DHIS2 as a DGPG (Sæbø et al., 2021), but this thesis extends the understanding by showing how the characteristics are fulfilled by illustrating how DHIS2 supports digital innovation as a digital platform.

More generally, this study contributes to the digital platform literature by confirming how software platforms are well suited for supporting digital innovation (K. J. Boudreau, 2012; Gawer, 2014; Parker et al., 2017) and can generate positive network effects (K. J. Boudreau, 2012; Constantinides et al., 2018; Gawer & Cusumano, 2002). However, what is new is how certain characteristics of software platforms and how it supports innovation can produce traits of a digital global public good with a purpose of supporting global health challenges such as pandemics. When digital technologies are open source, provides existing generic applications and packages, and exists in an ecosystem with a collaborative interactions, the capabilities and potentials of digital innovation are realized in much larger degree because the characteristics of digital technologies (recombination, problem-solution matching and generativity) can actualized through the open source nature and sharing of innovations. In other words, what we see in the case is how digital technologies are being leveraged in exact way that digital technologies promises, and it does so enabled by the software platform architecture, contents and ecosystem. This nuanced view of a digital platform answers to the call for research on platforms and digital technologies with non-commercial purposes (Koskinen et al., 2019; Nicholson, Nielsen, & Saebo, 2021) and, in this case, by showcasing a digital platform that can be globally open, available, and be consumed across contextual and geographical boundaries while assuring local relevance in implementation. More generally contributing to the information systems field, this research shows how a DGPG platform supports global scalability and large-scale distribution of sociotechnical arrangements (Sørensen, 2016) as a platform ecosystem of actors innovating, sharing, collaborating and leveraging on digital technology capabilities/architectures.

The thesis also have some practical implications. Some research suggests that convergence of technologies, people and organizations have the means to spawn innovations that are crucial for the greater good, such as fighting pandemics (Lee & Trimi, 2021). In this thesis, we have seen how a software platform with certain technological characteristics and architecture, and an ecosystem of contributing actors could lead to digital innovations for responding to Covid-19 that could be shared and adopted globally. The Covid-19 was a global problem that could only be stopped by globally collective response, and this thesis has shown some of the potential of how a DGPG software platform can contribute to such a global issue. Thus, the key takeaway for practitioners working in public health sector and even other areas of public service, is that a software platform considered a DGPG can be useful to leverage upon when responding to issues that relates to globally shared problems. Instead of having to develop information systems from scratch (including understanding all requirements, changes, health standards, etc), a platform ecosystem such as DHIS2 have potential be a collectively supported software tool where actors contribute with innovation, capacities, and collaborations to ensure a globally relevant software. Instead of responding alone, DGPG software platforms can be a way to respond together.

5.4 Limitations and further research

One limitation of this study is that most of the research referred to when positioning myself in the DGPG literature also use DHIS2 as the studied artefact. More research on other digital technologies are needed to gain a richer picture of how digital materials and sociotechnical constellations take form and materialize as a DGPG.

Similarly, this research has only been conducted looking at the dynamics between a software platform and two other countries. Even though other research on DHIS2 and Covid-19 response points to how the Covid-19 surveillance package was adapted and adopted in other countries (Poppe et al., 2020), more research needs to be done to capture a larger network of countries and how digital platforms support multiple and differing countries and contexts.

Another limitation is the narrow theoretical framing. Even though this thesis argues that some supporting factors of innovation in a software platform realizes a DGPG potential, there are several other factors which has not been mentioned in this thesis due to a restricted analysis. Other papers points out other very important factors of innovation related to the same case, such as agility and multi-sector collaboration (Amarakoon et al., 2021), standards

(Poppe et al., 2021), and platform culture/philosophy (Russpatrick et al., 2021). A recent research agenda of DGPGs for developement (still a pre-print and thus not mentioned earlier in the thesis) also points out the role of donors that support development, maintenance, and sustainability of DGPGs with funding (Nicholson et al., 2022). Donors are important actors in the DHIS2 ecosystem because they support development of core software directly and thus strengthening the innovation capabilities, but this factor has not been accounted for in this thesis. A general question remains to how existing conceptual and empirical apparatus can and should be used to enable a better understanding of DGPGs.

Lastly, even though this thesis frames the analysis and discussion as having a positive impact, digital platforms embodies an ontological uncertainty because we cannot foresee what developers of open source software platforms such as DHIS2 are going to do with it. Digital platform can become a massive asset for businesses that has proved to leverage on its benefits over the course of all of its development phases (Tan et al., 2015), but digital platforms in some development countries and in some sectors has also brought about negative impacts such as creating and maintaining deficiencies of institutional functions required by markets (Heeks et al., 2021) which reminds us that digital technologies, no matter how noble, can produce both positive and negative impacts. Further research on the topic of digital platforms as global public goods, should also focus on ethical and critical issues such as potential consequences and negative impacts on power dynamics (Hurni et al., 2021), how to incorporate value sensitive design in an ecosystem (de Reuver et al., 2020), and whether the openness of such platforms "*enable more-advantaged groups to extract disproportionate value from the work or resources of another, less-advantaged group*" (Heeks et al., 2021, p. 768).

Chapter 6

Conclusion

This thesis began by outlining a knowledge gap of understanding innovation with digital platforms with non-commercial purposes. Accordingly, and motivated by the context of Covid-19, the importance of digital innovation in the response to the pandemic, and the global nature of the problem situation, this study reduces the knowledge gap by presenting a case study of a software platform that supported digital innovation in two countries as a digital global public good. The guiding research questions were 1) *How can digital global public good software platforms support digital innovation?*, and 2) *How can our understanding of digital global public goods be informed by digital innovation and software platforms?*

The thesis provides insights into three key phenomena that extends our knowledge on software platforms as digital global public goods and answers the research questions. First, this thesis showed how a software platform supported innovation during the Covid-19 pandemic in two countries which relates to the first research question. Three supporting factors were identified, namely 1) enabling adoption of software by being freely downloadable, modifiable, and redistributable as open source software, 2) offering existing, customizable and generic software applications in a layered modular architecture, and 3) leveraging on local capacities, efforts and collaborations in the ecosystem.

Secondly, by studying how the software platform supported innovation, this thesis argued that software platforms that supports innovation in this way enacts the traits of being a global public good, because the combination of factors fits the traits of being globally non-exclusive, nonrivalrous, and locally relevant on a global scale. And thirdly, DGPG software platforms that support innovation in the aforementioned ways have potential to generate positive network effects that benefit all and self-enhances itself as a DGPG. These two discussions answers the second research question.

Seeing these three key insights together, this study contributes with knowledge on a software platform that supports innovation to address global challenges as a digital global public good. The main idea of this thesis is that by combining three theoretical concepts (digital innovation, digital platform, and digital global public good) we can study how flexibility of digital technology, scaleability of digital platform architectures, and the ecosystems of actors sustain a digital global public good software platform as vehicle for digital innovation to meet a wide range, unprecedented global challenges. However, these conclusions should be considered as a spark to conduct more research on digital global public goods and software platforms for non-commercial benefit. The nature of a digital global public good is still immature, and studying innovation in a software platform can only be considered a small step to gain a better understanding of DGPGs. More research broader contextual boundaries is also necessary. This research has only focused on one platform and two countries, and the findings in this research needs to be validated by other platforms and in networks of other and more countries to falsify, extend or confirm similar phenomena. More studies are needed to strengthen the theoretical foundation and conceptual apparatus for explaining the nature of DGPGs.

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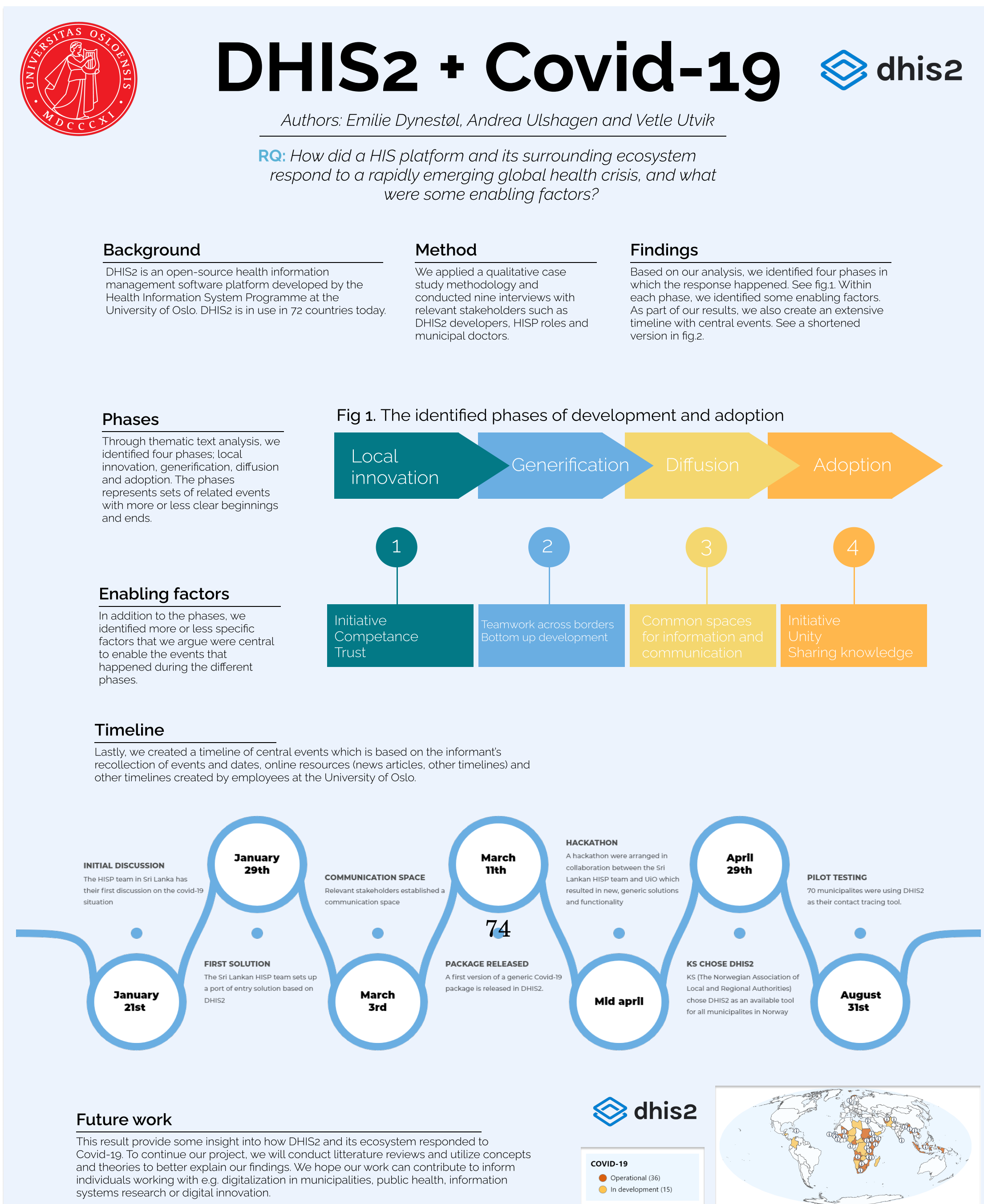
Appendix A

Research poster, ”DHIS2 +



Appendix B

Paper 1

DIGITAL TRANSFORMATION UNDER A PANDEMIC: A CASE STUDY OF COVID-19 CONTACT TRACING IN NORWAY

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Abstract

In March 2020 the number of confirmed COVID-19 cases in Norway increased rapidly, and the efforts to trace contacts of positive cases were under severe pressure. Contact tracing in Norway is the responsibility of the municipalities, and no standardized or coordinated contact tracing practices were at the time in place on the national level. The afflicted municipalities did their best to cope with the chaotic situation and did contact tracing using excel spreadsheets or pen and paper. These approaches have their flaws, and in particular, failed to scale in several municipalities. In this paper, we report from a case study of collaborative efforts made to address this challenging situation by the University of Oslo (UiO), the Norwegian Association of Local and Regional Authorities (KS), the Norwegian Public Health Institute (NPHI), and several municipalities. The DHIS2 software platform and experiences implementing DHIS2 for contact tracing in other countries were the basis for these efforts. We describe the process of designing and implementing DHIS2 to date and the experiences so far. We pay particular attention to the potential long-term implications of this process, which we see as a digital transformation of contact tracing in particular and disease surveillance in general in Norway. Our contribution is a rich case description as well as the identification of themes relevant to the further development of DHIS2 for contact tracing as well as other systems in a similar context. These themes include cross-municipal collaboration and information sharing across judicial/legal boundaries, standardisation and centralization of support structures, and potentially transformation of contact tracing practices.

1 Introduction

The SARS-CoV-2 virus, causing the outbreak of the COVID-19 disease, has severely affected health, economy and social interaction globally in 2020. While Norway so far is spared the high numbers of infected, hospitalized and fatalities seen in other countries, the disruption of the economy is massive and people's lives have changed.

The Norwegian health authorities responded to the pandemic along two different paths: an infection control strategy to reduce transmission and a treatment strategy to prevent deaths among people who become severely ill. The infection control strategy aimed to delay the onset of the epidemic and give the healthcare service more time to prepare, and then slow down transmission so that the epidemic is spread over a longer period and fewer become infected overall.

On March 12, 2020, the Norwegian Institute of Public Health (NIPH) had registered 500 people with COVID-19, many of them returning to Norway from abroad. On the same day, Norway closed down universities, schools and kindergartens, restricted the number of people that could gather for any kind of events and implemented other restrictive measures to control the spread of the virus. With a peak in the daily reported cases in late March, the number steadily dropped and stayed low during summer, and started rising again after July. This is considered as an effect of the society opening up again and travel restrictions being lifted. Clusters of infected persons have emerged in places where people meet, for example cruise ships, weddings and gyms. Continuously identifying and monitoring infected persons and identifying their contacts is crucial to break chains of infection and keep the situation under control. This contact tracing work is complex, resource intensive and is considered as a cornerstone in the response to limit the spread of COVID-19 until a vaccine is available to the general public.

Appendix C

Paper 2

AN INSTITUTIONAL ANALYSIS OF DIGITAL TRANSFORMATION OF COVID-19 CONTACT TRACING DURING A PANDEMIC

Research paper

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Abstract

With rising numbers of COVID-19 positive patients in March 2020, Norwegian municipalities, who are responsible for contact tracing, struggled to register all the infected and their close contacts. This was partly due to the scale of the pandemic and partly because the only tools they had were pen and paper and in some cases spreadsheets. To address this situation, some municipalities started exploring how digital health information systems could support them in handling the rapidly changing and unforeseen complexity of the COVID-19 contact tracing work. Drawing on an ongoing case study of disease surveillance in Norway, we first explain how contact-tracing work has undergone a rapid digital transformation. Then we offer an institutional analysis by using a perspective of institutional work forms to illuminate how the digital transformation has brought about long term institutional changes. We then argue that we have seen an institutionalization of digital contact tracing while manual contact tracing is still ongoing. Thus, both the new and the old institution stay alive and are central for different purposes. With this paper, we are contributing to research on digital transformation by theorizing how technology and more particularly digital transformations are intertwined with institutional change. We further contribute to research on institutional work by illustrating how this is a relevant lens to understand digital transformations.

Keywords: Digital transformation, Institutional work, Digital contact tracing, COVID-19.

1 Introduction

The COVID-19 pandemic has had shock-like effects in Norway as well as in the rest of the world. On 12th of March 2020 the Norwegian prime minister announced that "*Today, the government comes up with the strongest and most intrusive measures we have had in Norway in peacetime.*" (Røed-Johansen and Torgersen, 2020, p.). Reducing people's movement slowed down the spread of the virus but one of the most important tools health authorities use to control a fast spreading virus is contact tracing (FHI, 2021).

According to the Norwegian Institute of Public Health (NIPH), COVID-19 contact tracing consists of two main tasks (NDH, 2021). First, a contact tracer interviews the infected (hereafter the index) and identifies the index' close contacts. Second, close contacts are informed and followed up by a contact

Appendix D

Paper 3

Information Systems Resilience: The Role of Flexibility and Stability

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This paper contributes to conceptualization of information system resilience. By building upon and extending the framework of Heeks and Ospina (2019), we argue that an information system's ability to be resilient lies in its balance between stability and flexibility. Based on empirical findings we suggest that a stable core and flexibility to change is crucial when a digital system is faced with unforeseen adversities. We hope to contribute to more theorizing of the information system resilience and inspire further research on this subject. The paper may also have practical value for stakeholders working with implementation of national information systems in the health sector. This is a qualitative case study conducted together with the Health Information Systems Programme (HISP) at the Institute of Informatics, University of Oslo. Our findings are based on empirical insights related to the DHIS2 software during the Covid-19 response.

CCS Concepts: • **Information systems** → *Information systems applications.*

Additional Key Words and Phrases: information systems resilience, digital adversity

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1 INTRODUCTION

Resilience of individuals, societies and institutions were put to the test when faced with the outbreak of the Covid-19 disease early 2020. In the response to the pandemic, information systems played a significant role in handling crucial functions like e.g., contact tracing, vaccine registration, and general data collection and aggregation.

This paper answers the call for more research on how information systems can play a role in the response to a pandemic [13] and how digital technologies and innovations can contribute to building resilience [4, 9]. In this article, we take a closer look at how stability and flexibility of an information system relates to resilience in a context of adversity. We aim to answer the research question: "How does the balance of stability and flexibility of an information system relate to resilience?"

We deductively draw on the analytical framework of information systems resilience developed by Heeks and Ospina (2019) and contribute by suggesting extending the framework to capture the notion and role of stability-flexibility balance of an information system. The empirical material is based on a qualitative case study of a health management information system (HMIS) named District Health Information Software 2 (DHIS2) and its resilience against the Covid-19 pandemic.

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