



Hanna Raevuori

Identifying solutions promoting healthcare innovations during the Covid-19 pandemic

Systematized literature review

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Abstract

Author: Hanna Raevuori
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Introduction: Given the limited healthcare resources, there are no simple solutions to address the growing demand for care. Therefore, all forms of innovation that contribute to enhancing healthcare systems are necessary. Healthcare innovation processes are typically costly and time-consuming, but the global Covid-19 pandemic has demonstrated that extraordinary circumstances can accelerate the development of healthcare innovations. The aim of this literature review is to identify the enabling factors of healthcare innovation during the pandemic.

Methods: Systematized literature review was chosen to conduct the research. The literature search was completed in three databases: CINAHL Complete (Ebsco), ProQuest Central and ScienceDirect. The research protocol followed the framework presented by Niela-Vilén and Kauhanen (2015).

Results: Twelve peer-reviewed research articles, published between 2020 and 2022, were included to the review. The inductive content analysis process induced three themes answering the research question. The themes describing the enabling factors of healthcare innovation during the Covid-19 pandemic were Broad collaboration, Supportive structures and policies as well as Utilizing the momentum.

Conclusion: Several enabling factors promoting healthcare innovation during the Covid-19 pandemic were identified in the review. The main findings indicate that healthcare innovation benefited from broad cross-sectoral collaboration around common goals, digitalization and the rapid adoption of new technology, flexibilities in regulations that allowed regional adaptations, creative repurposing and strong sense of duty among the healthcare professionals sparked by the exceptional circumstances that the pandemic created.

Recommendations for future research: Further research is needed to comprehend the interdependencies among the various factors that facilitated innovative activities, particularly those findings that presented contradictory elements, such as regional adaptations.

Keywords: Innovation, Healthcare, Covid-19

Contents

1	Introduction	5
2	Innovation	6
2.1	Defining innovation	7
2.1.1	Open innovation	9
2.1.2	Innovation management	10
2.1.3	Innovation ecosystems	10
2.1.4	Innovative culture and environment	11
2.2	Innovation in crisis	13
2.2.1	Covid-19 pandemic	13
2.2.2	Impacts on the healthcare sector and innovation	14
3	Research purpose, aim and objectives	15
4	Research method and implementation	15
4.1	Systematized literature review	16
4.2	Search strategy	17
4.2.1	Research question and search terms	18
4.2.2	Selection criteria	19
4.2.3	Test searches	21
4.3	A literature search and study selection	22
4.3.1	Selection of studies	23
4.4	Evaluation	25
4.4.1	Critical appraisal	26
4.5	Data analysis and synthesis	27
4.5.1	Inductive content analysis	28
5	Results	30
5.1	Broad collaboration	32
5.1.1	Collaboration beyond traditional boundaries	33
5.1.2	Shared purpose	33
5.1.3	Engaging private sector	34
5.1.4	Building diverse communities	35
5.2	Supportive structures and policies	36
5.2.1	Investing in technology	37

5.2.2	Prioritizing through policy instruments	38
5.2.3	Regional flexibility	38
5.2.4	Supportive leadership	39
5.3	Utilizing the momentum	39
5.3.1	Flexible repurposing	40
5.3.2	A window of opportunity	41
5.3.3	Will-do-attitude	41
6	Discussion	42
6.1	Review of the results	43
6.2	Reliability and ethics	46
7	Conclusions	47
	References	51
	Appendices	56
	Appendix 1. Summary of the studies and Critical Appraisal Tool results	56
	Appendix 2. Example of the Inductive Content analysis	64

1 Introduction

Ensuring healthy lives and promoting well-being, while the population is ageing, is one of the greatest challenges for the future. Inequality highlights the differences in health, and those who can afford it, invest increasingly in their health and wellbeing. The key solutions to secure the quality and availability of health services for all, may be found in preventive healthcare, digitalization, automation, immigration, and longer careers, or perhaps through some completely new innovations. (Dufva 2020: 25.) Innovations, and the resulting growth, are essential for competitiveness and development (Ståhle & Pirttivaara 2015: 47). This applies especially to the healthcare sector, where effective changes are needed to improve the quality of patient outcomes, increase access to care, and reduce costs. Due to workforce shortages the need for innovation increases, as more tasks must be completed by fewer healthcare workers. (Cianelli et al. 2016: 4.)

Healthcare innovation processes can be expensive and time-consuming under normal circumstances, but the global pandemic of Covid-19 has shown that unusual times can accelerate the development of healthcare innovations to unprecedented speed. The extraordinary speed combined with global collaboration over well-defined problem, creates other bonuses, such as affordability of the innovative solutions. Combining the diverse skills of an innumerable amount of people, of all ages and professions, has provided several cost-effective and practical solutions that solve fundamental problems and help to cope with Covid-19. Even the ideas that are not immediately successful, benefit from the open and fast iteration process of the innovation development. As healthcare organizations return to normal operations it is important to sustain the novel approaches developed during the pandemic, but even more crucially, the organizations should sustain the processes that enabled such innovation. (Palanica & Fossat 2020: 645-646; Voke et al. 2022: 1.)

The two main theoretical approaches to study innovation are the enabling perspective i.e., finding out the hindering and contributing factors to innovation, and the outcome perspective, which focuses on the transformation of products, services, and processes. Generally, innovation effectiveness is measured from the latter, much narrower, perspective of a new product development success. However, the enablers of innovation that cover e.g., organizational processes, systems, culture, structures, and people are directly linked to the effectiveness of the outcomes. (Ahmed & Shepherd 2010: 166-167.)

This thesis presents a systematic literature review on the enabling factors of healthcare innovation during the Covid-19 pandemic. As stated above, there is a continuously growing pressure to cut healthcare costs and improve access to health services, while the need for care is increasing as the population is ageing. With limited healthcare resources there are no easy solutions to solve the dilemma, hence all types of innovations helping to improve the healthcare systems are needed. The literature review will examine the phenomena of healthcare innovation during the pandemic and present current information available on the environment and processes that stimulated the innovation. The aim of this review is to identify the solutions that have enabled innovation during the global crisis. The purpose is to provide information for healthcare organizations and their innovation ecosystems on the factors that could be utilized, not only at the time of possible future crisis but during normal times too, to enhance effectiveness in healthcare innovation.

2 Innovation

The theoretical background of the Master's Thesis will define innovation and present different innovation categories together with the concepts of open innovation, and innovation ecosystems. Innovative culture and capabilities in relation to healthcare are examined in detail. Finally, noteworthy findings and insights from recent research regarding healthcare innovation in a crisis are introduced.

2.1 Defining innovation

The word innovation originates from the Latin word *innovare*, which refers to change. Innovation can be thought of as a process where a series of changes are made creating value from ideas. (Tidd & Bessant 2014: 3.) Innovation can also be defined as creating something new that did not previously exist. It brings something new to the market and creates value for which people are willing to pay for. (Sigismund Huff & Möslin & Reichwald 2013: 5; Tidd & Bessant 2014: 5.) According to Rogers (2003: 12) innovation is an idea, object or practice that is considered to be new either by an individual or other unit, such as an organization. He states that it is irrelevant whether the idea is truly new, instead the perceived newness of it matters. Innovation helps organizations to reach their goals, such as providing better public services, and advances competitiveness by being a strategic resource. (Tidd & Bessant 2014: 16.) There are various types of innovation ranging from improving single components to system level innovation where for example a completely new version of some existing product is created. Incremental innovation creates value for the current way of doing business while radical innovation may change the whole market. (Tidd & Bessant 2014: 5-6.)

The WHO Health Innovation Group emphasizes that health innovation is not limited to product development and has agreed on a definition for health innovation as follows:

Health innovation is to develop and deliver new or improved health policies, systems, products and technologies, and services and delivery methods that improve people's health (WHO Health Innovation Group 2021).

Due to the various types of innovation and their high complexity, classification of innovation is helpful. There are several methods for classification e.g., the object of innovation, degree of innovativeness and innovation approach. Product, service, and process innovation complemented with social or organizational innovation and market innovation are typical classifications of innovations when studying the objects of innovation. Classification by the

degree of innovativeness can be observed through the scope of innovations i.e., whether the innovation is incremental or radical. Likewise, the innovation approach can be studied, and innovations can be classified as closed or open innovations. (Pham-Gia 2011: 16-17.) As demonstrated in Table 1. Different types of innovation, Mäntyneva (2012: 35) presents a categorization of innovation where the object of innovation can be product, service, business model or process and the degree of innovativeness is either radical or incremental.

Table 1. Different types of innovation (Mäntyneva 2012: 35)

Degree / Object	Product	Service	Business Model	Process
Radical				
Incremental				

Product and service innovations can be developments and changes to the functionality, feature, performance, quality, or cost of a product or service. A process innovation can be defined as either tangible or intangible, and it can be classified as either administrative or core process. Social innovations as well as organizational innovations cover alterations in organizations and institutions together with innovations in management and social behaviour. (Pham-Gia 2011: 16-17.) Innovations concerning locations, customers, regulations, business models and marketing instruments can be classified as market innovations or business model innovations (Pham-Gia 2011: 16-17; Mäntyneva 2012: 35, 44-45).

The degree of innovativeness refers to the scope of innovation as minor changes in products or improvement in services are considered to be incremental innovations. Incremental innovations are built on the organization's core capabilities and provided for existing markets while radical innovations

may fundamentally change the whole market, thus requiring the organization to have new capabilities. (Pham-Gia 2011: 17.) According to Mäntyneva (2012: 38) most innovations are incremental. Radical innovations often pose significant risks and require greater financial inputs than incremental innovations. In addition, radical innovations often take longer to develop from idea to implementation. Hence organizations generally focus their innovation activities and product development resources towards incremental innovations. (Mäntyneva 2012: 37-38.)

2.1.1 Open innovation

Innovation activities have traditionally been closed processes i.e., the process is kept within the organization and is self-made. On the contrary, open innovation relies on networks and cooperation at different stages of the innovation process. Successful innovation requires combining different types of knowledge, skills, capabilities, needs and interests, which can be found within the organization or through networking. Cross-organizational cooperation is often referred to as open innovation, which can be utilized to decrease the financial investments, thus reducing the risks. (Mäntyneva 2012: 133-134.)

Perkins (2008 cited in Ahmed & Shepherd 2010: 173) defines open innovation as the

leverage of capabilities and expertise of others to deliver differentiated and meaningful innovation.

The expansion of open innovation originates from the idea that it is impossible for one organization to possess all the required knowledge and skills. Thus, by combining the knowledge from multiple sources organizations should achieve better outcomes than in closed innovation process. Strategic alliances aim to unite resources from different organizations in order to achieve common goals. (Mäntyneva 2012: 133-134.) However, Ståhle and Pirttivaara (2015: 49-50) remind that there are great challenges in joining the interests of different organizations. In order to function effectively the innovation ecosystems must unite leadership and strong stakeholder engagement through strategies, policy

measures and practical actions while including universities, public sector, business world as well as end users.

2.1.2 Innovation management

Innovation is a process that needs systematic management. The core process comprises picking up on ideas to recognize opportunities, acquiring resources for implementation and developing the venture while creating value and capturing benefits. (Tidd & Bessant 2014: 16.) Open innovation management requires much more than just managing internal processes for successful developments. Series of external collaboration and processes must be monitored and managed. Therefore, organizations should focus on parallel and integrated innovation processes while encouraging stakeholders to participate early in the development process. The key element is to achieve the right balance between managing the organizations' core competencies in internal innovation activities and the capability to identify and harvest adaptable new ideas from other organizations. (Ahmed & Shepherd 2010: 173.)

Operating in open innovation ecosystems requires organizations to have mutual self-interests, open communication, and trust. The organizations should adapt rewarding systems that support the market success of ideas and enable the organizational culture to develop e.g., through the introduction of an idea submission and management system. Moreover, focus needs to be on managing and governing partners while ensuring that intellectual property is shared effectively. Ultimately, a proactive approach anticipating the customer needs through customer engagement in the innovation network needs a great consideration. (Ahmed & Shepherd 2010: 174-175.)

2.1.3 Innovation ecosystems

Innovation ecosystems emphasize the cooperation of various parties – companies, public organizations, financiers, and research institutions. The collaboration of universities, businesses and the public sector makes it possible to respond to the big societal challenges and needs. Within the ecosystem

versatile data flows, knowledge and technologies are combined. While there is no universal model for all innovation ecosystems the key enablers for a successful ecosystem are the operating methods, the culture including enthusiasm and strong interaction along with an environment supporting innovation activities. The ecosystems operate both virtually and locally, consequently digitization supplemented with physical connections becomes important. Innovation ecosystems aim to address social challenges and needs by utilizing regional expertise as well as internal and external networking. By solving these issues, they may also generate new business opportunities. (Stähle & Pirttivaara 2015: 47-50.)

2.1.4 Innovative culture and environment

Research shows that there is a strong correlation between innovation and organizational health, which underlines the need to understand that providing value to customers through innovation is heavily linked to the organizational culture, systems, and strategies (Ahmed & Shepherd 2010: 166-167). Ahmed & Shepherd (2010: 292-293) have recognised some key elements of highly innovative organizations compared to less innovative organizations. Highly innovative organizations emphasize creativity and long-term goals, giving freedom to the employees to reach the strategic goals. Less innovative organizations are more fearful of risks and focus on the short-term horizon, which turns their focus inwards and decreases communication, while highly innovative organizations interact effectively both internally and externally. They often have a system for collecting and evaluating new ideas, respecting diverse opinions and individualism. This individual freedom consequently motivates employees by deriving self-satisfaction from the feeling of achievement and recognition. In addition, the organizational environment is such that there is freedom to fail. Less innovative organizations tend to emphasize consensus and realism. Therefore, new ideas face more resistance and there is less individual autonomy. Rewarding systems do not give recognition based on individuals diverse thinking, behaviour, or actions, instead promotions are given e.g., based on career lengths. The organization's structure can either support or

hinder the innovation activities. Consequently, highly innovative organizations often have loose structures giving them flexibility to respond to external changes. (Ahmed & Shepherd 2010: 292-293, 298.)

According to Mäntyneva (2012: 57) organizations ability to innovate builds on top of the organizational culture. Oftentimes it is not the lack of ideas and vision hindering the development in the organization, but the conflict between innovation activities and organizational culture, operating systems and for example rewarding systems. Another major hindering factor is the risk-avoidance culture which, instead of maximizing the opportunities, tries to minimize risks and costs. (Mäntyneva 2012: 56; Ahmed & Shepherd 2010: 292.) The healthcare sector is, justifiably, extremely risk averse as healthcare workers constantly aim to ensure patient safety and prevent harm (Sensmeier 2019: 7). Various factors advocate to maintain the status quo. Incremental development is done, but major changes rarely take place. The relationships and agreements of partners contribute to the system's sustainability as well as regulation, infrastructure, and prevailing habits. (Hämäläinen & Jäppinen & Kivisaari 2011: 221.)

The highly trained professionals of the social and healthcare sector are motivated to develop their work. Thus, there are plenty of new ideas in the social and healthcare organizations. However, as the healthcare system and professionals are overloaded with work, often there is no time for creativity, development, experimentation, and implementation. In addition, innovation may not be seen as an investment for the future, where in a few years, better productivity or quality could be achieved. (Hämäläinen et al. 2011: 219-222)

According to Cianelli et al. (2016: 6-28) to promote a culture of innovation healthcare organizations should:

- promote and value divergent thinking to enable innovation,
- encourage employees to take managed risks,
- accept failure and learn from it,
- encourage agility and flexibility in developing solutions and

- embrace autonomy and freedom to boost employees' confidence.

2.2 Innovation in crisis

During difficult times a survival through a crisis is the most important driver for many organizations, often resulting in a lack of willingness to invest in R&D or to drive innovation. However, innovations can help organizations to create new growth opportunities, develop new markets and provide a competitive advantage to find a way out of the crisis. A crisis can present organizations with a great chance to improve effectiveness, competitiveness, and innovation capability, consequently transforming into a lean organization. (Pham-Gia 2011: 14.) Thus, the famous saying that an opportunity lies in every crisis.

Wiedner, Croft and McGivern (2020: 186-187) state that urgency, resource scarcity and collective identity are general drivers of innovation during crises. In addition, they argue that altered workforce characteristics, lower coordination costs i.e., smaller groups communicate more effectively, and decreased scrutiny enable improvisation. The urgency and limited resources experienced during a crisis can play an important role in fostering novel innovations in health and social care systems. Beyond the improvised innovations witnessed in the frontline of healthcare services, advancements in deprioritized health services have also the potential to benefit the broader health and social care system. (Wiedner et al. 2020: 188.)

2.2.1 Covid-19 pandemic

Covid-19 is a recently discovered coronavirus causing an infectious disease. It was first learned about in December 2019 following reports on viral pneumonia cases in China. The new coronavirus SARS-CoV-2 was named after its close relative SARS coronavirus. The disease it causes is called Covid-19, which is an abbreviation from the words corona, virus, disease and 2019. (WHO Coronavirus disease 2021; THL Koronavirus SARS-CoV-2 2023.)

Covid-19 is transmitted as a droplet infection and can also spread as airborne transmission or, although less common, through contact. The Covid-19 coronavirus causes a sudden respiratory infection that can range from almost asymptomatic to a severe disease. Symptoms may also vary as the disease progresses. (WHO Corona-virus disease 2021; THL Koronavirus SARS-CoV-2 2023.) According to the World Health Organization (WHO Coronavirus disease 2021) the most common symptoms of Covid-19 are a dry cough, fever and fatigue. Other symptoms are for example loss of taste or smell, headache, nasal congestion, muscle or joint pain, nausea and diarrhoea. (WHO Coronavirus disease 2021; THL Koronavirus SARS-CoV-2 2023.)

Approximately 80% of those, who develop symptoms, recover from the disease without the need for hospital treatment. Among those who get seriously ill, which is about 15% of those who develop symptoms, oxygen treatment is often required. Approximately the 5% of those who become critically ill, require intensive care. For individuals with severe symptoms Covid-19 may develop pneumonia, acute respiratory distress syndrome or other complications, that may be fatal. Many of those with severe symptoms have had certain risk factors, such as old age or severe heart disease. (WHO Coronavirus disease 2021; THL Koronavirus SARS-CoV-2 2023.)

2.2.2 Impacts on the healthcare sector and innovation

The coronavirus disease stressed health systems as the impacts of Covid-19 hit the healthcare sector worldwide in the spring 2020. Rapid innovations were required to develop specialized Covid-19 services and to address the rise in demand, while maintaining access to hospitals. Healthcare systems were forced to adapt to the unexpected demand for care, to manage transmission risks of the disease as well as to keep up with the rapid and constant updates in clinical practices as the treatment for the illness was still novel. (Usher et al. 2022: 287-288.) The scarcity of resources posed serious a risk of quality and delivery of services, yet it also served as a catalyst for improvisation and innovation. The exponential spread of the coronavirus disease forced the healthcare

organizations to improve the care delivery. Telemedicine and other remote care services were rapidly expanded, geographical cohorting was organized and dedicated Covid-19 hospitals were introduced in order to minimize transmission risk for healthcare workers and patients. In the midst of the pandemic, the healthcare professionals at the frontline displayed remarkable improvisation through various innovative solutions. For instance, the shortage of personal protective equipment was tackled by 3D printing masks. Similarly, the scarcity of ventilators was resolved by adapting oxygen tubing, enabling the treatment of multiple patients simultaneously. These improvised measures were born out of the urgent need to save lives, as healthcare professionals explored alternative approaches. (Wiedner et al. 2020: 185; Usher et al. 2022: 288.)

3 Research purpose, aim and objectives

The purpose of this systematized literature review is to support future healthcare innovation by providing current research information on the solutions that have enabled innovation in the middle of the crisis in the healthcare sector. More specifically, the review aims to identify the enabling factors of healthcare innovation during the Covid-19 pandemic. The objective is to look for insights, that will help to develop and strengthen healthcare innovation and the innovation ecosystems, not only in crisis, but at other times too.

The research question for the systematized literature review is: What factors have enabled innovation in the healthcare sector during Covid-19 pandemic?

4 Research method and implementation

A systematized literature review is used to conduct this research. This chapter introduces the systematized literature review method and describes how the process is implemented in this Master's Thesis. The research data consist of peer-reviewed science articles and the data is analysed via inductive content analysis.

4.1 Systematized literature review

The most important function of a literature review is to increase the theoretical understanding of a certain discipline or to evaluate an existing theory (Carter & Kulbok 1995 cited in Stolt & Axelin & Suhonen 2015: 7). Systematic literature reviews provide information about the quantity and quality of existing research data on the research subject as well as the possible inadequacy of the research data. (CRD 2008 cited in Valkeapää 2015: 56). A literature review helps to create an overall understanding of a certain subject or topic, and it may assist to identify inconsistencies or problems within the phenomenon. While there are multiple variations of the literature review methods, all of them comprise the typical parts, which are known as SALSA (Search, Appraisal, Synthesis, Analysis). The process contains four phases, the first one being a literature search, second one an appraisal i.e., critical evaluation, third is a synthesis based on the gathered data and finally an analysis is done. (Stolt & Axelin & Suhonen 2015: 7-8.)

Niela-Vilén and Kauhanen (2015: 23) likewise include the elements of SALSA, but divide literature reviews into five phases:

- 1. defining the research problem and purpose
- 2. a literature search and selection
- 3. evaluation of the data
- 4. data analysis and synthesis
- 5. reporting the results.

All phases of a literature review must be described in detail and with transparency, so that the reader is able to assess the implementation and reliability of each step (Holopainen et al 2008 & Booth et al 2012 cited in Niela-Vilén & Kauhanen 2015: 23). Systematic reviews strive to find existing research literature systematically to evaluate its quality and to make an analysis and a synthesis. The most important feature in systematic reviews is to discover answers to the exact and precise research questions by combining the results of several different studies. (Stolt & Axelin & Suhonen 2015: 13-14.)

Systematized literature review is a subtype of systematic reviews, typically conducted by a single researcher, whereas in systematic research there are two or more researchers (Grant & Booth 2009 cited in Stolt & Axelin & Suhonen 2015: 13-14).

Systematic reviews aim to identify and find all material relevant to the research question. In most literature reviews the data primarily consist of the original research articles. (Whittemore 2005 & Whittemore & Knafel 2005 & Aveyard 2007 cited in Niela-Vilén & Kauhanen 2015: 25). Since systematized literature review is conducted by a single researcher it is not necessary to find all available literature on the research subject (Grant & Booth 2009 cited in Lehtiö & Johansson 2015: 35). The search process is rather similar between systematic and systematized reviews, as a systematic search is conducted in both (Lehtiö & Johansson 2015: 35). However, systematic reviews often cover more databases and provide a more comprehensive search process due to involving two or more researchers (Stolt & Axelin & Suhonen 2015: 14).

A systematized literature review is an applicable choice to conduct this research, as it will help to create an overall understanding of the rapid innovation, and the environment and processes that stimulated the innovation amidst the pandemic. The review will identify the enabling factors and summarize the insights to support future healthcare innovation. By identifying these innovation enablers, it is possible to summarize recommendations or best practices, and perhaps offer some considerations on how to sustain them for future healthcare innovation.

4.2 Search strategy

Research protocol is a key element in producing a quality review (Khan et al 2001 & Phan et al. 2015 cited in Valkeapää 2015: 56). The protocol covers all advance planning as well as the precise documentation of the chosen solutions. The systematic search aims to find all publications that meet the selection criteria. (Khan et al 2001 & CRD 20228 cited in Valkeapää 2015: 56.) The

protocol for this review follows the framework of the five phases presented above by Niela-Vilén and Kauhanen (2015:23). The first phase of defining the research problem and purpose includes the utilization of the PICO model and defining the selection criteria as described in detail below.

4.2.1 Research question and search terms

A well-defined research problem and research questions are essential, since a too narrow perspective may lead to not finding enough research data, while a too wide research question creates the opposite problem of having too much data. Especially for a solo researcher conducting a Master Thesis, one should carefully assess the available resources and match the scope of the research accordingly. (Arksey & O'Malley 2005 & Aveyard 2007 cited in Niela-Vilén & Kauhanen 2015: 24).

The research question for the systematized literature review in this study is: What factors have enabled innovation in the healthcare sector during Covid-19 pandemic?

The researcher must define which search terms and phrases are used in the database searches based on what are the relevant concepts and terms for the research topic (Green et al 2006 & CRD 2008 cited in Niela-Vilén & Kauhanen 2015: 25). Systematic reviews use a precise search procedure by applying a PICO model to identify the relevant studies (The University of Warwick 2012 cited in Stolt & Axelin & Suhonen 2015: 14). The PICO model helps to identify the components of the research question such as population or problem, subject of interest, context, and outcome (Bettany-Saltikov 2012 & Hoitotieteen tutkimussäätiö 2013 cited in Lehtiö & Johansson 2015: 36). In this study three elements from the PICO model were used to identify the population (P), interest (I) and context (Co) of the research question: 'What factors have enabled innovation (I) in the healthcare (P) sector during Covid-19 (Co) pandemic?' as presented in Table 2. Defining the search terms according to the PICO components.

Table 2. Defining the search terms according to the PICo components

PICo	Search term
P (population or problem)	Healthcare
I (interest)	Innovation
Co (context)	Covid-19

Lehtiö and Johansson (2015: 37-38) recommend testing the search terms and phrases in databases to find the correct terms and keywords relevant to the study. Systematic literature search is often a long process, and the first test searches should focus on testing which keywords are applicable to the research subject.

4.2.2 Selection criteria

A key element in the research protocol is defining the inclusion and exclusion criteria. Identifying the relevant literature is easier when the criteria are comprehensive and valid, while decreasing the risk for the literature review being inadequate. The criteria also ensures that the literature review maintains its focus and may present some practical help for the researcher, for example by including publications only from certain years and in certain languages. (Whittemore & Knafelz 2005 & Green et al 2006 & Aveyard 2007 cited in Niela-Vilén & Kauhanen 2015: 26.)

As recommended by Valkeapää (2015: 59) a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist was utilized to make sure the inclusion and exclusion criteria for this review are precise and well-defined (Prisma statement 2023). The criteria chosen for this study, as presented in Table 3. The inclusion and exclusion criteria, ensures identifying the relevant literature. The inclusion criteria require the publications to be peer-

reviewed research articles, thus ensuring the scientific credibility of the source. A time limit is used to target the appropriate and novel research articles related to the context of the research which is the Covid-19 pandemic. The risk of misinterpretation of the source material is reduced due to the language criteria, hence only research articles in English and Finnish are included in the study. According to the chosen inclusion criteria the research article must address healthcare innovation and describe the enabling factors of the innovation process. This ensures that the aim of this research, which is to identify the enabling factors in healthcare innovation during the Covid-19 pandemic, can be achieved. The availability of the full text of the research article aims to ensure the correct use of the citations as referencing can be done based on an entire article instead of a summary.

Table 3. The inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Language: Finnish, English	Other than Finnish or English
Full text research article about healthcare innovation describing the enabling factors of the innovation process during the pandemic	Full text research article does not cover healthcare innovation and/or it does not describe the enabling factors of the innovation process during the pandemic
Published in 2020-2023	Published before 2020
Research article	Other than research article
Peer-reviewed	Not peer reviewed

After defining the search terms, it is time to choose the eligible databases. It is recommended to use more than one database to ensure that the research data is comprehensive enough. Selection of databases is done based on the

research subject. (Lehtiö & Johansson 2015: 42.) The databases selected for this literature review are listed below together with their contents as described in Metropolia LibGuides (2022).

- CINAHL Complete (Ebsco), Nursing, biomedicine, health sciences, and many allied health disciplines.
- ProQuest Central, Multidisciplinary. e.g., health and medicine, social services, arts, education, psychology.
- ScienceDirect, Multidisciplinary, e.g., medicine, natural sciences, social services, economics.

In order to obtain comprehensive results, the healthcare literature database CINAHL and the multidisciplinary literature database ProQuest Central were selected, supplemented by ScienceDirect, which is a publisher portal that gathers research articles from various databases.

4.2.3 Test searches

Given the novelty of the research context, the Covid-19 pandemic, a preliminary test search was conducted at the end of April 2022 in five databases (CINAHL, PubMed, ProQuest Central, ScienceDirect, and Emerald Insight) to ensure the availability of sufficient research data. The keywords, their synonyms and similar terms, such as Covid-19 and SARS-Cov-2, were tested. Due to the large number of research articles found, an information specialist from Metropolia library was consulted on April 29th 2022 over a Zoom session in order to refine the search terms. Based on the test searches and the consultation meeting, the population (P) of the review was refined to exclude social services to keep the search simple. It was also observed that limiting the scope of the review's interest (I) to cover only open innovation, was not necessary, as it did not help finding the relevant literature.

A second test search was conducted in March 2023 in three databases Cinahl, ProQuest Central and ScienceDirect. Due to the generic search terms a large number of search results (n= over 750,000) was found. In such cases Lehtiö

and Johansson (2015: 53) recommend making limitations to the search by focusing the search terms on the title or abstract. Thus, the search was refined to include only peer-reviewed research articles and the search terms had appear either in the title, abstract or as keywords of the article. These refinements were used to ensure the publications were relevant to the study and to limit the search results in the three databases (n=631).

In most databases the search phrases are formed using the Boolean operators AND, OR and NOT words, which combine the single search terms (Lehtiö & Johansson 2015: 38-39). Based on the PICo model and test searches the following Boolean search phrase was selected for this research: AB (innovation AND healthcare AND Covid-19). The selected search phrase must be modified for each database, as they each function slightly differently. The modified search phrases are described below in Table 4. Search phrases in the databases.

Table 4. Search phrases in the databases

Database	Search phrase
CINAHL Complete (Ebsco)	AB innovation AND AB healthcare AND AB covid-19
ProQuest Central	abstract(innovation) AND abstract(healthcare) AND abstract(Covid-19)
ScienceDirect	AB (innovation AND healthcare AND Covid-19)

4.3 A literature search and study selection

Once the inclusion and exclusion criteria have been defined the systematic review process proceeds to the search phase (Valkeapää 2015: 61). The

literature search may produce a wide scope of potential publications, but once evaluated, only a fraction is included in the study. Well-defined inclusion and exclusion criteria are the focal point at this stage of the process. (Khan et al. 2003 & CRD 2008 & Phan et al. 2015 cited in Valkeapää 2015: 61.) Following the framework of five phases presented by Niela-Vilén and Kauhanen (2015:23), the second phase of the review protocol covers the literature search and the study selection. The actual search was conducted in April 2023 in the selected three databases Cinahl, ProQuest Central and ScienceDirect. The literature search generated 476 articles from the chosen three databases. The Boolean search phrase presented above, refined to include only peer-reviewed research articles from scholarly journals, offered the following results: CINAHL Complete n=71, ProQuest Central n=326 and ScienceDirect n=79, totalling to n=476.

4.3.1 Selection of studies

Once the database searches are completed the selection process proceeds to deploy the inclusion and exclusion criteria by screening the articles based on the title and abstract (Valkeapää 2015: 64). The aim of the study selection is to ensure that all relevant publications are included in the review. Thus, the selection process must be precise, objective and minimize the potential risks related to decision-making. The selection process must be described and documented in detail to enable anyone reading the review to replicate the process. Piloting and documenting the selection process are recommended before starting the actual selection process. A pilot selection is executed using the data that was produced in the search process. This is a valuable stage in the process as piloting provides information on how well the selection criteria work in practice. (CRD 2008 cited in Valkeapää 2015: 61-64.)

The search strategy, describing the systematic selection of the studies in this review, is described in detail in Figure 1. Flow diagram of the search strategy based on Prisma Flow diagram. Before deploying the selection criteria to the search results, 31 duplicates were automatically removed using a Rayyan

research platform. Next, the inclusion and exclusion criteria were deployed on the remaining 445 articles. Five studies were removed due to wrong language and three more duplicates were removed manually at this stage. Valkeapää (2015: 64) argues that if it can be immediately determined that an article does not meet the criteria, it should be excluded, and the reasoning documented precisely. Based on the screening of the title and abstract of the remaining 437 articles, irrelevant studies (n=400) were excluded. For example, research concerning the pharmacy industry or nursing education were considered to be separate industries from healthcare, therefore not meeting the inclusion criteria. Likewise, for the purpose of this review, studies completed before the Covid-19 pandemic or studies not focusing on the context of the pandemic were excluded. After the screening of the titles and abstracts, 37 articles were chosen for the full text review. The study selection continued by applying the inclusion and exclusion criteria to the full text articles. It is recommended to screen through the reference lists of the articles to find all the relevant studies. Moreover, including the grey literature i.e., relevant studies found through the references, helps to tackle the risk of publication bias. Applicable studies should then be added to the screening process. (Valkeapää 2015: 64; Magarey 2001 cited in Niela-Vilén & Kauhanen 2015: 26.) A careful examination of the reference lists provided six more studies to be included in the screening process. The overall eligibility assessment of the full text articles revealed that 12 studies met the inclusion criteria and after quality assessment all twelve were selected for the literature review.

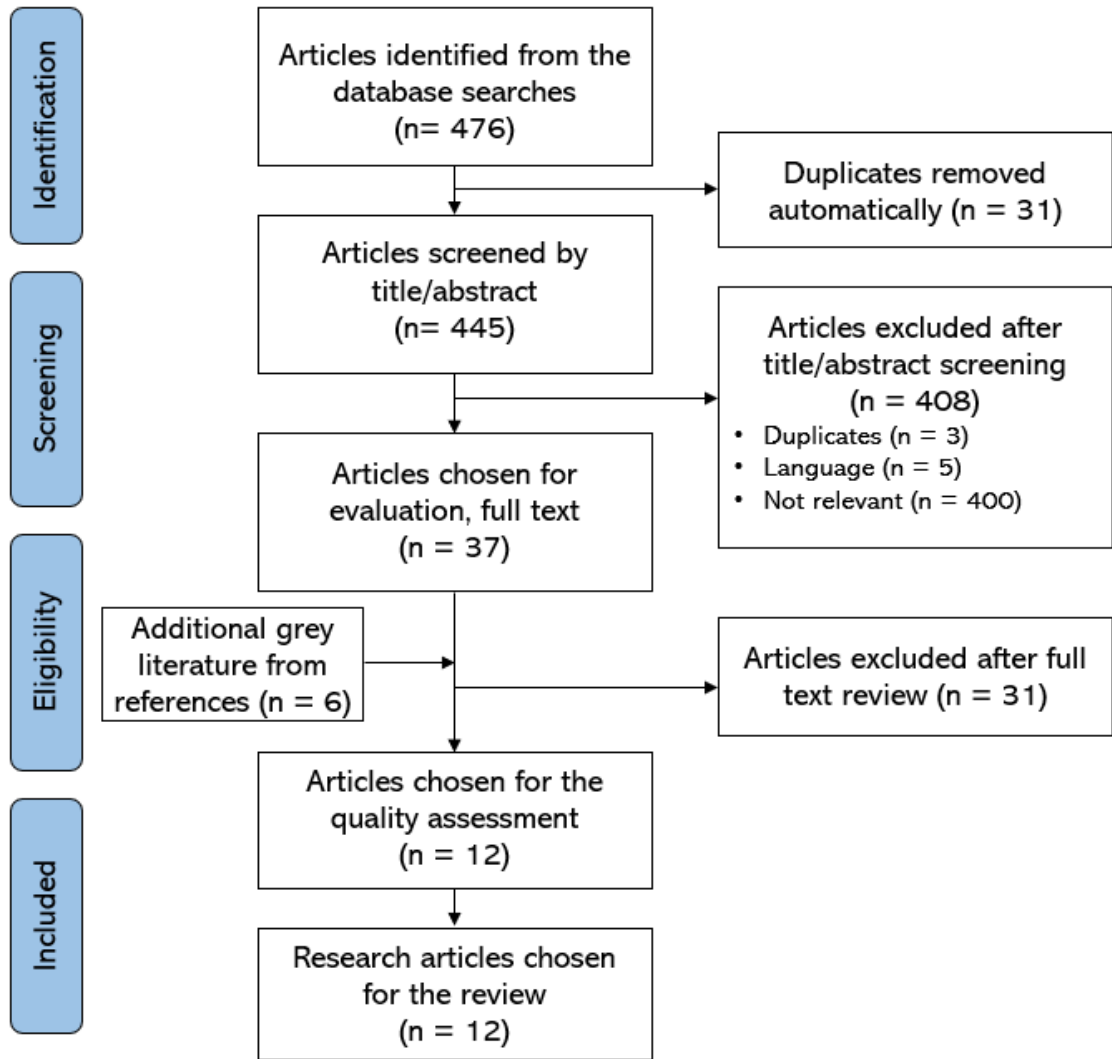


Figure 1. Flow diagram of the search strategy based on Prisma Flow diagram (Prisma statement 2023).

The study selection was completed according with the inclusion and exclusion criteria, which were formulated based on the research question. All in all, from the 476 studies that were identified from the databases, and six more articles added through grey literature, a total of 12 studies were eligible and relevant to the aim of this review.

4.4 Evaluation

The third phase of the review protocol is the evaluation of the data i.e., the critical appraisal (Niela-Vilén & Kauhanen 2015: 23). The purpose of the

evaluation is to describe and define the reliability of the results presented in each study and to assess their importance within the literature review. The evaluation is also done to avoid any bias in the results, thus the integrity and reliability of each study is evaluated separately. Systematic literature reviews aim to include studies of the highest quality, which underlines the importance of quality assessment. The use of ready-made critical appraisal tools increases the reliability of the review. Quality assessment of the selected studies should be done by using evaluation criteria applicable to their type but can also be done by using general criteria applicable for different types of research settings. To ensure as objective results as possible, a minimum of two researchers should evaluate the selected studies. However, thesis workers are an exception to this rule and can conduct the evaluation by themselves. (Lemetti & Ylönen 2015: 69-70; Niela-Vilén & Kauhanen 2015: 28-29.)

From the twelve studies that were chosen to answer the review question eight were qualitative case studies including both, multiple and single case studies. Two were cross-sectional studies, one was a mixed method study, and one was a retrospective analysis. The studies were published between 2020 and 2022, which corresponds the review's context of Covid-19. A third of the twelve studies were multinational (n=4) i.e., they covered multiple countries within the study, and an equal number of studies were conducted in United Kingdom (n=4). The rest of the studies were each carried out in different countries including Canada, China, Tunisia, and the United States of America.

4.4.1 Critical appraisal

The critical appraisal tool from Hawker et al. (2002) was chosen for the quality assessment of the studies as the framework enables reviewing disparate data systematically. The quality assessment criteria assist in grading studies conducted with various research designs. Points are assigned to nine different evaluation criteria themes, and these points can then be added up to calculate a final score. The themes in the checklist are: 1. abstract and title, 2. introduction and aims, 3. method and data, 4. sampling, 5. data analysis, 6. ethics and bias,

7. results, 8. transferability or generalizability, and 9. implications and usefulness. The themes are rated on a four-point scale from 'very poor', 'poor', 'fair' to 'good' and by giving points from 1 to 4 respectively, enables the researcher to rate quality of the studies. Hence, a quality assessment scale ranging from a minimum of 9 points to a maximum of 36 points is used to rate the studies.

Out of the maximum of 36 points the average score for the twelve studies chosen for this review was 29 points. Five studies were scored with 'fair' points of 25 or lower, with the lowest score being 21 points. Among the studies that received 'good' points, one study scored 29 points and the six remaining studies scored between 31 and 36 points. Thus, the overall result of the quality assessment of the studies, according to the Hawker's critical appraisal tool scale, ranges from fair to good. The highest-scoring theme was abstract and title with an average of 3,6 points out of a maximum of 4. The lowest-scoring theme, with 2,3 points on average, was ethics and bias. The rest of the themes scored on average between 3,1 to 3,5. The summary of articles together with the quality assessment ratings from the critical appraisal tool is presented in Appendix 1. Summary of the studies and critical appraisal tool results. The table summarizes the key information from the articles including the reference (authors), country, aim, study design, data and methods, main results of the study as well as the score from the quality assessment.

4.5 Data analysis and synthesis

The fourth phase of the review protocol is the data analysis and synthesis (Niela-Vilén & Kauhanen 2015: 23). The purpose of the analysis and synthesis is to organize and summarize the results of the selected studies. In systematic reviews, organizing and classifying the data is done to identify similarities and differences, which then enables the researcher to form a synthesis i.e., to combine different ideas into a connected whole. (Whittemore 2005 & Whittemore & Knafel 2005 & Aveyard 2007 cited in Niela-Vilén & Kauhanen 2015: 30.) Forming an analysis starts by describing and summarizing the key

information from the studies in a tabular form. As described in the evaluation phase, the key information from the studies selected for this review was summarized in tabular form in Appendix 1. Summary of the studies and critical appraisal tool results. The purpose is to create an overall picture and understanding of the data, which requires intensive reading and re-reading to become familiar with the material (Evans & Pearson 2001 & Aveyard 2007 cited in Niela-Vilén & Kauhanen 2015: 31.)

The second phase of the analysis is to find the similarities and differences and code the data accordingly by forming units, categories, and themes. This phase is often iterative in nature, meaning that the process is repeated until a conclusion can be made. The aim is to summarize the key points of the studies, especially from the results and conclusions sections. By combining the similarities, the units, categories, and themes are formed and named in a way that describes their content. In the third phase of the analysis, once a logical overall picture is composed through the iterative comparison of the similarities and differences, a synthesis is formed. (Evans & Pearson 2001 & Whitemore 2005 & Whitemore & Knafel 2005 & Aveyard 2007 cited in Niela-Vilén & Kauhanen 2015: 31.) The analysis method chosen for this review is an inductive content analysis as it is especially useful when the researcher aims to derive a practical solutions or applications of the findings, such as creating policies or guidelines for practice (Vears & Gillam 2022: 116). The data analysis process is described in detail below.

4.5.1 Inductive content analysis

Inductive content analysis is a common method for analysing data and is particularly well-suited to be applied in health-related research. Qualitative content analysis aims to systematically convert a substantial volume of text into a well-structured and organized summary of essential findings. Inductive content analysis is a specific type of qualitative analysis that emphasizes the importance of allowing themes and categories to emerge naturally from the data, rather than searching for pre-determined themes and categories within the

text. Vears and Gillam (2022: 113) propose that the key characteristics of inductive content analysis are the inductive process and iterative coding. (Vears & Gillam 2022: 112-113; Erlingsson & Brysiewicz 2017: 94.)

Inductive content analysis guidelines presented by Erlingsson and Brysiewicz (2017) as well as by Vears and Gillam (2022) were used to analyse the data of this review. In accordance with the guidelines, first step was to read and familiarize the text. Thus, the studies selected for this review were read multiple times to comprehend them and to gain a deeper level of understanding of their contents. Once familiarized, the texts were divided into smaller parts i.e., meaning units, capturing the content that is relevant to the research question. From the first round of analysis a total of 87 text blocks, concerning the enabling factors and other meaningful elements related to innovation during the pandemic, were identified and highlighted. These meaning units were copied to an excel-sheet and then condensed further while making sure that the core meaning remained. Special attention was given not to follow the existing structures and themes provided by the articles. Instead, all the data answering the research question was analysed going through the text line by line. The second round of the analysis resulted in 212 condensed meaning units. To allow the themes and categories to emerge naturally from the data required continuous self-reflection between the potential assumptions, based on previous knowledge, as well as the necessary pre-understanding to interpret the data. Following an iterative approach these condensed meaning units were first labelled by formulating codes, after which the 42 codes were grouped into categories and further into themes, as the highest level of abstraction. (Vears & Gillam 2022: 117-118; Erlingsson & Brysiewicz 2017: 94-97.) A visualization of the content analysis process following the framework from Erlingsson and Brysiewicz (2017) is presented in Figure 2. A visualization of the inductive process.

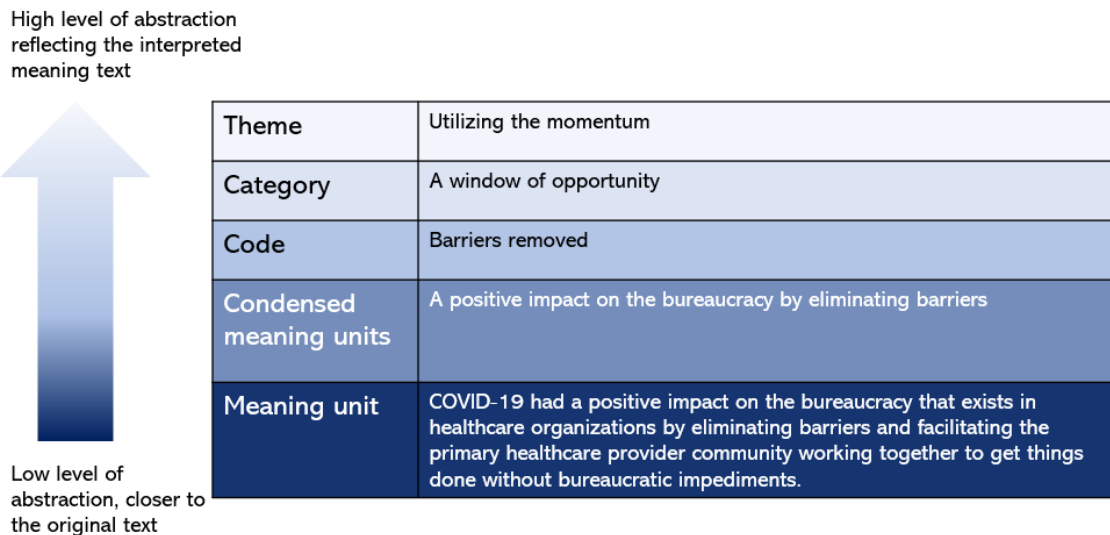


Figure 2. A visualization of the inductive process (Erlingsson & Brysiewicz 2017: 94).

After several rounds of iterative coding and categorization three themes emerged containing eleven categories. For the purpose of this review the final synthesis of the content analysis presents not just the three themes, but also the categories. This form of presentation visualises better the concrete action points that could be utilized within the healthcare sector. Also, to support the integrity and transparency of the process, a table containing an example of the content analysis is presented in Appendix 2. Example of the inductive content analysis. The table includes a few key illustrations on how the data was processed from condensed meaning units to codes, and finally into categories and themes. The results of the content analysis are presented and described in detail in the following chapter.

5 Results

The final fifth phase of the review protocol is the reporting of the results (Niela-Vilén & Kauhanen 2015: 23). The content analysis process induced three themes and eleven categories answering the research question by describing the enabling factors of healthcare innovation during the Covid-19 pandemic. The three themes are Broad collaboration, Supportive structures and policies as

well as Utilizing the momentum. Broad collaboration theme includes four categories which are collaboration beyond traditional boundaries, shared purpose, engaging private sector and building diverse communities. Supportive structures and policies theme also includes four categories which are investing in technology, prioritizing through policy instruments, regional flexibility, and supportive leadership. The third theme is Utilizing the momentum including the following three categories: flexible repurposing, a window of opportunity and will-do-attitude. These enabling factors of healthcare innovation are presented in Figure 3. The themes and categories presenting the enabling factors of healthcare innovation during the Covid-19 pandemic.

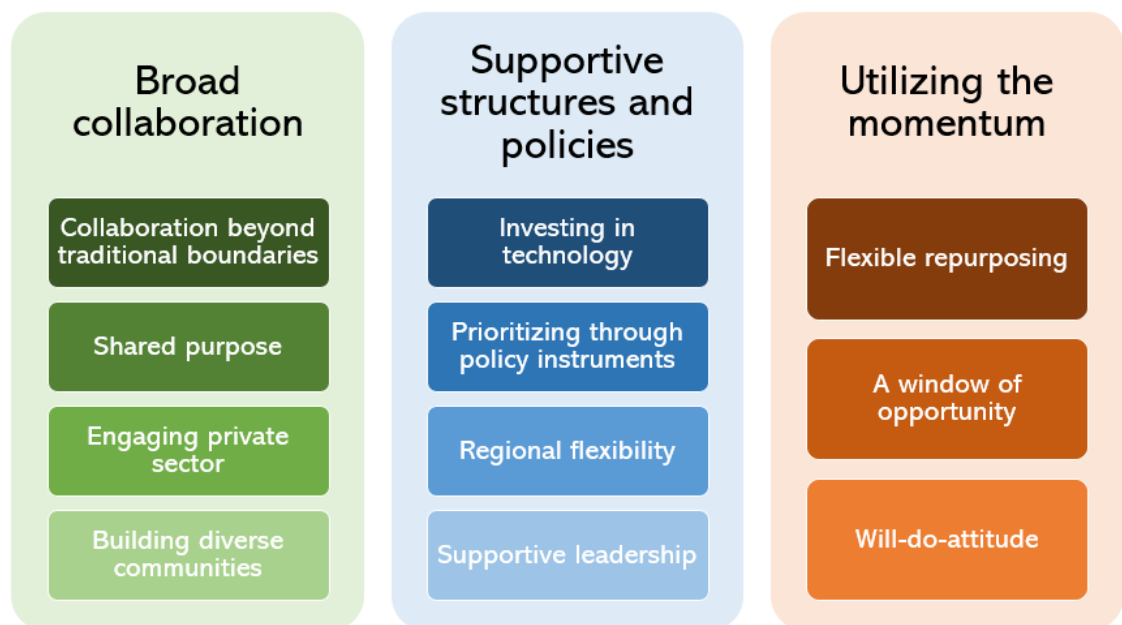


Figure 3. The themes and categories presenting the enabling factors of healthcare innovation during the Covid-19 pandemic.

The quality assessment results from the evaluation phase were utilized to rank the categories within each theme as presented in Appendix 2. Example of the inductive content analysis. More emphasis was given to the insights that originated from the studies with highest quality scores and less emphasis on the results deriving from the studies that scored only fair points. As systematic reviews aim to discover answers by combining the results of several different studies, more emphasis was also given to those results that originated from

several studies versus to the ones that were only mentioned in one study. The ranking of the results is visualised in such way that the categories at the top of the Figure 3 have higher ranking i.e., better points from the critical appraisal tool as well as several separate studies validating the content of the category. Correspondingly the categories lower in the figure have received less points from the quality assessment and the contents of these categories are formed based on fewer studies. For example, the collaboration beyond traditional boundaries category is at the top of the first theme since the individual codes within that category originate from several studies, all ranked with high quality assessment scores. Reversed, the supportive leadership category is on the bottom of the second theme, since the three codes it includes each emerged from fewer separate studies and the quality assessment scores had more variation.

It is noteworthy to observe that the themes together with the categories overlap one another. Hence, one enabling factor boosts another one and vice versa. The studies show that enabling factors such as shared purpose, ecosystems and repurposing contribute to the innovation proliferation and spread, but they are also interdependent. For example, the findings indicate that repurposing accelerates the process of innovation, but to do so it requires an ecosystem, which in turn needs to be formed around a common goal.

5.1 Broad collaboration

The first theme Broad collaboration includes four categories which are collaboration beyond traditional boundaries, shared purpose, engaging private sector and building diverse communities. The key enabling factors stimulating healthcare innovation within this theme are the diverse groups of people from different backgrounds gathered to collaborate on common interests and goals, in this case, to solve the dilemmas caused by the pandemic. The collaboration beyond traditional boundaries category gives examples on how broad collaboration networks support healthcare innovation. The shared purpose category discusses the collective actions, between the healthcare professionals

and other experts, working towards a common goal during the pandemic. The engaging private sector category will discuss the incentives that can be introduced to mobilize the private sector. Finally the building diverse communities category introduces different types of innovation platforms that help to combine the knowledge of professionals with atypical resources.

5.1.1 Collaboration beyond traditional boundaries

The findings derived from the Covid-19 pandemic suggest that innovation in times of crisis benefits from broad collaboration that reaches beyond the traditional boundaries of healthcare collaboration field. Interacting and collaborating with initiatives, outside of the usual scope of cooperation, may result in unforeseen collaboration opportunities. (Liu & Beltagui & Ye 2021; Liu & Shi & Yang 2022; Dąbrowska & Keränen & Mention 2021.) Several studies recognised the importance of cross-industry and cross-disciplinary relationships, both formal and informal, as driving forces to accelerate healthcare innovation (Liu et al. 2022; Dąbrowska et al. 2021; Abbassi & Harmel & Belkahla & Ben Rejeb 2022; Liu et al. 2021.) The research from James, Liu, Stephens and White (2022), trying to understand the role of interpersonal relations in three medical innovation cases, states that improvised relationships i.e., relationships that happened by chance rather than intentionally, were essential in enabling the innovation activities. Ecosystems were one of the key elements in providing a broader context for collaboration and enabling the exchange of capabilities across traditional organizational boundaries during the pandemic (Liu et al. 2021).

5.1.2 Shared purpose

Covid-19 created an extraordinary situation for the healthcare sector where, boosted by the sense of urgency, suddenly all professionals were working towards a common goal. This common interest united not only the healthcare professionals but also the stakeholders, private sector, patients, and citizens. Common innovation objectives, such as developing personal protective

equipment or ventilators, brought together companies from pre-existing networks, along with newcomers who wanted to pitch in to accelerate the innovation process. (Breton et al. 2022; Mitchell et al. 2022; Liu et al. 2021). Especially pre-existing professional relationships were essential in the speedy innovation processes as teams could be formed quickly by professionals who had previously worked closely together. Even the weak or passive pre-existing relations were useful, as they could be re-enlivened to support the rapid innovation. (James et al. 2022.)

In addition, a renewed and strengthened sense of community contributed to creating a productive atmosphere for innovations amidst the pandemic. Recognizing the importance and time sensitivity, colleagues responded promptly and collaboratively, ensuring smooth progress without any hindrances. Furthermore, the increased use of technology created an opportunity for more responsive ways of working. Working towards a common goal gave the perfect opportunity to improve collaborative relationships and reignite the sense of community. (Bertello & Bogers & De Bernardi 2022, Breton et al. 2022; Mitchell et al. 2022; James et al. 2022.)

5.1.3 Engaging private sector

An example of an UK based ventilator production project highlighted the important role of the private sector in rapid innovation. It was recognised that the global companies and their capabilities were the key to the success in the speedy development of the ventilators. (Liu et al. 2022.) Breton et al. (2022) found out that the pandemic context renewed the priorities of some providers and stakeholders emphasizing their social responsibility. The more socially responsible way of servicing a wider population resulted in service innovations improving primary care access in the middle of the crisis. Another study by Chen, Xu, Husain and Galea (2021) analysing the impact of policy instruments used in China during the pandemic, found out that among other means, such as regulatory flexibilities, the government together with local authorities were able

to mobilize the private sector by introducing incentives and promises on funding.

5.1.4 Building diverse communities

Research by Liu et al. (2022) demonstrates that involving the citizens as innovation partners is a highly effective approach for generating ideas and finding solutions to combat the Covid-19 crisis. The innovation potential in community-based responses relies on the scope and scale (Dąbrowska et al. 2021), but it also sparks the diffusion of innovation through a greater acceptance and adoption of innovations that originate at the regional level or emerge from grassroots efforts (Breton et al. 2022). According to Bertello et al. (2022), studying EUvsVirus-hackathon hosted by the European Commission, collective actions between institutions, authorities and ecosystem actors can be effectively managed by maintaining a balance between top-down hierarchical approaches and bottom-up grassroots efforts. Several studies concluded that through the involvement of diverse crowds, including skilled experts and atypical resources such as ordinary people, graduates and retired professionals, unexpected and fruitful innovative solutions can emerge to combat the pandemic. By including the general public to the search and development of innovative solutions individuals with variety of skills and knowledge are able to contribute to solving the complex problems (Bertello et al. 2022; Dąbrowska et al. 2021; Vermicelli & Cricelli & Grimaldi 2021; Liu et al. 2022.)

Findings from the studies by Liu et al. (2022) and Vermicelli et al. (2021), focused on crowdsourcing in the healthcare sector during the pandemic, suggest that utilizing crowdsourcing can be a successful approach. They state that crowdsourcing is convenient way to generate innovative and effective solutions addressing the health and economic difficulties arising from the pandemic. With the help of digital tools, crowdsourcing can engage a diverse pool of innovative actors to collaborate on addressing the problems and challenges. These individuals contribute with knowledge, ideas, resources, and

solutions in a cost-effective way. According to Bertello et al. (2022) hackathons such as the EUvsVirus, are a valuable model for crowdsourcing and due to their nature of dismantling knowledge boundaries, they can effectively boost disruptive innovation. This applies not only to novel solutions addressing well-defined problems, but also to complex scientific, technological, and societal challenges, such as the issues related to Covid-19. Similarly, ecosystems affect the acceleration of innovation by combining a diverse set of knowledge, perspectives, resources, and capabilities (Bertello et al. 2022). The case study by Dąbrowska et al. (2021) investigating the rapid development of a digital GetUsPPE platform, exemplifies how a diverse group of stakeholders joined forces on voluntary basis to establish a novel and efficient ecosystem. The ecosystem enabled the gathering of personal protective equipment from various sources to healthcare professionals. The findings from several studies suggest that ecosystems together with different types of crowdsourcing models such as hackathons, represent crucial participatory structures that enable innovation. However, in order for the benefits to be realized ecosystems need to be built around a shared purpose. (Liu et al. 2021; Bertello et al. 2022; Dąbrowska et al. 2021).

5.2 Supportive structures and policies

The second theme Supportive structures and policies includes four categories which are investing in technology, prioritizing through policy instruments, regional flexibility, and supportive leadership. The key characteristics defining this theme are the pivotal role of technology combined with flexibilities in regulations as well as the success of regional solutions and adaptations. The first category, investing in technology, gives examples of the essential technological capabilities, both pre-existing and those implemented during the pandemic. The prioritizing through policy instruments category illustrates how authorities can stimulate healthcare innovation with flexible regulation and use steering mechanisms to direct the innovation activities according to their needs. The regional flexibility category highlights the bottom-up initiatives and the need

for regional leeway while the supportive leadership category reminds about the importance of agile and committed leadership.

5.2.1 Investing in technology

Several studies identified technology as a key enabling factor for healthcare innovation during the Covid-19 pandemic (Chen et al. 2021; Dunleavy et al. 2021; James et al. 2022; Liu et al. 2021; Liu et al. 2022). Chen et al. (2021) argue that the booming digital health landscape and the overall society's digitization prior to the pandemic benefitted the implementation of new digital health interventions along with retrofitting telemedicine. Prior to the outbreak of the pandemic, China had more than 13,000 healthcare facilities across the country equipped with some form of telemedicine system. The pre-existing infrastructure for telemedicine was a significant factor promoting innovation as retrofitting telemedicine, for example by adding features for remote patient monitoring, was considerably easier than to begin with nothing. The pre-existing IT infrastructure, in the form of availability of 3D printers, was an essential factor in speeding up the innovation process also in the case of developing and producing personal protective equipment, 3D printed visors, in the UK (James et al. 2022.)

Chen et al. (2021) noticed that the rapid implementation of technology played an important role in stimulating healthcare innovation in China. In just few weeks of time, with the help of local departments of national telecommunications companies, over two hundred healthcare facilities, with low-level of IT infrastructure, were equipped with ability for virtual rounds and remote CT scans. (Chen et al. 2021.) Breton et al. (2022) identified that the rapid acceptance and implementation of virtual care, which had been an underutilized method in Canada before the pandemic, was an enormous enabler for access to care as well as an opportunity for innovation.

In addition to the benefits regarding pre-existing IT infrastructure and the speedy implementation of new technology, the rapid acceptance and

willingness to engage with novel technologies and other innovative solutions were also directly linked to the effects of the pandemic (Mitchell et al. 2022; Chen et al. 2021). Digital platforms and applications, which had reached national popularity prior to the pandemic, lowered the barrier for user acceptance of new Covid-related health applications in China (Chen et al. 2021).

5.2.2 Prioritizing through policy instruments

By designing motivating policies and support schemes governments, healthcare authorities and other policymakers can foster an innovation friendly environment (Dąbrowska et al. 2021; Chen et al. 2021). In China policy instruments were used to promote digital health interventions by establishing priorities and steering the activities of a diverse group of private technology companies in line with the government priorities. Other examples of utilizing policy instruments to enable innovation during the pandemic include flexibilities in insurance policies and easing the registration approval process of novel telemedicine solutions. All in all, during the worst pressure of Covid-19, there was minimal debate or discouragement from the Chinese regulators regarding, for example, the clinical effectiveness of novel telemedicine solutions. Instead, when the extensive pressure on the healthcare system decreased, the regulator issued the necessary guidelines for digital health interventions. (Chen et al. 2021.) In Canada policies and performance targets were renewed to encourage service providers to provide population-wide access for primary care. Renewed interest in providing wider access to services stimulated innovation and improved access to primary care for many. (Breton et al. 2022.)

5.2.3 Regional flexibility

The liberation of governance rules and removal of local barriers resulted in increased flexibility in healthcare systems and processes (Mitchell et al. 2022). The findings show that Covid-19 brought greater regional flexibility by allowing implementation of tailored innovations. The regional leeway, together with

increased decentralized decision-making, made it possible to adapt to local needs and facilitate the rapid and agile responses during the pandemic. (Breton et al. 2022; Chen et al. 2021; Dąbrowska et al. 2021). In Canada, regional decision-makers helped to adapt the innovations to local contexts as top-down initiatives originated from higher-level authorities in response to the pandemic. However, the innovations that emerged locally or were bottom-up received higher acceptance. (Breton et al. 2022.) Overall, regional flexibility and decentralized decision-making accelerated the diffusion of existing innovations as well as the creation of new innovations tailored to meet the local needs. (Breton et al. 2022; Chen et al. 2021; Dąbrowska et al. 2021).

5.2.4 Supportive leadership

Breton et al. (2022) found that the Covid-19 pandemic enabled innovation through agile leadership and engagement of both provincial and regional leadership. Likewise, Dunleavy et al. (2021) studying the specialist palliative care service innovation in response to the pandemic, remarked strong leadership as one of the factors enabling change identified by the respondents. Supportive leadership can also be implemented by playing the role of an orchestrator as the European Commission did by hosting the EUvsVirus hackathon (Bertello et al. 2022) or by acting as a facilitator, as the Chinese local government office did in Shanghai by sourcing IT products and applications to private sector in order to strengthen surge capacity (Chen et al. 2021). Support was also shown through the practice of digital technology companies helping governments (Chen et al. 2021) and by schools and universities providing resources and funding for healthcare innovation projects (James et al. 2022).

5.3 Utilizing the momentum

Theme three Utilizing the momentum includes three categories which are flexible repurposing, a window of opportunity and will-do-attitude. The key characteristics arising from the third theme are the exceptional circumstances and opportunities the pandemic brought combined with the strong sense of duty

unifying the healthcare sector. The flexible repurposing category discusses how innovations are enabled by exaptation i.e., repurposing for example products, technologies, or processes to uses that they were not initially designed for. A window of opportunity category explains how the pandemic created a unique momentum, which enabled creativity and favorable circumstances to make dynamic changes. Finally, the will-do-attitude category is presented, including enabling factors such as the sense of duty and openness to change.

5.3.1 Flexible repurposing

One of the rapid responses to the Covid-19 pandemic was reorganizing healthcare resources. Several studies demonstrate that effective reorganizing of financial and human resources expedited the innovation process.

Reorganization of the same resources by combining and sharing human and other resources across different departments, teams, and organizations helped to deal with the pandemic and consequently, several innovations emerged through the reallocation. (Breton et al. 2022; Dunleavy et al. 2021; James et al. 2022; Liu et al. 2022.) Greater flexibility in systems and processes were also described as beneficial (Mitchell et al. 2022; Dunleavy et al. 2021). In Canada, it was observed that the pandemic reduced the demand for primary care temporarily at the beginning of the first wave. The decreased patient demand enabled adaptations to be made in the care delivery and created an opportunity to generate organizational innovations. (Breton et al. 2022.)

According to Ardito, Coccia and Messeni (2021) who studied technological exaptation by examining two different drugs originally purposed to treat other diseases but ended up treating Covid-19, exaptation was a pivotal driver of innovation during the Covid-19 pandemic. The study suggests that technological exaptation is one of the main elements of flexibility in crisis management. Moreover, Ardito et al. (2021) propose that longer exaptive distance stimulates radical innovation, meaning that when the distance between the original context of intended use and the new context is significant, the probability for radical innovation increases. However, the greater the exaptive

distance is, the more effort it requires to be able to successfully adapt or repurpose an existing product or process for a new use.

5.3.2 A window of opportunity

Covid-19 pandemic has effectively reduced the bureaucracy within the healthcare organizations by eliminating, at least temporarily, barriers that previously hindered progress, leading to improved collaboration among healthcare professionals. This resulted in accelerated adoption and development of innovative practices within organizations and created a unique window of opportunity to redesign healthcare services and make progress on important issues that previously had faced barriers. (Breton et al. 2022; Mitchell et al. 2022; Chen et al. 2021.) James et al. (2022) noted that it was widely understood among the healthcare professionals that this window of opportunity was due to the crisis situation and once things returned to normal, they would once again encounter barriers and hindrances. The findings suggest that Covid-19 stimulated the process of making dynamic changes (Chen et al. 2021) where speed was one of the key elements (Mitchell et al. 2022). The mode of creativity and engagement in finding creative solutions contrasted with the organizational culture that prior to pandemic had been more resistant to change and characterized by a preference for maintaining the status quo (Breton et al. 2022).

5.3.3 Will-do-attitude

The findings from several studies suggest that the pandemic enabled innovation through collective sense of responsibility and staff flexibility (Breton et al. 2022; Dąbrowska et al. 2021; James et al. 2022; Liu et al. 2022, Dunleavy et al. 2021). Liu et al. (2022) identified the will-do attitude of the companies stimulating the ventilator development in the UK, while James et al. (2022) argue that the project team developing the 3D printed visors were driven by passion and sense of responsibility. The pandemic context renewed the sense of duty of the healthcare workers and created a collective sense of

responsibility. (Breton et al. 2022.) Dąbrowska et al. (2021) highlight that the GetUsPPE platform was developed on a voluntary basis and intrinsic motivations drove the actors.

6 Discussion

This systematized literature review was conducted to create an overall understanding of the environment and processes that stimulated the rapid innovation amidst the pandemic. More specifically this thesis aimed to identify the enabling factors of healthcare innovation and to summarize the insights and recommendations to support future healthcare innovation. While there is a growing number of studies investigating the healthcare innovations developed during the Covid-19 pandemic, only few studies have been designed to evaluate and identify the different contextual factors, such as the external environment, organizational aspects, technological infrastructure, and human motivations influencing the innovation process. In order to increase the probability of successful innovation, it is important to address these enabling factors at the micro level (e.g., motivations of individuals), as well as the wider context at the meso level (e.g., organizational cooperation) and at the macro level (e.g., governmental policies and other steering mechanism).

This review investigated with sincere interest, and in systematic manner, what were the elements that supported the generation and spread of innovations. The findings of the systematized review revealed that there were multiple interrelated factors that enabled healthcare innovation amidst the Covid-19 pandemic. The three themes that emerged from the reviewed studies were: Broad collaboration, Supportive structures and elements, and Utilizing the momentum. Each theme includes from three to four categories which present the enabling factors of healthcare innovation. These findings are now discussed further to assess how well they align with the previous research, how to sustain them to support future healthcare innovation and what possible contradictions should be considered before applying them into practice. Also, the reliability and the ethical questions regarding this review are discussed in this chapter.

6.1 Review of the results

The main findings of the review indicate that several enabling factors promoted healthcare innovation during the Covid-19 pandemic. The analysis shows that the pandemic created an exceptional situation in the social and healthcare sector, where professionals from different teams and across organizational boundaries worked towards a common goal driven by the sense of urgency. The state of emergency streamlined and expedited collaboration by removing typical healthcare bureaucracy, colleagues responded to messages faster than usual and consequently the development of innovative solutions accelerated. The pandemic also renewed the collective sense of duty of healthcare workers and maximized staff flexibility making the conditions prosperous for innovation. The previous research establishes that streamlined collaboration and improved communication are not uncommon features in emergency situations, as crisis innovation endeavours tend to feature extensive coordination (Gross & Sampat 2021: 274).

The results indicate that engaging with stakeholders from different fields creates collaboration opportunities beneficial to innovation. Shared interests play an important role in establishing ecosystems, which foster cooperation and enable diverse groups of innovative actors to collaborate and contribute to the ideation and development of innovative solutions. The results align with open innovation theory, introduced by Henry Chesbrough in 2003, stating that organizations should indeed search ideas and knowledge for innovation from external sources. In addition to ecosystems, different types of crowdsourcing models represented crucial participatory structures that enabled innovation during the pandemic. This too is in line with the open innovation theory, as crowdsourcing, with a wide range of applications such as hackathons, is recognized as an efficient and beneficial tool for innovation. (Mäntyneva 2012: 133-138; Brabham et al. 2014 cited in Vermicelli et al. 2021). Having shared goals and interests is essential as organizations form strategic alliances and ecosystems, albeit more challenging during the normal times (Mäntyneva 2012: 133-134; Stähle & Pirttivaara 2015: 49-50; Ahmed & Shepherd 2010: 174-175).

The analysis shows that rapid implementation and acceptance of technology combined with the booming digital health landscape and the overall society's digitization prior to the pandemic were key enabling factors for healthcare innovation during the Covid-19 pandemic. The swift acceptance and implementation of various digital services, such as virtual care, improved access to healthcare during the pandemic and accelerated innovation activities. Adding features, such as remote patient monitoring, to pre-existing digital health solutions was considerably easier and faster than starting from scratch. Likewise, the availability of 3D printers was essential in generating rapid innovations. Thus, the pre-existing IT-infrastructure significantly eased the development of innovative solutions for Covid-19 treatment. The previous research reminds, that while the transformation towards digitalized healthcare is considered to be a solution to many current societal challenges (Lindberg & Lindberg & Söderberg 2017: 4-7) the usage of digital health services is still undeveloped, and its full potential has been unexploited (Gjestsen & Wiig & Testad 2017: 7).

The results illustrated that governments, healthcare authorities and other policymakers were able to mobilize the public and private resources by designing motivating policy instruments. Different steering mechanisms, such as regulations, policies and other support schemes were useful in coordinating the healthcare innovation efforts from various sectors. Incentives helped to engage the private sector and to align efforts towards the public purpose as well as to foster an innovation friendly environment. The greater regional flexibility combined with decentralized decision-making allowed the implementation of rapid and locally adapted innovations during the pandemic. The previous research on innovative policy solutions by Torfing and Ansell (2017: 41-44) states that complex problems require strong political leadership to give direction to processes of innovative problem-solving, to ensure widespread support, and to allocate enough resources to the realization of innovative solutions. In their research, published prior to the pandemic, they argue that political leadership is currently hindered to contribute, due to poor positioning, resulting in lack of opportunity and inputs. However, it was discovered that even though public

authorities are often criticized for lacking flexibility, the Covid-19 pandemic demonstrated that when governments are put in high demand, they can be agile and adaptive. (Janssen & van der Voort 2020: 1.)

The results also indicated that the mode of creativity and engagement in finding creative solutions, especially through technological exaptation, were pivotal drivers of innovation during the Covid-19 pandemic. Previous research supports the findings of exaptation being a useful tool in producing radical innovations, especially when the distance between the original context and the new context is longer (Andriani & Ali & Mariano 2017: 320). Mäntyneva (2012: 37-38) adds, that radical innovations are less common due to the higher risks, longer development time and greater financial inputs that they require compared to incremental innovations.

When reviewing the results in the light of the research question 'What factors have enabled innovation in the healthcare sector during Covid-19 pandemic?' it is important to notice that this review focused on the enabling factors, i.e., the beneficial side of the elements. However, the identified factors are complex in nature and while there are beneficial elements regarding innovation, there are also contradictions. The circumstances that the healthcare systems were forced to cope with amidst the pandemic, for example the urgency, resource scarcity and decreased scrutiny, are not a guarantee for innovation but may instead create risks and lower the quality of care (Wiedner et al. 2020: 187). Another contradiction regarding the rapid healthcare innovation during the pandemic, was the risk of innovating too fast in the ecosystems. As current information on the disease and its treatment kept changing, also the specifications for innovative products, such as ventilators, changed. (Liu et al. 2021: 418.) Chen et al. (2021: 34) remind that while decentralized decision-making promotes innovation activities, it also creates variation and regional differences. Rapid, decentralized innovations were useful at facing the pandemic at community level, but they also led into less of consistency in standards, policies, data accuracy, and risk assessment algorithms.

6.2 Reliability and ethics

According to Niela-Vilén and Kauhanen (2015: 26) publication bias should be assessed in every literature review. This chapter will assess the strengths and limitations in the implementation of this review. This systematized literature review was planned and conducted following the review protocol framework proposed by Niela-Vilén and Kauhanen (2015). The research question was carefully formulated, and the search strategy was designed to align with it. To add credibility to the search process, an information specialist was consulted to refine the search terms. A PRISMA checklist was applied in conducting the study selection criteria. Since the pandemic has affected healthcare systems and innovation worldwide, the criteria covering studies only in English and Finnish, may be a minor limitation to the review. However, the studies selected for the review did cover several countries from different continents rather comprehensively, hence providing a global perspective on the issue. The study selection process was conducted diligently, with efforts made to minimize bias during the selection process. However, it is important to note that this review is a thesis work completed by a single researcher. As a result, the available resources were limited, and there was no prior experience in conducting a systematic literature review. Furthermore, when a review is conducted by a single researcher instead of two or more, there is a higher risk of relevant studies going unnoticed (CRD 2008 cited in Valkeapää 2015: 66). To assess the quality of the selected research articles a critical appraisal tool by Hawker et al. (2002) was used. The twelve selected studies received evaluations ranging from fair to good. To give credibility to the findings, the quality of the studies was incorporated into the analysis and synthesis by prioritizing studies with higher quality. To ensure unbiased analysis and results, it is crucial to be mindful of one's pre-existing understanding. This involves actively preventing assumptions and personal beliefs from unconsciously influencing the analysis process. Simultaneously, drawing upon one's pre-existing knowledge is valuable for fostering a deeper understanding of the data. (Erlingsson & Brysiewicz 2017: 95.) A special attention was paid to process the data objectively and not let the assumptions and personal beliefs affect the results.

When evaluating the limitations of this review, it is noteworthy to observe that the research context is relatively new. In May 2023, approximately one month after the database searches were conducted, the World Health Organization announced that Covid-19 pandemic is no longer causing a public health emergency, though it continues to be an ongoing health issue globally (WHO News 2023). The novelty of the topic is both, one of the strengths and one of the weaknesses of the review. The need for this review is definite, as there is a lack of systematic evaluation on the enabling factors of healthcare innovation amidst the pandemic. However, since the global disruption of healthcare systems has only just started to pass, it is important to note that the available sources may be incomplete and further research for a comprehensive understanding of the topic is needed.

Ethical Recommendations for Thesis Writing at Universities of Applied Sciences guidelines and checklist published in 2020 by the RDI committee of the Rectors' Conference of Finnish Universities of Applied Sciences (Arene) were used to conduct this review. The responsible research conduct included ensuring the integrity and transparency of the data selection, evaluation, analysis and reporting of the results as well as following the referencing guidelines of Metropolia University of Applied Sciences (2022). In addition, Turnitin plagiarism detection system was used to verify the authenticity of this review. Given that a systematized literature review examines existing published literature, a separate research permission was not required. Furthermore, this review did not receive any external funding, and there were no other relevant interests involved in its creation.

7 Conclusions

The Covid-19 pandemic has strained healthcare systems, overwhelmed and disrupted the healthcare services, and caused economic challenges. At the same time, it has highlighted the need for rapid innovation, adaptation, and collaboration. This review examined healthcare innovation at the time of Covid-19 pandemic aiming to support future innovation. Specifically, it investigated

which factors enabled healthcare innovation during the pandemic. Several enabling factors promoting healthcare innovation during the Covid-19 pandemic were identified in the review. The main findings indicate that healthcare innovation benefited from broad cross-sectoral collaboration around common goals, digitalization and the rapid adoption of new technology, flexibilities in regulations that allowed regional adaptations, creative repurposing and strong sense of duty among the healthcare professionals sparked by the exceptional circumstances that the pandemic created. To summarize, some insights and perspectives are provided on the possibilities of creating favorable conditions for healthcare innovation in the future, not just in crisis, but at normal times too. These insights supporting healthcare innovation are: 1) encouraging broad cross-sectoral collaboration around common goals, 2) enhancing technological capabilities and designing motivating policy instruments and 3) supporting creative repurposing and flexibility. The findings from this review provide evidence on how healthcare innovations have been developed and diffused within the context of Covid-19 pandemic. However, further research is needed to comprehend the interdependencies among the various factors that facilitated innovative activities, particularly those findings that presented contradictory elements, such as regional adaptations. Additional research is required to verify and compare these aspects as well as to ensure the effectiveness of the different enabling elements in the long term. To conclude, even though it is not feasible to recreate the contextual elements of the pandemic, learning from the different approaches and enabling factors may be useful for creating favorable conditions to healthcare innovation in the future.

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Appendices

Appendix 1. Summary of the studies and Critical Appraisal Tool results

The following table contains the summary of reviewed articles together with the quality assessment rating from the critical appraisal tool. The table summarizes key information from the articles including the reference (authors), country, aim, study design, data and methods, main results of the study as well as the score from the quality assessment. The color-coding of the quality assessment scoring (red-yellow-green) was utilized in the inductive content analysis to emphasize the studies with highest quality.

Summary of the studies						Quality assessment										
Reference	Country	Aim	Design	Data and methods	Main results	Themes 1-9										
						1	2	3	4	5	6	7	8	9	TOTAL	
Breton et al. (2022) COVID-19 - an opportunity to improve access to primary care through organizational innovations? A qualitative multiple case study in Quebec and Nova Scotia (Canada)	Canada	The general aim of this study was to describe the organizational innovations developed or adapted during the COVID-19 pandemic's first 18 months to improve primary care access in two provinces in Canada.	Qualitative multiple case study	We conducted a multiple case study based on 63 semi-structured interviews (n = 33 in Quebec, n = 30 in Nova Scotia) conducted between October 2020 and May 2021 and 71 documents from both jurisdictions. We recruited a diverse range of provincial and regional stakeholders (e.g., policy-makers, decision-makers, family physicians, nurses) involved in reorganizing primary care during the COVID-19 pandemic using purposeful sampling (e.g., based on role, region). Interviews were transcribed verbatim and thematic analysis was conducted in NVivo12. Emerging results were discussed by team members to identify salient themes and organized into logic models.	We identified and analyzed six organizational innovations. Four of these pre-dated COVID-19 but were accelerated by the pandemic context. The remaining two innovations were created to specifically address pandemic-related needs. Innovation spread and proliferation was influenced by several factors, such as a strengthened sense of community amongst providers, decreased patient demand at the beginning of the first wave, renewed policy and provider interest in population-wide access (versus attachment of patients only), suspended performance targets (e.g., continuity ≥80%) in Quebec, modality of care delivery, modified fee codes, and greater regional flexibility to implement tailored innovations.	4	4	4	4	4	3	4	4	4	4	35/36

Chen et al. (2021) Digital health interventions for COVID-19 in China: a retrospective analysis.	China	The aim of this research is to analyze the impact of policy instruments to promote digital health interventions for COVID-19 containment and to identify the contextual factors and mechanisms associated during the early stage of COVID-19 in China.	Retrospective analysis	Policy documents were identified and retrieved from government portals and recognized media outlets. Data on digital health interventions were collected through three consecutive surveys administered between 23 January 2020 and 31 March 2020. 266 unique digital health interventions meeting our criteria were extracted from 175 narratives on digital health interventions submitted by 116 participating companies. Thematic analysis was conducted to describe the scope and priority of policies advocating for the use of digital health technologies and the implementation pattern of digital health interventions.	In this study, national policy directives and self-reported digital health interventions between late January and March 2020 yielded the following four important findings: 1. Policy directives stimulate private sector engagement, 2. Decentralized interventions preceded top-level introduction of binding rules, 3. Digital health interventions benefitted from pre-outbreak digital landscape, interim incentives, and regulatory flexibility, 4. Patterns of digital health interventions may reinforce disparities across different levels of healthcare facilities.	4	2	3	3	3	1	3	3	3	25/36
James et al. (2022) Innovation in crisis: The role of 'exaptive relations' for medical device development in response to COVID-19	United Kingdom	The study aims to understand the nature of the micro-relations within medical innovations that are undertaken in response to COVID-19	Interpretive case study	The study adopts an interpretive approach to inductively exploring three cases of medical innovations variously driven by the needs of the COVID-19 pandemic. Case study method is used to gain in-depth information of a research site and enable its contextually accurate interpretation. The method also enables the acquisition of data from multiple sources that allows the triangulation of findings. The cases, consisted of the development of a novel oximeter (Case 1), the production PPE visors using 3D printing technology (Case 2), and the development of a rapid diagnostic test (Case 3). Semi-structured interviews with key personnel at the heart of each of the three medical innovations were used to gather rich data with four project leaders.	The analyses provided confirmatory evidence of the important roles that are played by exaptive pools, forums and events in the forging of links and sharing of knowledge between individual and institutional actors prior to COVID-19.	3	4	4	3	3	2	4	3	3	29/36

Abbasi et al. (2021) Maker movement contribution to fighting COVID-19 pandemic: insights from Tunisian FabLabs	Tunisia	Our research aims to present a concrete example of the key role played by the makers' community in supporting the Tunisian healthcare system in the fight against COVID-19, through open-source innovations.	Qualitative single case study	To investigate this research question, we adopted a qualitative approach based on a single embedded case study and collected data through participant observation technique. The case study describes a process of crisis-driven innovation based on 3D printing technologies in order to provide personal protective equipment (PPE) to healthcare professionals.	Our results show that the experience of the Tunisian makers during the COVID-19 outbreak is in line with the four main building blocks identified by Giusti et al. (2020) in the classification framework for open innovation in healthcare ecosystems: healthcare ecosystems' stakeholders (traditional and new such as makers and FabLabs); knowledge transfer among them during the exploration and exploitation stages of innovation development (sketches, 3D models, prototypes and mass production); players' motivations for innovation (crisis answers and open source) and players' position in the innovation process (upstream, local and regional).	3	3	2	2	3	2	2	3	2	22/36
Liu et al. (2022) Open Innovation in Times of Crisis: An Overview of the Healthcare Sector in Response to the COVID-19 Pandemic	United Kingdom	It aims to contribute to the theory of open innovation by exploring its new meanings, approaches, and connection to the business ecosystem paradigm during crisis.	Mixed methods study	Combines a structured literature review, secondary document review and thematic analysis.	Through data analysis, four key themes relating to open innovation in the healthcare sector in response to the COVID-19 era are synthesized as: (A) Crowdsourcing and social innovation; (B) digitalization and platform innovation; (C) modularity, design, and technology exaptation; and (D) relationship, network and ecosystem.	3	4	3	4	4	1	4	4	4	31/36

Mitchell et al. (2022) Service change and innovation in community end-of-life care during the COVID-19 pandemic: Qualitative analysis of a nationwide primary care survey	United Kingdom	To provide detailed insights and understanding into service changes and innovation that occurred in UK primary care to deliver end-of-life care during the first phase of the COVID-19 pandemic	Cross-sectional study	Online survey responses were analysed using descriptive statistics and thematic analysis. Participants were general practitioners and community nurses, circulated via regional and national professional networks. A total of 559 valid responses were received from 387 community nurses, 156 general practitioners and 16 'other'.	Three qualitative themes were identified: COVID-19 as a catalyst for change in primary palliative care; new opportunities for more responsive and technological ways of working; and pandemic factors that improved and strengthened interprofessional collaboration.	4	3	4	4	4	3	4	4	4	34/36
Liu et al. (2021) Accelerated innovation through repurposing: exaptation of design and manufacturing in response to COVID-19	United Kingdom	The purpose of this research is to understand how repurposing has taken place in this context, to create knowledge for innovation practice in general and accelerated crisis response in particular.	Qualitative multiple case study	To understand the role of exaptation in responding to COVID-19, multiple (80) cases of firms involved in repurposed production were examined. Data were collected by examining the official websites, social media accounts and press releases of each of the identified organisations.	Both design capability and manufacturing flexibility are valuable for innovation in conditions of market or technological turbulence. And this research suggests that they are both enablers of accelerated innovation.	3	4	3	4	3	4	4	4	4	33/36

Dąbrowska et al. (2021) The Emergence of Community-Driven Platforms in Response to COVID-19	United States of America	Specifically, our focus was to understand how community-driven platforms come together in times of crisis and leverage diverse actors and resources.	Descriptive single case study	To explore and analyze the GetUsPPE platform, we employed descriptive case study logic (Yin 2018) and content analysis of publicly available materials, including the GetUsPPE website, and blogs, Twitter, and LinkedIn posts about GetUsPPE. We also analyzed YouTube interview videos with GetUsPPE representatives and articles about GetUsPPE published in The Guardian, The New York Times, and other media outlets and scientific journals.	Our analysis of the GetUsPPE example yielded six major insights for providing innovative solutions in global emergencies: 1. A grassroots-level coalition of volunteers, 2. A self-organized, bottom-up, community-based approach to developing solutions, 3. Local, bottom-up, community-driven initiatives, 4. The platform strategy and network efforts, 5. A complex web of diverse stakeholders convened and collaborated on a voluntary basis to build and grow rapidly a massive and fully functional ecosystem. 6. Public health crises and social emergencies can trigger cross-disciplinary co-innovation and collaboration and increase the scope and scale of community-based responses.	3	2	2	3	2	1	3	3	2	21/36
Vermicelli et al. (2020) How can crowdsourcing help tackle the COVID-19 pandemic? An explorative overview of innovative collaborative practices	Multinational	Our work aims to review and classify those initiatives, based on the crowdsourcing model, that have been put into place to face the emergency generated by the novel coronavirus pandemic.	Qualitative multiple case study	We identified 16 crowdsourcing initiatives. In order to find relevant information, we browsed the Web, consulting search engines, databases that collected crowdsourcing projects (e.g. Crowdsourcing Week, 2020), and aggregators of resources related to the current COVID-19 pandemic (e.g. EU-Citizen Science, 2020). We selected the initiatives based on the relevance of the topic, the relevance of the strategic intent, and backing organizations (e.g. well-known intermediary platforms, such as those gathered in the list by Board of Innovation (2020)).	Evidence from the 16 projects suggests that across disparate domains, crowdsourcing produces novel and effective solutions. Results demonstrate that crowdsourcing can be an effective strategy for eliciting novel and effective solutions to health and economic challenges in the light of the COVID-19 pandemic.	4	3	2	2	2	2	3	2	2	22/36

Dunleavy et al. (2020) 'Necessity is the mother of invention': Specialist palliative care service innovation and practice change in response to COVID-19.	Multinational	To map and understand specialist palliative care services innovations and practice changes in response to COVID-19 (CovPall).	Cross-sectional study	Online survey of specialist palliative care providers, disseminated via key stakeholders. Data collected on service characteristics, innovations and changes in response to COVID-19. Statistical analysis included frequencies, proportions and means, and free-text comments were analysed using a qualitative framework approach. 458 respondents: 277 UK, 85 Europe (except UK), 95 World (except UK and Europe), 1 missing country. 54.8% provided care across 2+ settings; 47.4% hospital palliative care teams, 57% in-patient palliative care units, and 57% home palliative care teams.	The crisis context meant services implemented rapid changes. Changes involved streamlining, extending and increasing outreach of services, using technology to facilitate communication, and implementing staff wellbeing innovations. Barriers included; fear and anxiety, duplication of effort, information overload, funding, and IT infrastructure issues. Enablers included; collaborative teamwork, pooling of staffing resources, staff flexibility, a pre-existing IT infrastructure and strong leadership.	4	2	3	2	2	2	3	2	2	22/36
Bertello et al. (2021) Open innovation in the face of the COVID-19 grand challenge: insights from the Pan-European hackathon 'EUvsVirus'	Multinational	The aim of our study is to shed light on how hackathons can be leveraged, in practice, to promptly address the COVID-19 crisis, gaining inductive insights on how they can work before grand challenges.	Qualitative single case study	Our research question: 'How does a hackathon function as a tool for open innovation to address the COVID-19 grand challenge?' answers to Eisenhardt et al.'s (2016) call to investigate grand challenges through inductive methods. We sought to provide a rich description of a single case.	We have closely investigated the pan-European hackathon EUvsVirus in order to shed light on how it addressed the COVID-19-related challenges. We have inductively derived four elements that can enable open innovation before societal challenges, requiring urgent action and long-term thinking: broad scope, participatory architecture, online setting, and community creation. All of these aspects, however, also represent organizational challenges that can turn into benefits only through appropriate organizational design.	4	4	3	4	4	3	4	4	3	33/36

Ardito et al. (2021) Technological exaptation and crisis management: Evidence from COVID-19 outbreaks	Multinational	We specifically analyze the patterns of critical innovations to cope with new coronavirus disease (COVID-19) that is generating public health and economic issues worldwide.	Narrative multiple case study	We adopted a narrative approach examining vital innovations that ended up treating COVID-19 even though they were originated to treat other diseases (more or less distant from the COVID-19 domain), as the antiviral drug Remdesivir and the antirheumatoid arthritis drug Tocilizumab.	Results reveal that technological exaptation, especially if characterized by a longer exaptive distance, is a potential driving force of innovation to cope with COVID-19 in the short-term and other similar issues. Through a narrative approach focusing on two case studies, this study suggests that exaptation is a pivotal driver of innovation in crisis management. Specifically, we contend that, at least in the short term, crisis models for innovation should be based on technological exaptation.	4	4	4	4	4	4	4	4	4	36/36
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Appendix 2. Example of the Inductive Content analysis

Example of the Inductive Content Analysis				
<i>Research questions: What factors have enabled innovation in the healthcare sector during Covid-19 pandemic?</i>				
Author	Condensed meaning units	Code	Category	Theme
Breton et al.	a positive impact on the bureaucracy by eliminating barriers	Barriers removed	A window of opportunity	Utilizing the momentum
Zheng et al.	an ecosystem provides a boarder context (e.g. for a new supply chain)	Broad collaboration network	Collaboration beyond traditional boundaries	Broad collaboration
Breton et al.	common interest (amongst providers, stakeholders, and patients)	Common interest / goal	Shared purpose	Broad collaboration
Wei et al.	common innovation objectives	Common interest / goal	Shared purpose	Broad collaboration
Breton et al.	decentralized decisionmaking	Decentralized decisionmaking	Regional flexibility	Supportive structures and policies
Chen et al.	financial incentives from local governments	Incentives	Engaging private sector	Broad collaboration
Breton et al.	greater policy flexibility	Policy and regulatory flexibility	Prioritizing through policy instruments	Supportive structures and policies
Chen et al.	agility of the public sector in introducing regulatory flexibilities	Policy and regulatory flexibility	Prioritizing through policy instruments	Supportive structures and policies
Chen et al.	flexibilities in using policy instruments	Policy and regulatory flexibility	Prioritizing through policy instruments	Supportive structures and policies
Ardito et al.	exaptation is a pivotal driver of innovation	Repurposing / exaptation	Flexible repurposing	Utilizing the momentum
Dunleavy et al.	Staff flexibility enabled quick implementation	Staff flexibility	Will-do-attitude	Utilizing the momentum

*The traffic light color-coding of the studies visualizes the quality assessment results from the critical appraisal tool scoring (red represents fair scores, green good scores).