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From pilot to clinical practice: Barriers and facilitators in the implementation of artificial intelligence in health care

A multiple case study of Swedish AI projects

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Affirmation

I hereby affirm that this Master thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text. This work has not been submitted for any other degree or professional qualification except as specified; nor has it been published.

Stockholm, June 11th, 2021

Sophie Monsén Lerenius

From pilot to clinical practice: Barriers and facilitators to the implementation of artificial intelligence in health care

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Abstract

Background: Artificial intelligence, AI, will be instrumental in how health care will evolve over the coming decades, contributing to the development of for example personalized medicine, clinical decision support, and image processing. Whereas AI today is commonly used within several other domains, health care AI projects are still in the research- or pilot-phase and few are implemented into clinical practice. This emphasizes the importance of an in depth and consolidated understanding of the barriers but also the facilitators for these projects. Only when fully understood can the required measures be put in place and contribute to an improved process for implementation.

Aim: To contribute to an improved process of clinical implementation of AI in Swedish health care by identifying key barriers and facilitators.

Method: An exploratory, multiple case study design was used, and data collected through semi-structured interviews with leaders of AI-projects in Stockholm (n=4) and their stakeholders (n=10). Interviews and data-analysis was guided by the NASSS (Non-adoption, Abandonment, Scale-up, Spread and Sustainability) framework for implementation of technology in health care. In a directed qualitative content analysis, five themes evolved, and barriers and facilitators were categorized into each theme within the attributable NASSS domain.

Results: Key barriers and facilitators were identified within the five themes named Data & Informatics, Business model, Innovation culture & competence, The innovation to implementation process and Regulatory & Legal.

Conclusion: The implementation work of AI solutions in a clinical setting is complex and challenges current structures for innovation and implementation. Essential prerequisites to facilitate an improved process from pilot to clinical practice are lacking or needs to be strengthened. Aspects to consider for an enhanced process are suggested.

Keywords: Artificial Intelligence; Implementation research; Clinical Decision Support Systems; Innovation process; NASSS Framework, Technology Readiness Level

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Abbreviations and glossary

AI	Artificial Intelligence
ALF	Agreement of Mediacl education and reserach (avtal om läkarutbildning och forskning)
CE-marking	Claim that a product meets the requirements of the Medical Device Directives
CFH	The Center for Health Data (Centrum för Hälsodata)
EHR	Electronic Health Care Record
FDA	United States Food and Drug Administration
FoUU	Research Development and Education (Forskning, Utveckling och Utbildning)
GDPR	General Data Protection Regulation
HC	Head of Clinic (Verksamhetschef)
IVO	Swedish Health and Social Care Inspectorate (Inspektionen för Vård och Omsorg)
IT	Information Technology
KI	Karolinska Institutet
KS	Karolinska University Hospital (Karolinska Sjukhuset)
ML	Machine Learning
MDR	Medical Device Regulation
MPA	The Swedish Medical Products Agency (Läkemedelsverket)
NASSS	Non-adoption, Abandonment and Challenges to the Scale-up, Spread and Sustainability Framework
NASSS CAT	NASSS Complexity Assessment Toolkit
NBHW	The Swedish National Board of Health and Welfare (Socialstyrelsen)
HSF	Health and Medical care Administration (Hälso och Sjukvårdsförvaltningen)
HSN	Health and Medical Care Board (Hälso och Sjukvårdsnämnden,)
POC	Proof of Concept
PMCK	A virtual precision medicine center at KS (Precisions Medicinskt Centrum Karolinska)
PPA	Public Procurement Act (LOU, Lagen om offentlig upphandling)
Proprietary solution	The health care provider/hospital takes the full responsibility for patient security (Egentillverkning)
RCT	Randomized Clinical Trial
RS	Region Stockholm is responsible for all publicly financed health care in Stockholm County Council
RWD	Real World Data

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1. Introduction

1.1 Background

AI in medicine and health care – the historic perspective
Medical research has now benefitted from Artificial Intelligence, AI, for the past 50 years, continuously advancing and progressing in line with the evolution of computer science, hardware- and software-technology and biomedicine.

Initial focus in the 1950s up to the 1970s was to build computational models of the scientific knowledge and problem-solving heuristics used by biomedical scientists. Furthermore, systems for clinical data processing and interpretation for medical decision-making were developed. Unfortunately, after the first generation of systems were developed the first so called "AI winter" emerged due to an initial excessive enthusiasm failing to fulfill the promises originally expected.(1)

After the 1970s the development focused on knowledge engineering paradigm for designing expert systems and heuristic problem-solving methods and rule-based systems for a wide range of fields beyond biomedicine. This led to a commercially driven optimism of the promise of knowledge-based systems. Mainly it was the high cost of developing, maintaining, and keeping the systems up to date that contributed the second AI Winter" by the mid-to-end of the 1980s.(1)

Over the past two decades, more of an "AI hype" has developed. Contributing to this hype was initially novel kernel methods of machine learning and shortly afterwards focusing around deep learning and machine learning through a new generation of "deeper" multi-layered models.(2) It was not until 2012 that the subtype of deep learning was widely accepted as a viable form of AI.(3) This development was enabled by the use of labelled big data, along with markedly enhanced computing power and cloud storage, leading to that the field of AI in medicine and health care is now more visible and influential than ever before.(2)

Definition of AI
The definition of what is "real AI" and not has been extensively discussed and varied over the past decades of development. In this report, Artificial intelligence will be referred to as autonomous and adaptive systems that are based on learning algorithms to produce results, unlike static rules or algorithms to handle data.(4) The different subdisciplines of AI, such as the techniques for Machine Learning, Neural Networks/Deep Learning, Natural Language Processing are all included into the wide definition of Artificial Intelligence in this report.(4)

The Hype of AI
Moving forward, Artificial intelligence, AI, will be instrumental in the way health care will evolve over the coming decades.(5-9) AI will not only be a fundament in achieving

personalized medicine, but it also holds the promise to contribute to the development within risk prediction, clinical decision support, image processing and diagnostic support.(8, 9)

An attempt to exemplify the hype of AI in health care by counting how many papers indexed on PubMed have "AI" in the title, showed that between 2012 to 2017 this number roughly doubled, but between 2018 to 2019 this number increased almost tenfold (1 413 publications).(10) Beyond academic research, the trend is mirrored by accelerating FDA (US Food and Drug Administration) approvals.(3, 10) In the last five years there was a doubling of the number of FDA approvals for devices endowed with some forms of AI.(10)

The future economic impact of AI within health care is a complex but also neglected question.(11) A systematic review from 2020 aimed to summarize the cost-effectiveness studies dedicated to AI in health care. Out of the 66 studies reviewed only six thoroughly addressed the economic impact assessment and none met the established quality criteria.(11) However, one attempt was made in 2017 by consultancy company Accenture. Their estimate was that in the US market alone, key clinical health AI applications combined could potentially create $150 billion in annual savings for the US health care economy by 2026.(12)

Few examples in clinical settings globally

Whereas AI is already used in everyday life in several domains, such as retail, media, automotive, banking and education, the use of AI applications within the health care clinical setting are currently scarce.(9, 13, 14) A large number of studies and pilots have been performed and especially in the area of image processing. However, even within ophthalmology and radiology that are in the forefront within AI, real world examples are relatively few.(3, 5, 10, 14-16)

Risks and challenges of implementing AI

Besides the opportunities, also the high-level challenges and risks of AI in the health care sector have been widely discussed for some years, both from the perspectives of the health care providers, patients and policy makers. Primarily the focus has been on the ethical risk, weighing personal integrity against the dependence of access to large quantities of health data. Furthermore, the legal and liability risks as well as bias of data is widely discussed. Among the challenges, transparency and explainability of models as well as lack of resources, financial and human, are mentioned.(14, 17)

AI in health care in Sweden

The area of Artificial intelligence, AI, within Life Science is "hyped" also when looking at Sweden. Several recent reports have been made in order to map the Swedish AI landscape within health care and there is a large amount of ongoing AI initiatives, and the hope for the future is high.(5, 6, 18, 19) For example, it has been suggested that the full use of AI in the public sector can create a value of SEK 140 billion annually in Sweden and an estimated economic potential for AI in the Swedish health care sector of SEK 30 billion per year.(20)

Consequently, several recent initiatives have contributed to the attention of AI within health care. Among others, some very recent can be highlighted; in 2020, the Knut and Alice Wallenberg Foundation (KAW) put SEK 3.1 billon into Data-Driven Life Sciences (DDLS) over the next 12 years to contribute to basic research within this field. There are several more initiatives from the KAW Foundation within the field, summing up to approximately SEK 10 billion, all focusing on basic research.(21)

Similarly, but with the mission to accelerate the real applications of artificial intelligence in Sweden one example can be highlighted; The AI Sweden organisation was founded in 2019, boosted by a SEK 100 million grant from Vinnova for 2020-24, with a 2020 addition of a Stockholm node directed towards climate and health.(19)

Several of the Regions in Sweden have projects or applications within AI. In a report from the Swedish National Board of Health and Welfare (Socialstyrelsen), from 2019, the Regions reported that they have in total 90 AI projects based on machine learning already "in use" or to be used "very soon" and over 70 projects in "research phase".(6)

Artificial Intelligence is a crucial fundament within the important work of Precision Medicine. Thus, in 2020 a task force for accelerated implementation of precision medicine was initiated by Karolinska University Hospital, Karolinska Institutet and Region Stockholm. As a result, a virtual precision medicine centre PMCK (Precisionsmedicinskt centrum Karolinska) was recently established. The purpose of PMCK is to promote seamless collaboration between academia and health care in diagnostics, treatment, development and research. PMCK will initially work to consolidate and expand the successful collaboration that has developed over several years between the Clinical Genomics facility at SciLifeLab and Karolinska University Laboratory.(22)

AI@KI – artificial intelligence at Karolinska Institutet

Additionally, at Karolinska Institute, a strategic project was initiated by KI top management in 2019 named AI@KI. The aim of the project was to map, describe and assess the maturity of all activities at KI related to artificial intelligence (AI). The more long-term goal of AI@KI is to strengthen the footprint of KI within the area of AI and increase the number of solutions that contribute to improved health care and patient lives. The early findings of the AI@KI project are in line with the earlier described state of AI in Sweden; there are several promising initiatives but there is a large variety of maturity and so far, relatively few have been implemented and are in current clinical use.(19)

Nevertheless, all reports conclude that Sweden seems to face the same global development as earlier described with few practical examples of applied AI within the health care domain.(4-6, 18, 19) Most projects are still in research- or pilot-phase and few are yet implemented into the real world of clinical practice.(4, 5, 7, 19, 23) The efforts so far, tends to be mainly defined as "vertical"; i.e. the projects seen are within limited medical fields and based on the efforts of a single person with strong driving spirit rather than structured efforts building platforms for the use of AI.(5, 6, 19)

1.3 Problem description

The described gap between projects and the reality of using AI in clinical practice in Sweden (5-7, 19) reinforces that there are several challenges associated to the implementation process. Poor uptake of technical innovations is often explained in terms of barriers and facilitators. High level risks and challenges with the implementation of AI in health care have been discussed in general terms as well as described in international cases, mostly from the field of radiology or ophthalmology.(8, 14-16, 24) However, looking at the local, Swedish perspective, there seem to be very few (if any?) initiatives to investigate this. Thus, the current problem is that there is insufficient knowledge about the barriers of the AI implementation process and which facilitators might help to overcome the barriers and improve the process.

The substantial opportunities that AI could bring to Swedish health care and the vast amount of promising AI projects emphasizes the importance of an in-depth and consolidated understanding of the challenges but also the facilitators that face these projects. Only when fully understood, the required measures can be put in place and contribute to an improved process of implementation, both from a top-down ("decision maker") as well as from a bottom-up ("innovator") perspective.

1.4 Aim

The aim of this study was to contribute to an improved process of clinical implementation of AI in Swedish health care by identifying the key barriers and facilitators.

1.5 Objectives

The objective was to identify the key barriers and facilitators for an improved implementation process of AI moving forward, by studying multiple cases of Swedish AI health care projects as well as their stakeholders, mapping out the process from innovation to clinical implementation.

1.6 Research questions

How can the clinical implementation process of AI solutions be facilitated?

- What key barriers can be identified?
- What key facilitators can be identified for an improved implementation process of AI moving forward?

2. Theoretical Framework

2.1 Conceptual Frameworks

A conceptual framework is a system of concepts, assumptions, expectations, beliefs, and theories that aims to explain either graphically or in narrative form, the main objects to be studied. Conceptual frameworks increase the efficiency of research and the generalizability and interpretability of research findings.(25) By prespecifying factors demonstrated in prior research to influence the phenomenon of interest, in this case implementation of technology in health care, conceptual frameworks increase the relevance of the research findings for informing implementation practice.

2.2 Implementation theory

Implementation science uses a theoretical approach to explain and understand the success or failure of any implementation.(26) Within the field of implementation science, strategies for the adoption of digital technologies have been extensively addressed. A widely used framework by researchers and practitioners to predict and explain user acceptance of information technologies is the Technology Acceptance Model, TAM. TAM, first developed already in 1986, models the system usage intentions and behavior as a function of perceived usefulness and perceived ease of use.(27) The TAM model has been developed further and in 2000 the original TAM, was extended to include new influential determinants to PU and an increased understanding of these determinants and their long-term impact, referred to as TAM2.(28) In 2008, a further developed version was introduced, TAM3 and as opposed to its earlier versions it exposes how certain determinants are moderated by the user's experience.(29)

Another example is the "Consolidated Framework for Implementation Research", CFIR, from 2009. It is a conceptual framework developed to guide systematic assessment of multilevel implementation contexts to identify factors that might influence implementation and effectiveness. The CFIR is composed of five major domains, each of which may affect an intervention's implementation; Intervention characteristics, Inner setting, Outer setting, Characteristics of individuals involved in implementation that might influence implementation, Implementation process.(30)

Lastly, a commonly used example of implementation theory is the "The Integrated Technology Implementation Model" (ITIM) introduced in 2015 with the aim to create an all-encompassing mode to bridge the gap between technology adoption and implementation science. The model highlights the elements that affect the process of integrating technology into health care practice and guides the selection of interventions leading the user to adopt and provides a conceptual guide for nursing leadership, vendors, and engineers to focus their work on technology adoption.(31)

2.2.1 The NASSS Framework

Focusing on the health care clinical setting, the implementation of new technologies is very complex and involves a large variety of different stakeholders and organizational structures as well as strict legal and regulatory standards.(32) The relatively recent work of Greenhalgh et al aims to theorize and evaluate Non-adoption, Abandonment and Challenges to the Scale-up, Spread and Sustainability (NASSS) of health care technologies and developed the NASSS Framework in 2017.(32)

2.2.2 The seven domains in NASSS

The NASSS framework aims to detect the determinants of implementation process of complex technologies in health care within seven domains;

1) The condition/The illness
2) Technology
3) Value Proposition
4) The adopter (clinician)
5) The organization
6) The wider institutional and social context.
7) Continuous embedding and adaptation over time

The framework takes a dynamic perspective by following the interactions between these domains over time.(32) *Figure 1* presents a graphical illustration of the NASSS Framework and more details on each domain. As a complement to the theoretical NASSS framework Greenhalgh et al. developed the "NASSS-CAT (complexity assessment tool) interview", a set of prompts for conducting semi-structured research that lists key questions to address various stakeholders within each domain.(33)

2.2.3 The NASSS Framework application for this study

For this study, the NASSS Framework for implementation for new medical technologies in health care was selected to help guide and theorize the collection and data analysis of barriers and facilitators.(32) The main reason for this was that Greenhalgh et al developed the NASSS Framework focusing on the challenges of going beyond small-scale demonstration projects to Scaled-up technology that is fully mainstreamed and part of business. Greenhalgh et al 2017, highlights the multiple complexities of health care that contributes to the fact that is extremely difficult to go beyond small-scale demonstration projects and developed the NASSS Framework in order to help with this particular issues.(34) Furthermore, the Framework is based on a literature review of the 28 previous developed implementation frameworks as well as 165 interviews with the aim to produce an evidence based, theory informed, but also accessible and usable framework to identify and help address the key challenges in different domains and the interactions between them.(34)

Albeit the Framework itself does not cover the barriers nor the facilitators directly, there are a few examples where the NASSS framework has been applied to highlight barriers and facilitators of the implementation process.(14, 16, 35) On the other hand, it is worth noting that the NASSS framework was mainly developed to consider very large

organizations and different stakeholders *within* the organization, for example a technology being implemented into a larger hospital with one IT department, several units, nurses, clinicians etc. Consequently, this was taken into consideration when using the framework as a guide to suit the purpose for this study.

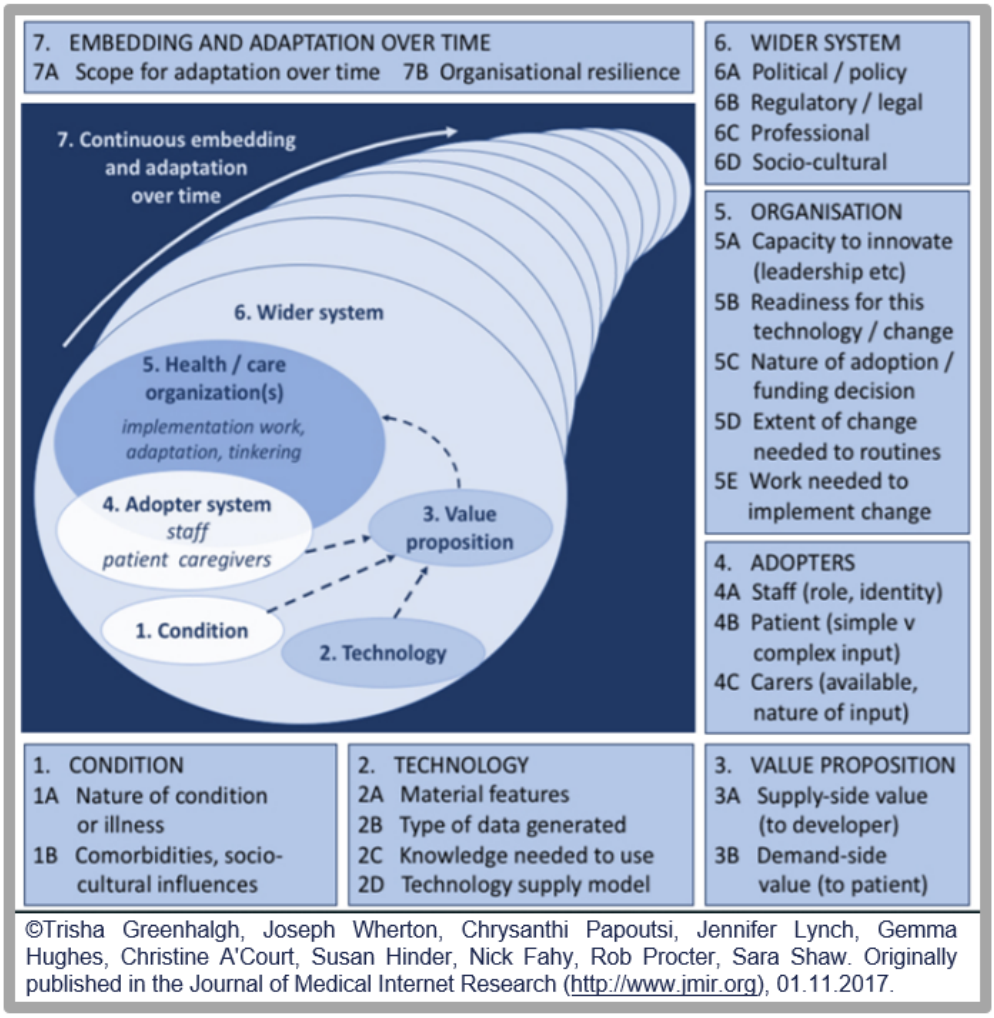


Figure 1. *The seven domains and their interaction in the NASSS Framework, Greenhalgh et al 2017(34)*

2.3 Defining implementation

Several perspectives of the term implementation can be considered with regards to the use of novel technologies. Firstly, the organizations maturity of embracing and implementing new technical solutions can be considered, secondly it is important to understand the implementation readiness of the technology itself and lastly it is important to understand the various levels of implementation and the spread of the technology once is in use.(34, 36, 37)

To assess the organizational maturity, one relevant example with regards to AI implementation is the Health care Information and Management Systems Society's, HIMSS's, Analytics Adoption Model for Analytics Maturity, AMAM, which is designed to measure and advance an organization's analytics capabilities.(36) Given the purpose of this study, this assessment model was not applied as it was not relevant.

With regards to assessing a certain technology's maturity and its readiness for implementation, the Technology Readiness Level, TRL, is a common model. The TRL model has also more recently been applied to assess various AI applications.(37) Thus the Technology Readiness Level was used in this study to roughly assess the maturity of the AI technology used in AI project cases. The nine Technology Readiness Levels are described below.(38)

TRL 1 Basic principles observed
TRL 2 Technology concept formulated
TRL 3 Experimental proof of concept
TRL 4 Technology validated in lab
TRL 5 Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6 Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7 System prototype demonstration in operational environment
TRL 8 System complete and qualified
TRL 9 Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Lastly, considering the various levels of implementation and spread of novel technology in an health care organization, Greenhalgh et al (2017) address the challenges associated with moving from a local demonstration project to one that is fully mainstream and part of business.(34) Thus, the starting point is in Local Pilot and ends in Long-term sustainability. The levels of implementation described can be seen below.(34)

1. Local Pilot (project in clinical setting)
2. Sustained adoption (fully mainstreamed and part of operations)
3. Local scale up
4. Distant spread (transferable to new settings)
5. Long-term sustainability (maintained long term through adaptation to context over time)

In this study, for an application or a solution to be considered implemented into clinical practice, it must be in operational, real world use by clinicians, serving its purpose i.e. to improve the health of patients in some way. This would be referred to as "Level 2" in the list of levels based on Greenhalgh et al 2017.(34)

3. Methods

3.1 Study design

Considering that AI applications to be used in health care settings are still in an emerging phase, an overarching evaluation or retrospective assessment of their implementation work was not feasible. Instead the focus of the study was to identify the facilitating factors and the barriers which these projects have faced so far and particularly exploring how the process could be facilitated moving forward.

The study used an exploratory, qualitative research design, specifically a multiple-case study design in order to empirically explore the area and the data was analyzed in a directed qualitative content analysis . Both interviews and data analysis were guided by the NASSS (Non-adoption, Abandonment, Scale-up, Spread and Sustainability) framework for implementation of technology in health care. Interviews were complemented by desk-top research analysis based on internal documents from respective projects as well as publicly available materials such as web-sites and on-line articles.

This study was done as a Master Thesis during spring semester, January 2021 – June 2021.

3.2 Methods for data collection

Focused, semi-structured interviews were made to collect data from study participants. This method was chosen as it is an effective way of obtaining data from key informants and required only the use of simple equipment that was readily available i.e. recorder and computer. Additionally, the interview format allowed for clarification of information given by study participants in contrast to other methods. On the other hand, it is relatively time consuming to conduct interviews and document them.(39)

In this study, the collection and data analysis of barriers and facilitators was guided by the NASSS framework for implementation for new medical technologies in health care organizations. (32) To complement the theoretical NASSS framework Greenhalgh et al. has developed the “NASSS-CAT interview”, a set of prompts for conducting semi-structured research.(33) The prompts are part of a set of tools that were developed in seven co-design workshops involving 50 stakeholders such as industry executives, technical designers, policymakers, managers, clinicians, and patients.(33) The NASSS-CAT Interview prompts were used as a basis and inspiration for the development of the interview guide used in this study, however several questions were altered to suit the certain setting and the purpose of the study. The interview guides were developed before interviews, based on the NASSS-CAT prompts (33)with a semi-structured approach, some questions required short and straight answers while others were left open for the participants to give their opinion sometimes with follow up questions in order to explore

deeper. In order to test the clarity of the questions and the language one test interview was conducted.(40)

The NASSS CAT Interview prompts helped to guide how the seven domains described by Greenhalgh et al. could be divided between various stakeholder groups in order to capture all relevant perspectives. One interview guide was developed for the AI project cases and another for all other stakeholder interviewed.

In the interviews with study participants representing the AI cases, the focus was on the first three domains described: the condition/the illness, the technology, and the value proposition of the respective technology. In interviews with stakeholders the focus was instead on further understanding the adopter, i.e. the caregiver/hospital/clinic, its organizational structure, and the wider institutional and social context i.e. the remaining domains. See *Appendix A* and *Appendix B* for the full interview guides.(34)

When applying the theoretical framework of NASSS on AI as the "new technology", it is important to consider that AI as such is not a homogenous technological solution, but rather a common denominator in all the cases studied in this report.

Study participants were contacted over e-mail or telephone and asked to participate in the study. In most cases, one-to-one interviews were preferably conducted to avoid the internal impact of group interviews. Due to the Covid-19 situation, most interviews were conducted digitally over Zoom, however some participants preferred to meet in person. Interviews were conducted in Swedish and participants were informed about method of data collection and analysis. All interviews with participants were recorded to audio-files and detailed notes were made based on the recordings. Key highlights that could be used as anecdotal evidence were transcribed in Swedish. Quotes were freely translated from Swedish to English but were approved by study participants. Consent was obtained for use of a recording device to record the interview. In total 14 interviews were conducted (11 zoom and 3 face to face). Interviews lasted for 30 – 60 minutes. None of the participants requested to be anonymous.

3.3 Methods for data analysis

Qualitative data analysis was chosen for this study as it offered an advantage to assess detailed data from a large complex environment and to explore the real-life experiences of the participants.(40) A directed content analysis approach offered a flexible and pragmatic method for developing and extending the current knowledge base within the chosen field.(41) The NASSS Framework helped to identify important areas and focus the questions as well as provided guidance about the variables of interest, also referred to as a deductive category application approach.(41)

Firstly, to analyze the data from the recorded interviews, each dataset was read multiple times to obtain a sense of the whole, and occasionally the audio files were listened to repeatedly to avoid misinterpretations.

Secondly, all statements relevant for the aim of the study were identified from the data, extracted, and put into an excel spreadsheet, mapping similar statements next to each other per respondent. By including all the key statements for all participants in the same spreadsheet, common categories (themes) could be identified. Thereafter, the NASSS framework and its seven domains served as an analytical framework and by using a deductive principle, the statements were categorized as either a facilitator or a barrier and sorted into the most suitable NASSS domain. The purpose was to develop the analytical categories (themes) and subcategories of facilitators and barriers but also highlighting any differences or similarities between the responses from the different study participants.

The analysis was made in Swedish and the relevant text in the spreadsheet thereafter translated into English as well as quotes from interviews. As part of an iterative process, labelling and categorization into themes were checked multiple times and modified throughout the work.

To ensure reliability and validity of the study several considerations were made. A test interview was performed and then using the subsequent interviews to verify the responses. Furthermore, it was secured that neither the interview guide nor the follow up questions were leading questions.(40)

3.4 Study setting

Given the objective of the study, the focus was on applications using AI or having an aim to be used in a clinical setting. Thus, the focus was on AI projects within a speciality care setting with the clinician as its main stakeholder. Consequently, applications such as administrational, triage, patient flow and patient applications were excluded, as well as applications to be used in a Primary Care setting. Furthermore, given the limited timeframe of the study and the natural connection to the Karolinska Institutet, the Greater Stockholm geographical area was set as a boundary when selecting projects and study participants.

Figure 2A attempts to illustrate the study setting, with key stakeholder groups relevant in the process towards clinical implementation for the cases studied

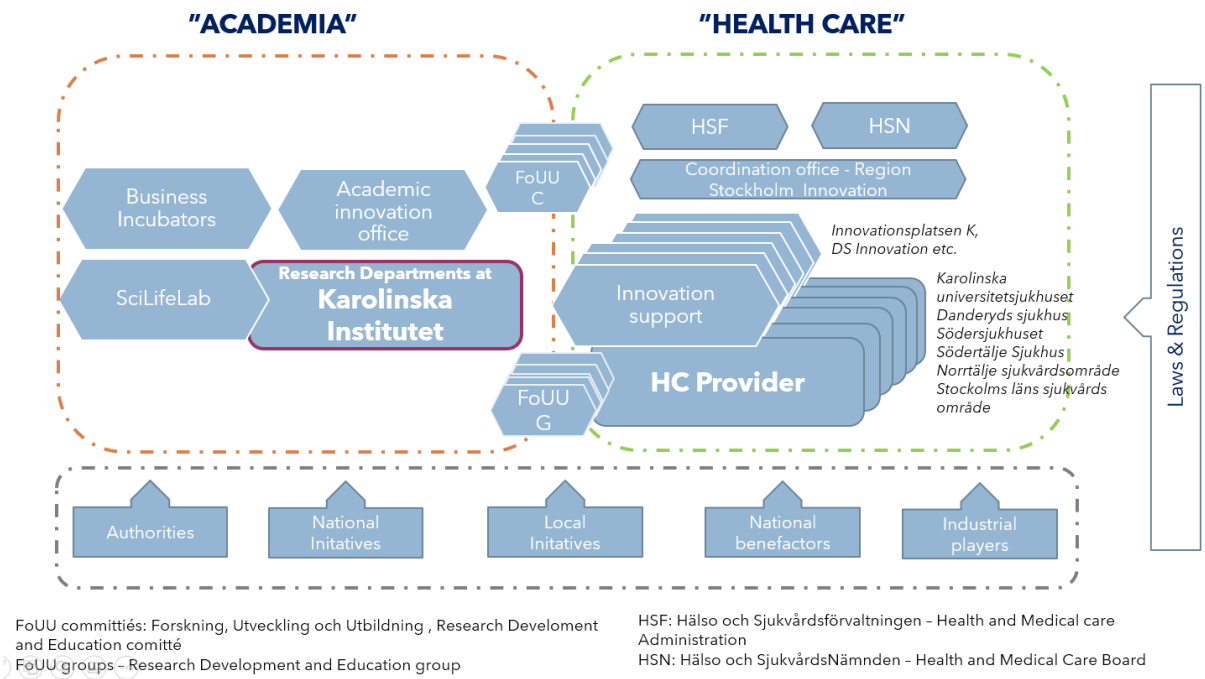


Figure 2A. *A simplified, figure that aims to illustrate key stakeholder groups relevant in the process towards clinical implementation for the cases studied, also referred to as the "innovation and implementation system".*

3.4.1 Academia innovation system Stockholm - the left-hand side

The Academia on the left hand in *Figure 2A* is covered mainly by Domain 2 (Technology) and Domain 3 (Value proposition) of the NASSS Framework.(34) Below key relevant stakeholder groups are highlighted, and additional information provided.

Karolinska Institutet
The university Karolinska Institutet (KI) is Sweden's single largest center of medical academic research. KI is located in Stockholm and a natural central point of the academic innovation system in Stockholm. In this study, KI, is the origin of all the cases studied.

Science for Life Laboratory, SciLifeLab
SciLifeLab was initiated in 2010 jointly by four host universities Karolinska Institutet, Royal Institute of Technology (KTH), Stockholm University and Uppsala University. In 2013, SciLifeLab was appointed to be a national research infrastructure and today has operations at most major Swedish universities. As SciLifeLab is an academic center, everyone who works there is employed at one of the host universities.(42)

Innovation offices - academia
In Sweden there are currently twelve so-called Innovation Offices that on behalf of the Ministry of Education aims to increase the utilization of research. In Stockholm there are three innovation offices, KTH Innovation, Stockholm University Innovation and KI Innovations. The innovation office main task is to provide qualified support in matters of

utilization of research results, e.g. in commercialization including patenting and licensing, knowledge exchange and principles for contract research. Furthermore, the innovation offices should inspire, inform, and stimulate researchers and others. The Innovation Offices are funded by Vinnova, the Swedish government agency that administers state funding for research and development.(43)

Business incubators
Business incubator is an organization that aims to promote and facilitate the path of start-ups to growth and profitability. The incubator's main task is to offer qualified business advice or business coaching, as well as networks to facilitate contacts with customers, partners, and investors. The main business incubators in Stockholm are KI Innovations AB, Sting and the Stockholm University Incubator.(44)

KI innovations AB - Innovation Office & Incubator
KI Innovations AB, has since 1996 been an incubator and a wholly owned subsidiary of Karolinska Institutet's holding company. Karolinska Institutet's innovation system offers education, professional networks, financing, entrepreneurial expertise, and business development, as well as incubation opportunities for projects and companies in life science. KI innovations is the only one of its kind in Sweden, offering both the" Academic innovation Office" as well as the "Incubation services" within the same organization. The KI Innovations Business Incubator is jointly financed by both Karolinska Institutet and Vinnova.(45)

3.4.2 Health care provider innovation system Stockholm – the right-hand side

Health care illustrated on the right hand in *Figure 2A* is covered mainly by Domain 1, "the illness", Domain 4 "the adopter" and Domain 5 "the organization(s)" of the NASSS Framework.(34) Below key relevant stakeholder groups are highlighted, and additional information provided.

The Health and medical care administration (HSF)
The task of the Health and medical care administration (HSF) estimates the need for health care and dental care in the Stockholm region. Based on that need, the administration orders the care and needed and monitors the results and quality of the care.(46)

The Health and Medical Care Board (HSN)
The Health and Medical Care Board is responsible for ensuring that there is a range of health and medical care that meets the needs of the population. The board shall ensure that health care is managed, coordinated and developed in such a way that the combined resources are adapted to the needs of the population.(47)

The Coordination Office for Region Stockholm Innovation
The Coordination Office for Region Stockholm Innovation, (Samordningskansliet för Region Stockholm Innovation) answers questions about innovation development and to guide within Region Stockholm. They are responsible for the initiative "Vägen in i

vården", a single entry point for employees and companies. As a first step, a contact form is filled in by the innovator / company and a contact person will return within three weeks. The Region Stockholm Innovation then sends an inquiry to its network of Innovation Support Units with the form as a basis.(48)

Health care provider Innovation support units

There are innovation support units at several of the Regions health care providers that are part of the Region Stockholm Innovation network. According to SLL webpage the units capture good ideas, inspire and show opportunities and act as a link between health care and companies. They also provide innovators with support throughout the innovation process, from needs and market analyzes to prototypes and marketing plans.(48)

The current health care provider Innovation support units are; (48)

- DS Innovation / Danderyds Sjukhus
- Innovationsplatsen / Karolinska Universitetssjukhuset
- Innovationsslussen / SLSO (Stockholms Läns Sjukvårdsområde)
- StS Innovation / Södertälje Sjukhus
- SÖS Innovation / Södersjukhuset
- Tiohundra / Norrtälje Sjukvårdsområde

ALF agreement between KI and Region Stockholm

Collaboration between Karolinska Institutet (KI) and the Region Stockholm is based on the so-called ALF agreement, which regulates the state's compensation to the county councils for certain costs in connection with education and medical research. Region Stockholm allocates funds of approximately the same size as a supplement to the ALF compensation. KI and the Region Stockholm are jointly responsible for the distribution of these resources.(49)

FoUU committés and FoUU-groups

Through the regional ALF agreement, collaboration between Karolinska Institutet (KI) and the Region Stockholm is organized on three levels; at management level, hospital level / equivalent of research, development and education (Forskning och Utveckling, Utbildning) committees and at operational level of research, development and education groups. The management team has two groups under it; an education council and a research council. Unique to the geographical area of Stockholm is that Karolinska Institutet and the Region Stockholm in the regional ALF agreement have chosen to include all educations that is dependent on health care participation. Together, Region Stockholm and KI have worked with the implementation of the cooperation organization and the work in the various councils and committees has taken shape. The collaboration is also followed up and evaluated.(49)

The Region Stockholm Innovation Fund (Innovationsfonden)

The Region Stockholm Innovation Fund (Innovationsfonden) started in 2015 and consists of MSEK 15, which is distributed twice a year to support new and ongoing projects in the areas of health care, traffic, culture and growth and regional planning. Since the start, almost 800 applications for project funding have been received, of which about 330 have

been granted. Follow-up of the projects' development is done continuously. Anyone who works at least 50 percent in the Region Stockholm can apply.(48)

3.4.3 Laws and Regulations of relevance

There is a vast number of laws and regulations controlling health care. Below a selection of the most relevant ones given the scope of this study are highlighted, and additional information provided.

General Data Protection Regulation & The Patient data act
The General Data Protection Regulation (GDPR or Dataskyddsförordningen) for the processing of personal data is applied in Sweden since 2018.(50) Several regulations complement the GDPR. The Patient data act (Patientdatalagen) is one complement to GDPR and is applied by all care providers, both public and private. The rules governing processing of personal data within health and medical care can be found in the Patient Data Act (2008:355), which when it came into force in 2008 superseded the Care Registers Act and the Patient Records Act.(50)

Patient Security Law
According to the Patient Security Law (Patientsäkerhetslagen 2010:659), the health care provider, is responsible for planning, leading and controlling the care so that it lives up to the demand of "good care".(51) There is an obligation to practice medicine in accordance to evidence based medicine including the potential choice of decision support or results from an AI solution.(6)

The Public Procurement Act
Public procurement in Sweden is governed by the Swedish Public Procurement Act (2016:1145 – LOU Lagen om Offentlig upphandling). Consequently, this applies to all purchases within public organizations. The Swedish Competition Authority is the supervisory body for public procurement.(52)

European Union Medical Device Regulation
The safety and functional requirements imposed on medical devices are regulated by the EU Medical Device Regulation, MDR (EU 2017/745) and the In Vitro Diagnostic Medical Devices Regulation IVMDR (2017/746).(54). They replaced three prior EU directives in 2017 and will progressively replace existing directives during a transition period until May 2022. First is the MDR that will come into force May 26th, 2021 and the IVMDR in May 2022.(53) The new MDR application implies stricter risk classification and thus higher demands on validation.(19) Medical devices placed on the market must meet all requirements in the regulations and be CE-marked. CE marking is the medical device manufacturer's claim that a product meets the essential requirements of the MDR.(55)

The regulatory responsibility for Medical Devices in Sweden is divided between The Swedish Medical Products Agency (Läkemedelsverket), The National Board of Health and Welfare (Socialstyrelsen) and the Swedish Health and Social Care Inspectorate (IVO). The Swedish Medical Products Agency develops regulations and is responsible

for the supervision of medical devices. The National Board of Health and Welfare regulates the use medical devices in health care as well as products developed as "hospital proprietary solutions".(6) "Hospital proprietary solutions" products, are pre-approved as the health care provider themselves takes on the full responsibility for the patient security when the product/solution is in use. Swedish Health and Social Care Inspectorate, is responsible for the supervision of health care providers usage of medical devices and "hospital proprietary" products or solutions.(4)

3.5 Selected case studies

The first step in the selection of Artificial intelligence projects, was a thorough desk-top research of the area. Secondly, a rigorous mapping had already been done in the work performed by Prof. Magnus Boman in the AI@KI project. From this gross list of projects, a final selection was made of four projects based on geographical area (Greater Stockholm) and type of application (Specialty Care) as described in section *3.4 Study setting*. Study participants availability to talk to the researcher was inevitably also a factor to consider in the final list of projects included.

A total of four cases were selected for inclusion in the study and are briefly presented in *Table 1* below. In the table there is also a short description of the purpose of the AI solution, an assessment of its current level of usage/implementation based on the Levels of Implementation as well as the Technology Readiness Level, TRL, both described in section *2.3 Defining implementation*.(34, 38) Details from interviews; names and title of the participants as well as time, date and format of the interview can be found in *Appendix C*.

Three of the cases had a connection to the Karolinska Institutet in Stockholm and were at various stages towards clinical implementation. The earliest was in the demonstration pilot phase and the latest close to "CE-marking" and already integrated into the care plan at one unit in the hospital. When mapping the cases against the Implementation Levels and Technology readiness levels described in section *2.3 Defining implementation*, two of the four cases were still at TRL level 4; technology validated in lab and thus did not have a corresponding Implementation Level. One of the AI projects was in Level 1 and only 1 was reaching Sustained adoption, Level 2.(34)

Also included was the Integrated AI Diagnostics, the I-AID project, a Vinnova funded project at Karolinska University Hospital, involving clinicians, but also researchers from KI as well as industrial players. The I-AID initiative itself included three AI pilots, all three today at various stages of implementation. The first pilot improved magnetic resonance imaging for multiple sclerosis patients (MS in *Table 1*). The second pilot was as electroencephalography database for improved neurodiagnostics (EEG in *Table 1*) and the third was an automated analysis of digital pathology images for colorectal cancer (Cancer in *Table I*).

Case	Purpose of AI solution	Implementation Level (34)	TRL(38)
DeepNews Neo	Risk prediction/early warning system of Sepsis in premature infants.	Not yet reached Level 1. Retrospective pilot finalized at KS.	TRL 4; technology validated in lab
PathFX	Survival prediction of metastatic bone cancer patients to support in treatment decision.	Level 2. Integrated into Orthopedic unit Care Plan at KS.	TRL 8; system complete and qualified (CE-marked)
DeepMed	Decision support system to classify fractures according to guidelines to support in treatment decision.	Level 1. Clinical pilot finalized.	TRL 5; technology validated in relevant environment
I-AID	Integrated AI Diagnostics - Three pilots, all within image processing.	**MS:** None.	TRL 4; technology validated in lab
		EEG: None.	TRL 2 – technology concept formulated
		Cancer: None.	TRL 4; technology validated in lab

Table 1. *Presentation of the AI cases studied, description of the purpose of the AI solution as well as an estimation of their current Level of implementation(34) and Technology Readiness Level, TRL(38).*

3.5.1 DeepNEWS – real-time sepsis detection in premature infants

The Deep Machine Learning-based Novel Early Warning System (DeepNEWS) for early detection of sepsis in premature babies was developed at CMM/KI and the paediatric departments; including NeoIVA, Paediatric IVA and infectious disease wards. The work was done under the lead of Professor Eric Herlenius at the department of Women's and Children's Health together with experts from KTH.(19)

The DeepNEWS solution is an algorithm customised to a Swedish hospital environment, handling all data from the constant monitoring of the premature babies, both automated and manual registrations, and covers the entire population in NeoIVA. The model provides a binary (yes/no) classification of sepsis infection as well as a prediction of complications in real-time by physio marker indication. A risk reduction strategy recommended by the model can then suggest the optimal intervention and do so in time to prevent sepsis infection.(19)

3.5.2 PATHFx /Prognostix AB – survival prognosis for metastatic bone cancer patients

PATHFX is clinical decision support tool generating the likelihood of survival at several time-points post-surgery or post-radiation treatment of patients living with metastatic bone disease based on patient registry data.(54)

The solution has its origin at KI with Jonatan Forsberg MD, PhD and Rikard Wedin MD, PhD, both co-founders of PATHFx. The solution has been validated using large international datasets which have been the focus of prior external validation studies.(55)

PATHFx is based on six, unique, machine-learned algorithms and provides an individualized survival trajectory suitable for clinical and surgical decision-making. PathFX is free of charge and available to users worldwide. This has enabled a large number of users around the world and it currently has around 1100 registered users. One of the Clinics that uses the system on a daily basis is the clinic where the Founder, Rikard Wedin is working where PATHFx is integrated into the care plan of the orthopaedic unit.

From the start, PATHFx had a vision to integrate PATHFx with the hospitals electronic health records (EHR), health data registries, and industry. However, in the latest version 3.0 PATHFx has transitioned away from costly, outdated, proprietary software to open source architecture.(56) This is done as an effort to stimulate collaboration, ease compatibility and streamline the development of new models.(55)

PATHFx has several years of collaboration with KI Innovations and founded a company Prognostix AB in 2016. The PathFX product received a CE-marking in May 2021.

3.5.3 DeepMed AB - Fracture identification and classification

DeepMed is a fracture classification solution using an AI technique called deep learning to automate the identification of fractures on radiographs and classifies them according to the detailed Foundation/Orthopaedic Trauma Association 2018 standards.(57)

The system was developed within the orthopaedic unit at Danderyds hospital in Stockholm, by Dr.Max Gordon. One pilot on ankle fractures was performed and promising results published in Acta Orthopaedica in 2020 where the solution reached a high degree of correct classification and attained the required performance to aid with a detailed ankle fracture classification.(57) The same solution could be scaled up to other parts of the skeleton. As the type of fracture is an important part of orthopaedic decision-making, this is an important step toward computer-assisted decision-making.

A company, DeepMed AB, was founded in 2016 and the work has received support by Sting, a Swedish start-up accelerator.(58)

3.5.4. I-AID - Integrated AI diagnostics

The I-AID project aimed to create structures for development and implementation of AI in health care and develop the basis for a “RealityLab” within the imaging unit (Bild och Funktion) and the Pathology unit at Karolinska University Hospital. The project was co-led by Professor Birgitta Janerot Sjöberg and was funded by Vinnova between 2017 - 2020. More specifically the goal was to, within identified clinical needs, perform a tender, development, validation, and clinical implementation of a not yet CE-marked product based on AI within medical radiology.(59)

The I-AID included three pilots. Upon closing of the I-IAD project, none of the three pilots reached clinical implementation during the three year timeframe.(59)

The first pilot was using AI analysis of magnetic resonance imaging brain scans to avoid using contrast agents in Multiple Sclerosis patients (MS). The MS pilot had upon finalization of the I-IAD project a signed agreement with an industrial partner and an established process for accessing data as well as a platform for validation and implementation moving forward.(59)

The second pilot was to improve and make electroencephalography (EEG) diagnostics more efficient. The aim was to build a database for AI development. This project was upon completion of the I-AID project on hold as the procurement process could not be finalized because of key competences to lead the projects had been lost.(59)

The third pilot was within the field of pathology, developing an automatic analysis of digital pathology scans from colorectal cancer. This pilot was at the date of finalization of the I-AID project in the last phase of the procurement process.(59)

3.6 Selected stakeholders – from both academia and health care

Stakeholder mapping and analysis is critical to properly conduct health innovation processes.(60) With this in mind, a high-level stakeholder mapping was performed and the work performed by Prof. Magnus Boman in the AI@KI project was used as a starting point (19) and additional organisations were added during the research phase. In this process, key actors in the earlier described innovation system were identified and potential study participants were mapped. A prioritization was made due to resource, time and limitations of respondent availability. In some cases, “snowballing enrolment “was undertaken, when participants highlighted other stakeholders as important during interviews and was consequently added to the study material. A few of these interviews were thus outside the prior described geographical boundary of Greater Stockholm but were nevertheless included in the study material as they were considered to represent the various stakeholder groups independently of geographical location.

In total 10 study participants identified as stakeholders were interviewed. Due to limitations in time, far from all key stakeholder groups could be covered. All 14 study participants are presented in *Table 2*, meeting details can be found in *Appendix C*.

Stakeholder	Name	Organization 1	Title 1	Organization 2	Title 2
AI project case	Forsberg, David	Paediatric Research Unit Department of Women's and Children's Health, Karolinska Institutet	PhD, Member of the DeepNEWS research group	The paediatric department; including NeoIVA, Karolinska University Hospital	MD
	Gordon, Max	Founder and CEO of DeepMed AB	Research Leader AI, Karolinska Institute	Chief Physician	Orthopaedic unit Danderyd Sjukhus
	Janerot Sjöberg, Birgitta	Funktion och Teknik, CLINTEC, Karolinska Institutet	Scientific Director, Professor	Bild och Funktion, Karolinska University Hospital	Senior Physician, Head of FoUU
	Wedin, Rikard	Co-developer of PATHFx, Chief Executive Officer	Prognostix AB	Orthopaedic surgeon	Karolinska University Hospital
Academic innovation office	Kallas, Åsa	KI Innovations AB	Project Manager /Business Coach		
Health Care Provider	Georgii-Hemming, Patrik	Karolinska University Hospital	Chief Medical Information Officer	Karolinska Institutet	
	Lindsköld, Lars	SweLife	Portfolio Manager, SWEPER	eHealth Unit, Department of Healthcare digitalization , Region Västra Götaland	Regional developer
	Lingman, Markus	Region Halland Hospital Group Sweden	Chief Strategy Officer	Region Halland Hospital Group Sweden	Senior Physician, PhD
	Skyttberg, Niclas	Chief Medical Officer	Aleris Health care provider	Karolinska University Hospital	Former Chief Medical Information Officer
Karolinska Institutet	Höög, Jan-Olov	Karolinska Institutet, Department of Medical Biochemistry and Biophysics	Professor	EIT Health, European Institute for Innovation & Technology	Member of Supervisory Board
	Sundberg, Carl-Johan	Coordinator Science & Society at the President's office, Karolinska Institutet	MD, PhD, Professor	Dpt of Learning, Informatics, Management & Ethics (LIME), Karolinska Institutet	Chair
SciLifeLab	Wirta, Valtteri	Head of Unit, Clinical Genomics Facility, SciLifeLab / Karolinska Institute	Facility director	Genomic Medicine Center Karolinska, Karolinska university hospital, SciLifeLab	Head of unit
The Health and medical care administration, HSF	Laporte Castro, Ruth	The Health and medical care administration, Region Stockholm	Coordinator Digitalization and Strategic Planning		
	Ulvstedt-Stadius, Katja	The Health and medical care administration, Region Stockholm	Senior Project Manager		Author of "Långtidsutredningen 2040" Perspective report Development of care and Digitalization

***Table 2**: Study participants grouped by key stakeholder groups*

3.7 Ethical considerations

The study involved conducting interviews with human subjects working on AI related healthcare projects as well as stakeholders within the AI healthcare area, predominantly in the Stockholm region in Sweden. Thus, it is important to comply with Swedish ethical regulations as well as European Union General Data Protection Regulation (GDPR).

All study participants were introduced to the study per e-mail. In the first e-mail participants were informed that ideally the interview was recorded and that participants name, and title would be published in the study. If a respondent wished to keep their identity confidential, the information was to be de-identified. Participation in the study was voluntary and could be withdrawn at any time.

See *Appendix D* for e-mail templates used in the communication with study participants. All contact with study participants were made in their native language Swedish in order to avoid misunderstandings. Thus, the templates in *Appendix D* has been translated from Swedish to English.

An oral or written consent was agreed with all persons participating in the study, both to agree that the interview was recorded and that the study participants name, and title were to be published in the study. Furthermore, all participants individually gave approval of the titles used in the final thesis to avoid mistakes and more importantly approvals were collected for all quotes used in the text. Participant permission to use quotes was collected per email and any quotes single participants did not want to be published were adjusted or deleted. Furthermore, after individual approvals of quotes, participants were sent the finalized thesis prior publication and given over eight weeks to read and reflect to secure that were no objections to quotes together with the name of the participant in full context.

The audio-files and notes from the interviews were on the author's computer and deleted after finalization of the report, in June 2021.

For the results of the thesis, it was considered relevant to know who stated what and in which professional role. However, personal opinions of the participants in the context of this study represent sensitive data as they could potentially be classified as political opinions. Nevertheless, ethical approval was not sought from the Swedish Law on Ethical Clearance (2003:460) as it does not apply to Degree thesis at undergraduate and master level. Alternately, the appropriate measures with individual participant consent described above was taken and all participants gave permission to add the quotes together with their name.

4. Results

4.1 Overview - Key barriers and facilitators sorted under NASSS domains

In the qualitative content analysis of the interviews, common themes evolved. The themes identified were “Data & Informatics”, “Business Model”, “Innovation Culture & Competence”, “The innovation to implementation process” and “Regulatory & Legal”. Based on these common themes, findings were analyzed using the NASSS framework, then sorted into the most relevant NASSS domain and categorized as either a facilitator or a barrier.

In total eleven main barriers and eleven main facilitators were identified. Barriers and facilitators in each theme are summarized and described below in *Table 3*.

NASSS Domain	Theme	Key barriers	Key facilitators
2: The technology/ The innovation	**Data & Informatics**	Insufficient IT infrastructures and absence of technical innovation environments	Increased collaboration with regards to health data
		Low “data maturity”; lack of data governance structures and general "data" hygiene	Focus on IT infrastructure for development and implementation
3: The value proposition	**Business Model**	Difficult to develop sustainable Business Models	New co-development models evolving
5: The organization(s)	**Innovation Culture & Competence**	Broad set of competences needed	Increased focus on innovation and the development of care
		Reimbursement counteract incentives to innovate	Interdisciplinary skills and collaborations
		Decentralization and a general fear of ”doing wrong”	Cultural shift towards data maturity
	The innovation to implementation process	Complex structures for innovation, clinical implementation and collaboration	A more structured and systematic way of working together with innovation
		Unclear process for clinical implementation	Strengthened support and governance
		Insufficient financing of the clinical research and implementation phase	Strengthened collaborations between academia, health care and industry
6: The external context for innovation	**Regulatory & Legal**	General ambiguity on how to interpret regulations	The future will bring more clarity on regulations
		Requirements of The Public Procurement Act (LOU) and new MDR	Joined forces on policy issues

Table 3. *Overview of key barriers and facilitators within respective themes, sorted under the appropriate NASSS Domain.*

4.2 Identified Key barriers

Below *Table 4* highlights the key barriers identified in interviews. Every theme is described in further detail with major findings and highlighted when perspectives oppose within the same theme. The pilot projects as well as stakeholders have highlighted challenges in more general areas, all not specifically connected to the AI itself. As expressed by one of the Project leaders;

> *"There were problems hiding under each new stone lifted in the process."*

Theme	Barriers
Data & Informatics	Insufficient IT infrastructures and absence of technical innovation environments
	Low "data maturity"; lack of data governance structures and general "data" hygiene
Business Model	Difficult to develop sustainable Business Models
Innovation Culture & Competence	Broad set of competences needed
	Reimbursement counteract incentives to innovate
	Decentralization and a general fear of "doing wrong"
The innovation to implementation process	Complex structures for innovation, clinical implementation and collaboration
	Unclear process for clinical implementation
	Insufficient financing of the clinical research and implementation phase
Regulatory & Legal	General ambiguity on how to interpret regulations
	Requirements of The Public Procurement Act (LOU) and new MDR

Table 4. *Key barriers identified in interviews per theme*

4.2.1 Data & Informatics

Insufficient IT infrastructures and absence of technical innovation environments
From interviews, it was shown that in all the AI project cases, the researchers themselves built their own local IT infrastructure and developed and set up their own solutions or processes for acquiring data, since the existing infrastructure did not match their requirements and purpose of the research.

> *"Currently, each research group must themselves solve everything that has to do with IT infrastructure and solutions for making data available."* Patrik Georgii-Hemming

There are several perspectives highlighted within this area also from stakeholders, whereas a few have themselves experienced the same challenges but also an understanding that this is not a sustainable way moving forward.

"We understand that our own IT infrastructure is not sustainable in the long term, which is why we have been packaging all our solutions in containers for a year now so that we can move our tools to any IT environment." Valtteri Wirta

When approaching the clinical implementation phase, in most cases, ideally the AI solution needs to be integrated into the existing environment and into the clinical setting. This phase is experienced as a barrier, as the IT environment in a hospital is a secure run-time environment that is not replicated as a test environment for innovations. Concerns on how to integrate the solutions in a safe way, in order to test and evaluate the applications in a real-world setting was raised by several study participants. For example, during the I-AID project, it was discovered that currently there is nowhere within the Karolinska University Hospital environment where AI can be used for image processing without disturbing the routine clinical IT-environment.

"Today there is nowhere where you can immediately use AI on health care medical imaging data for image processing without risking the whole clinical system going down - it is not dimensioned for this." Birgitta Janerot Sjöberg

There is a need expressed by participants to create and support technical environments with hardware and software as well as an understanding of the special needs of the researchers.

"We sent a request to the Hospital IT department to gain access to Clinisoft and received a response 6-7 months later." David Forsberg

It was noted in interviews that in Stockholm researchers who are approaching the phase to test in a real-world clinical setting have established collaborations with hospitals outside the Region in order to test and further develop their solutions.

Low "data maturity"; lack of data governance structures and general "data" hygiene

Models based on AI are dependent on a large amounts and high quality of the collected data. Several of the stakeholders, experienced multiple aspects of "the data itself" as barriers, mentioning the semantic and contextual challenges as well as the format and quality of data. For the majority of AI research projects in Stockholm today, a dataset from the real-world clinical data is extracted and several assumptions and new logic rules are made to create a separate research dataset. For example, the researcher may have to choose one out of hundreds of definitions of Blood Pressure from the EHR, extracts it to an external database, washes and refines the data further by giving it a new model and terminology. Hence, both the technical, semantic and operational conditions are changed, making the algorithm functioning to perfection in the research context, but probably not as well in the clinical context.

"We start talking about using an advanced combustion engine before we have even come up with the idea of drilling for oil." Niclas Skyttberg

Here, another perspective was highlighted, that researchers need to raise their understanding of the difficulties in implementing the algorithm in a clinical context and thus lower their expectations on data used in the development.

"The academics want super-stringent solutions that work very well and instead it becomes a theory monster when in the dirty clinical environment that clinicians are used to."
Markus Lingman

Some of the study participants indicate a low awareness in general of "the value of data" and that there is a generally low degree of "data maturity" within the adopter system. This should be considered a hindering factor for the implementation for AI. Looking at the "case perspective" they did not express the need in the same explicit way as some of the stakeholders, nevertheless they have real world experiences of the challenges of the lack of "data hygiene". For example, one of the research groups had a PhD student focusing solely on the task of using text data from radiology reports but it was unsuccessful and suspended after spending one year on it. Within another research group, the process of data annotation was immensely quicker when given access to the use of another software for patient records (CliniSoft). Access to the software, where data is captured and stored more categorized, allows for speedier development and the research group can go from manual annotation of 300 patient records in the course of three years to 1000 intensive care records in one year.

From a health informatics perspective there is a clear consensus that there is a lot of hard work that needs to be done before implementing AI into the real word of clinical practice.

"As for AI, it can almost be like a shimmer of ridicule for someone who understands how care really works, since the gap between how actual health care still is conducted to these very modern ways of looking at how to use IT and AI. You can be thrown out right away and be accused of being completely out of touch with reality.
On the other hand, it is an important part of our future, but there are so many steps on the way to get there." Patrik Georgii-Hemming

4.2.2 Business Models

Difficult to develop sustainable Business Models

The cases described in the study were all at various levels of implementation, thus they were in different stages of development of their Value Proposition and business model. However, they all experienced challenges in defining a business model that could serve as a sustainable one for the future. For example DeepMed, experienced barriers in defining the value proposition to customers given their current willingness to pay, whereas PathFX have taken on a business model of an open, web-application that might not be neither financially sustainable in the longer perspective as it is free of charge for users. This on the other hand was a consequence of the difficulties securing interoperability with the existing clinical IT environment. Both PathFX and DeepMed have had prior discussions on potential electronic health care record integration, but they were not taken further and no test for integration has been performed so far.

Similarly, DeepNEWS have also pondered around the best business model for the future, should it be an "add-on" to existing monitor equipment in the ICU or instead integrated into a software or hardware being tied up to one commercial player?

"How can we do this prospectively without locking ourselves into a commercial cycle"
David Forsberg

From a stakeholder perspective, several study participants describe the business model challenge as a consequence of the current regulatory landscape in combination with the fact that the Region does not CE-mark products. The challenge described is that researchers and in many times also the hospital first is part of inventing, developing and testing a solution, then the solution is sold to a company to be CE-marked and go through the tender process of the same hospital. Consequently, there is a risk that the hospital will not be able to use the solution in the future (if the tender is not won). Furthermore, the hospital needs to pay money for something that they were already part of developing. Lastly, there are many examples of innovations sold to companies that have then closed it down, rather than developing it further.

"First you are involved in the research and development of a product, then you might not be allowed to use it in the clinic because it has to go through procurement and lastly the clinic needs to pay for something that they themselves were part of developing." Birgitta Janerot Sjöberg

4.2.3 Innovation Culture & Competence

Broad set of competences needed

Both from a case and a stakeholder perspective, examples were given in interviews that illustrated the importance of the broad set of competences needed both to develop but more importantly also to implement an Artificial Intelligence solution.
Below is a list of the skills mentioned interviews as crucial from various perspectives in order to successfully implement an AI solution into clinical practice;

- **Medicine** – an understanding of the need and/or potential
- **Technical** – basics of Artificial Intelligence
- **Implementation** – Experience of change management and leadership
- **Legal & Regulatory** – MDR, IVDR, CE marking etc
- **Ethical & Data Security –** GDPR etc
- **Tenders** – Process and Tactics of The Public Procurement Act
- **IT Infrastructure** – strategy, platforms
- **IT maintenance** – DevOps, i.e. software development (Dev) and IT operations (Ops)
- **Informatics** - Standards, Terminology, Data Hygiene etc
- **Intelligence** – Latest development? Other solutions in the market?
- **Health Economics** – evaluate and propose value propositions

Several of the study participants paint a picture of a generally low understanding of both the possibilities and requirements needed for AI. Moreover, experiences from the cases

with the Innovation support units (DS Innovation and Innovationsplatsen Karolinska University Hospital) confirm this view.

Looking at the Adopter system and given the earlier described dependence of Heads of Clinic, this person must trust the solution and serve as a champion. To achieve that, a certain level of understanding of AI is crucial both in order to make a decision and to secure funding.

Reimbursement model counteract incentives to innovate

It was highlighted in interviews that the current reimbursement-model in health care, with a tight budget control and strong focus on production is contradicting the incentive to innovate within the clinics. Focusing on measuring and reimbursing for example the number of surgeries, patient visits, x-ray exams and not quality or patient satisfaction results in weak incentives to adopt new solutions, since it is not generating any short-term direct effect on the clinic budget.

"What we get paid for in health care also guides what we do. The current governance model does not fit well with the change we now need to make." Patrik Georgii-Hemming

Another aspect of this barrier is when the innovation entails an investment cost for the clinic, but the potential savings generated will be outside of the own clinic, there is naturally less incentive to invest given the current reimbursement system.

Decentralization and a general fear of "doing wrong"

The "organic" or more ad-hoc as well as the "decentralized" nature of both the "Karolinska Institutet" side and the "Stockholm Region" side *(Figure 2B)* is suggested to be a contributing factor to some of the barriers faced by the participants.

First, looking at "Karolinska Institutet" side of *Figure 2B*, the cases, i.e. the research groups have all grown organically out of single, research ideas, as "ad-hoc projects" and today act as standalone cases, all trying to cope with similar, but very complex issues. As an example, they have been struggling with the interpretations of The Patient data act, GDPR, Data Security and have established a high level of knowledge and are well-informed on newly released precedencies for future guidance.

"Of all the challenges that a research group has, I would like to say that about 90% are common challenges and 10% are unique." Patrik Georgii-Hemming

On the "Stockholm Region" side in *Figure 2B*, each health care provider is responsible for organizing to facilitate innovation. Ultimately, the Head of Clinic is responsible for the development of care including decisions on use of data, implementation of new solutions and how to allocate the budget, there is a natural high level of decentralization. Consequently, the health care provider has a responsibility to decide how to best support their Heads of Clinic in this process.

Furthermore, case interviews witness an almost exhausted feeling from the various efforts that have been made trying to get the attention and progress towards implementation within the Region Stockholm. Many hours in fruitless meetings, which only result in another meeting. There is currently little guidance and discussions on for example data security and ethics dominate and are perceived as difficult. Thus, there seems to be a widespread general "fear of doing wrong" as described by study participants. Bottom line, it is the Heads of Clinic who is responsible. Currently, they are put in a very exposed position, where in many cases to refrain feels like the only or at least the safer option. This also leads to elongated processes and long lead-times for involved parties, something expressed by several of the participants.

"It's like an impervious mass trying to talk to someone who can make a decision within the Region. We have done everything we can do, ticked off everything and yet we sit here several years later and still look for a person who can say that this is ok." Max Gordon

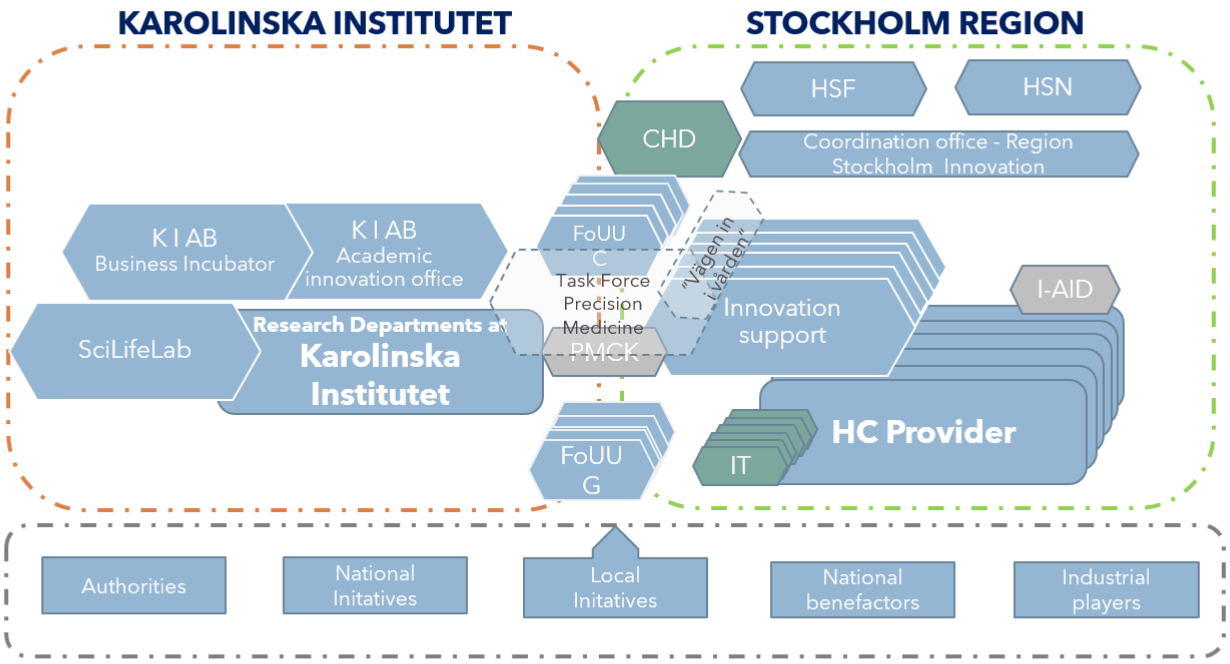
4.2.4 The innovation to implementation process

Complex structures for innovation, clinical implementation, and collaboration

A key contributing factor acting as a barrier is the current complexity of the structure and organization of the "innovation and implementation system" in Stockholm. There are numerous different actors, offering similar kinds of support in the process.

"It actually takes a very long time as an employee at KI Innovations or as an employee within the Region before you understand each other's offers. Imagine what it is like for the innovators." Åsa Kallas

Figure 2B below attempts to illustrate additional structures involved in the implementation of AI in health care revealed in interviews (in green) on each side as well as highlights important, but not permanent structures (in grey).



PMCK: A virtual precision medicine center at Karolinska University Hospital (Precisions Medicinskt Centrum Karolinska)
CHD: Center for Health Data (Centrum för Hälsodata)
KI AB: Karolinska Innovations AB

Figure 2B. *A simplified graphical figure of "the innovation and implementation system". It aims to illustrate key structures involved in of AI in health care in Stockholm revealed in interviews (in green), projects of importance (in grey).*

On the "Karolinska Institutet" side of the innovation and implementation system, the core is centered around all the individual researchers and research groups, however no central function responsible for the innovation to implementation process, for example coordinating and governing, was mentioned in interviews. On the other hand, there is KI Innovations AB, a subsidiary of KI, both acting as an Academic Innovation office as well as a business incubator for innovations from KI. Nevertheless, KI researchers are free to turn to other academic innovation offices such as KTH innovation but also business incubators such as Sting that are outside the medical academic context.

Important to add within the academic context in Stockholm is the SciLifeLab as it is a very large academic hub and workplace. However, all employees at the SciLifeLab are actually employed at one of the host universities, in this case Karolinska Institutet.

On the "Stockholm Region" side, there is a central coordination office at Region Stockholm Innovation as well as the Network Region Stockholm Innovation, consisting of the six units at hospital for Innovation support.

Early interaction from the end user is considered to be a key success factor for successful implementation. Based on interviews, many of the study participants have highlighted the importance that the end user/clinician is involved early on but also the difficulty trying to reach the right people within the health care provider organization. This emphasizes the

need for collaboration between academia and health care, but currently prerequisites for these collaborations are mostly on an ad-hoc, non-formalized project basis. As expressed in one of the interviews;

”KI has no real structure for long-term interaction with the Region for innovation issues specifically. There is no central point for innovation issues - there is no one in the management who is responsible for coordination and there is no "internal body". Instead there are many areas and the issue has been outsourced to Karolinska Innovations AB.”
Carl Johan Sundberg

Currently, there are several organizational structures, initiatives and projects in place with the aim to support innovation and the development of care. Nevertheless, several of the participants, from different perspectives, highlight the fact that they currently experience no, or very little, central support or cohesion. Thus, there is a feeling both that there is a high level of double work and that “the wheel is reinvented” again and again. For instance, the innovation support units at hospitals, where Innovationsplatsen at Karolinska University Hospital is the one mainly highlighted but also DS Innovation, have themselves experienced the challenges of going from pilot to sustainable clinical implementation and there seem to be few best practice cases to learn from. An underestimation of the complexity of the task, high employee turnover, not considering and building the existing prerequisites and conditions, but instead trying to build something new have contributed to these challenges according to participants.

“Currently, the hospital innovation offices work in a sheltered environment and contribute to the problem.” Niclas Skyttberg

Unclear process for clinical implementation
From interviews, there seems to be no clear process nor consensus on a “preferred path” for the innovators to relate to in their struggles from innovation to clinical implementation. Interviews emphasized the difficulties of taking the AI solution from being a “hospital proprietary solution”, i.e. Level 1 to the next Level 2, Sustained adoption. There is high level of vagueness or uncertainty on how the process best could look like after the hospital proprietary solution stage. What is the “preferred path” or visionary process?

“There is a high level of ambiguity about how an innovation goes from research and local development into a product.“ Max Gordon

Similarly, the final report of the I-AID project states that, despite the many years of collected experiences and projects of research and development collaborations with industry and academia, the final solutions or products generated from these projects, have not reached the end users nor created value for clinicians or patients. Additionally, the I-AID report concludes that this is because the prerequisites to drive a project all the way to ready solutions or products to be implemented in health care, in this case, in most cases do not exist.(59) This view was reinforced in interviews.

"What is missing is the next level, i.e. how do we 'dock' innovation and creative proposals into our organizational structure so that it has long-term sustainability."
Carl Johan Sundberg

In this study, all innovators were connected to KI and also had "combined positions" working on one of the Regional Hospitals. Despite similar preconditions, they chose different Innovation support partners, i.e. "paths". DeepMed works with DS Innovation as well as STING Incubator and PATHFx works with KI Innovations AB. DeepNEWS have not yet proceeded to this stage.

Interviews witness mixed experiences of the innovation support system, mainly positive in the initial phases but failing to support moving forward. One reason mentioned was a general lack of understanding and competence of AI and that the evaluation of the innovation was not made in a professional way, making sure that the decision was made by a team with the right up to date expertise of both AI but more specifically the medical expertise being able to fairly evaluate the solution's medical potential.

Furthermore, an inability to assist with the right connections within the Region was mentioned. A perception in interviews is that it is, despite utilization of innovation support, up to the innovator to establish contacts and identify the "local champion" that could take the process further inside the health care provider. On the "Stockholm region" side, there have been efforts to establish a single entry point, via the "Vägen in till vården", where the innovator fills in a form, which is then sent to the various Innovation Support Units at the hospitals.(48) None of the participants had experience of this new entry point.

Insufficient financing of the Clinical Research and Implementation phase
From interviews it is clear that there is a gap in the financing for the clinical implementation phase. Resources are focused on the early, creative and innovative phases as well as for routine care, but less resources (and focus) are invested to establish and implement new methods and ways of working. Interviews with the AI projects support this view as they received adequate funding in early phases from "Innovationsfonden" among others, however experienced major difficulties when moving forward in the process towards commercialization and implementation.

For DeepMed for instance, there is both the obstacle of achieving approval from the local clinic to take on the server cost of a couple of hundred thousand SEK per year to continue using the solution, as well as the high cost for the CE-marking estimated to over a million SEK.(58) Efforts to attract venture capital or similar has been made but expressed as difficult as these actors prefer to invest in CE-marked products already commercialized.

4.2.5 Regulatory & Legal

General ambiguity on how to interpret regulations

Since there currently is no single database collectively handling the health data within the region, it has implications and requires high demands on for instance Data Security. As mentioned earlier, the responsibility lies on the Head of Clinic as the data owner. There are several considerations that needs to be considered to ensure compliance but there are currently several uncertainties within this area with regards to regulations, GDPR but also the new MDR.

As to the new, stricter demands on CE-marking, The Swedish Medical Products Agency (Läkemedelsverket) has had difficulties to provide guidance or support when contacted. Several of the cases failed to receive an answer upon request on what will be required after May 26th, 2021.

"We have asked The Medical Products Agency, but they were unable to give us any clarification whether we need a CE marking or not after May 26th."
Rikard Wedin

Consequently, there is an ambiguity in how to interpret regulations which results in inconsistencies even within the same Region or between academia and health care, both with regards to GDPR and also which solutions are allowed to be used or not. There are yet few precedents and no best practice cases to lean upon.

Requirements of The Public Procurement Act and new MDR

AI products in the market already today are classified as class I devices, without any active review of a regulatory authority. The new, stricter MDR regulations imply that AI software will no longer be accepted as class I medical devices but will require review by clinical experts at Notified Bodies. This will consequently lead to an elimination of solutions that are currently in use. More importantly it will have dramatic consequences for the projects/newly founded companies like the cases studied in this study, since they do not have the resources required to complete this process by themselves.

"The new MDR will unfortunately lead to an enormous elimination of companies. To get a bill of SEK 300,000 just to talk to a Notified body - not many small start-up companies with a researcher from a university have that money." Markus Lingman

Furthermore, currently the MDR and thus also The Swedish Medical Products Agency (Läkemedelsverket), prohibits the introduction of continuous learning systems.(4) From a regulatory perspective the learning functionality of the AI solution is not allowed to be activated when in clinical use, since the demands of validation cannot be fulfilled by the manufacturer. As a consequence, the manufacturer needs to "lock the algorithms" into different, sequential, defined software versions. Hence, it can be viewed as if the optimal use of AI allowing it to be a self-learning system is obstructed by the current regulatory requirements.

Lastly, there is uncertainty and a challenge on how to plan and design the validation studies for an AI solution with a similar design as for pharmaceutical trials with criteria of e.g. blinded and randomization. For example, the challenge of keeping it blinded is evident if for example DeepNEWS would be applied as an add-on decision support for one of the monitors used in the ICU. Currently, there are very few projects that have proceeded to the stage of performing randomized clinical trials, RCT's, thus few best practices exist.

4.3 Identified Key facilitators for an improved implementation process of AI

Below *Table 5*, highlights the key facilitators for an improved implementation process of Artificial Intelligence in health care. Every theme is described in further detail with major findings.

Theme	Facilitators
Data & Informatics	Increased collaboration with regards to health data
	Focus on IT infrastructure for development and implementation
Business Model	New models evolving
Innovation Culture & Competence	Increased focus on innovation and the development of care
	Interdisciplinary skills and collaborations
	Cultural shift towards data maturity
The innovation to implementation process	A more structured and systematic way of working together with innovation
	Strengthened support and governance
	Strengthened collaborations between academia, health care and industry
Regulatory & Legal	The future will bring more clarity on regulations
	Joined forces on policy issues

***Table 5**. Key facilitators identified in interviews per theme*

4.3.1 Data & Informatics

Increased collaboration with regards to health data
Several of the study participants expressed a clear need for data to be coordinated, i.e. having data both for the clinical, daily operations as well as for retrospective analysis.

> *"I am convinced that the most interesting data for future research will be generated in health care. It will not be a retrospective characterization of bio banked samples, but it will be prospectively generated data from health care."* Valtteri Wirta

Having data for both clinical and research use would remove several of the experienced barriers described earlier and create solutions better adjusted to succeed all the way into a clinical implementation. For example, within Karolinska University Hospital and the I-AID project, there was a clear need for a parallel archive for research and development connected to the electronic health care record to be used for the development without the risk of interference with the ordinary archives for patient care.(59) Developing AI solutions and training them on the real data from the same environment, creates optimal prerequisites for a successful implementation (translation) into the real-world clinical setting. Looking at for example Region Halland, the research database is simply a mirror of the clinical database and basically all kinds of health data is stored in the same repository.

The Center for Health Data, CFH, was mentioned by many participants as a positive and important initiative. The center was started in 2019 as a collaborative organization within the Region Stockholm and offers researchers a single point of contact and a secure, uniform process for handing over health data. It does not establish its own databases but coordinates the disclosure of data for purposes that are permitted under current secrecy and data legislation.(48) However, as highlighted by study participants, the current set up of CFH has a limitation as it only handles data for research purposes and mainly functions as a single point of contact to ease administrative burden on researchers, not for the development of care.

"Previously, in Stockholm you had to fill in 17 different forms for different places if you were to retrieve images from different information owners, but now there is at least just one point of entry." Birgitta Janerot Sjöberg

Focus on IT infrastructure for development and implementation

IT is a fundament for the development and implementation of AI within health care. Thus, there is a need for a well-defined IT organization and strategy in order to facilitate the development but also the implementation of AI in health care. This includes a purposeful infrastructure and IT platforms. For this to be fruitful long-term, this work needs to be coordinated between academia and health care.

"IT is a key part of AI work and in AI implementation, a clear, well-defined IT project must be an integral part of the project plan. To create a platform for more general AI development and implementation, a dedicated IT with proper management is urged on"
Quote from the I-AID report, p 37.

"I would have helped if we had a closer collaboration with the hospital's IT administration, smoother solutions and better dialogue with them. Ideally, there should be a research manager in each IT department." David Forsberg

During interviews, it was suggested that the current pause of the large procurement work for the next electronic health care record system in Region Stockholm could be used as an perfect timing opportunity to focus on overall strategy and choice of a sustainable, flexible data model and thereafter work on the next layer, the user interface including EHR. This would allow for an infrastructure so that each time a datapoint is created, a future algorithm knows how to interpret it.

"Ultimately, we want to put the algorithm on top of the data." Lars Lindsköld

4.3.2 Business Model

New models evolving

Lately, new models have emerged mainly because of CE-marking requirements and the notion that even though the health care provider is part of developing a solution and

investing resources, it still needs to pay for using the solution when commercialized in the end. For example, in the I-AID initiative at KS ”Innovation procurement” was used as a strategic tool to achieve collaboration between internal and external expert competence and try to bridge the gap and accelerate implementation of AI.(59) A similar model as used in I-AID is also advocated in Region Halland.

Key characteristics of the “new model” illustrated in Figure 3

- Researcher develops a solution in close collaboration with end-user/clinician and manufacturer/industry
- Filed as “hospital proprietary products” under the development phase
- The solution is then handed over/given away to manufacturer/industry player (commercial player) that drives the commercialization process; CE-marking, tender/procurement process etc.
- The commercial player receives the rights to sell the solution/product outside the walls of the health care provider
- The health care provider receives the right to use the solution/product without cost
- All parties bear their own costs and contribute to a joint development project, and where all parties also receive value as a crucial incentive to participate (as indicated by the respective arrows in Figure 3)

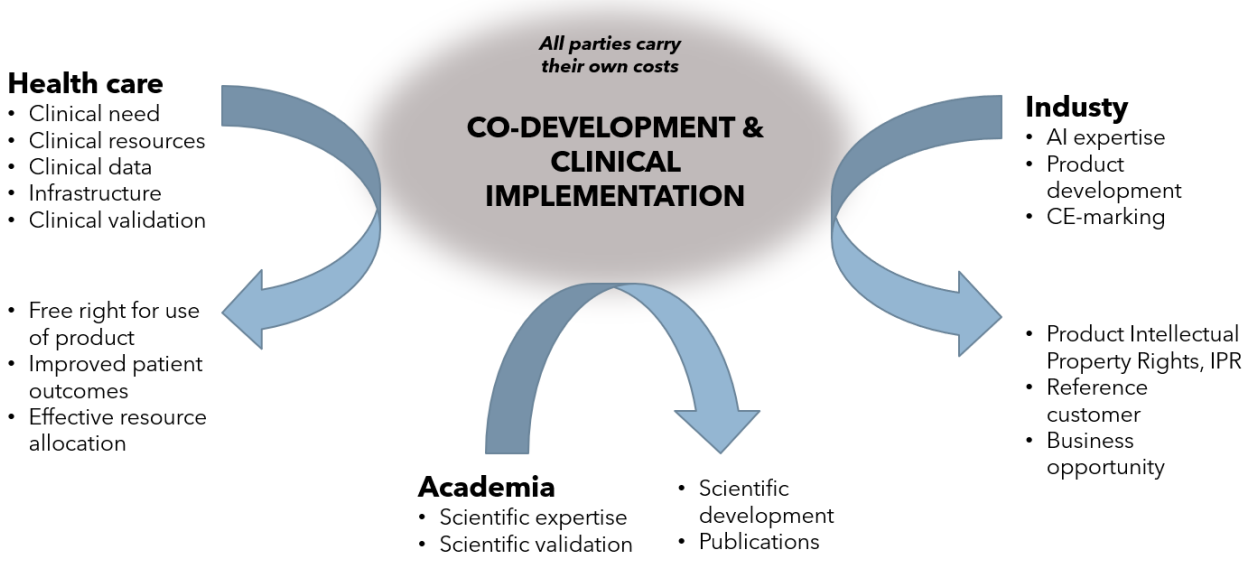


Figure 3. *Model from Vinnova report I-AID (p.16), Janerot B et al. 2021, reuse approved by creator Borgegård T, Innovationsplatsen Karolinska.(59) Translated from Swedish to English by author. Illustration of the new innovative business model for co-development and implementation.*

4.3.2 Innovation Culture & Competence

Increased focus on innovation and the development of care

As earlier discussed with regards to incentives, the current primary focus of health care is not on innovation and the development of care, but rather on the production of care, which also has an impact on the culture of the organization(s). Prerequisites that allow the clinics to take on their responsibility of innovation and development of care would facilitate a shift in culture.

Close collaboration between end-user and innovator is a success factor for implementation of the solution. Interestingly, all three cases, PATHFx, DeepMed and DeepNEWS had innovators that had "combined positions" between clinical work and research work at KI. This possibility to have "a combined position" between clinic and research, facilitated not only the correlation between the clinical need and the invention, but also close cooperation early on as well as support from local management, i.e. the Head of Clinic, that proved to be beneficial to take the solutions to their current state.

As earlier discussed, Heads of Clinics have an exposed position not only being responsible for how to best innovate and develop the clinic, but also being legally accountable for solutions implemented. Thus, there is a need to create prerequisites to involve the Heads of Clinics early, secure the right competence and support so that there is a certain level of understanding of AI in order to make a decision and secure funding later on.

"If there is no AI competence within management, this is reflected in the culture and then you are in big trouble." Markus Lingman

Interdisciplinary skills and collaborations

In interviews, it was evident that the character and competence of the innovator was a key facilitator. All AI project leaders in this study possessed strong interdisciplinary skills, for example programming and served both as a local champion in the clinic as well as demonstrated true qualities of an "Innovator" with strong determination an indefinite amount of extra hours were put into their projects.

A key success factor for all projects that were highlighted specifically was to secure interdisciplinary skills within the project. One way of securing this are collaborations outside the KI and health care context. DeepNEWS is a good example having a PhD student from the Royal Institute of Technology, KTH, co-supervised by the Principal Investigator of the project. PATHFx on the other hand had access to cutting edge technology in the USA via their founding partner, to the Walter Reed National Military Medical Center's ML technology and competence.

"We would never have gotten this far in the project without the programming and technical skills of our PhD colleague from KTH - it was absolutely key." David Forsberg

Cultural shift towards data maturity
With regard to the earlier described barrier connected to the quality of the data that is used to train and adjust the AI algorithms to fit the needs in the real world, a well-known expression is applicable, “garbage in, garbage out”. This expression refers to the fact that, no algorithm, no matter how smart or intelligent it is, can produce value if its input lacks value in the first place.

"Everyone wants to invest in fancy solutions [AI] – but why no action? Simply because there is no fuel[harmonized data]!” Niclas Skyttberg

To come closer to a solution in this aspect, a strong focus on data work is needed in the organization(s), requiring efforts in data governance practices, data awareness and data hygiene. This cannot be driven solely from an IT or Informatics perspective. In order to succeed in this transformation, it needs to be led by the clinicians themselves.

“We need to stop being a data collector, start being an operator.” Lars Lindsköld

"Using data generated in health care for discovery - that dimension hardly exists today. It may not be the direct interest of health care, but indirectly it is. I see an enormous potential here that we cannot take advantage of today." Valtteri Wirta

4.3.3 The innovation to implementation process

Develop a more structured and systematic way of working together with innovation
For a fruitful “innovation to implementation process” of AI, a strategy and a vision on how to achieve this would be beneficial among all key stakeholders. It was revealed in interviews that currently there seems to be little consensus and clarity on how the process from pilot to clinic should evolve in the best possible way. Thus, a need for support for a more structured and systematic way of working with innovation from first idea all the way to implementation in clinical practice was highlighted. The process is very complex, and several actors need to be intertwined along the way, academia, health care and industry. Financing needs to be secured for the later stages already early on in the process.

“Many people just say that 'it cannot be this complicated' to get new AI solutions into clinical use. But unfortunately, it was this complicated if it was going to turn out well in the end. We must all work for regulatory simplifications and share good experiences". Birgitta Janerot Sjöberg

Looking at the early process, in the innovation phase, the interviews witnessed that both support as well as financing was working sufficiently. All cases exploited the possibility to use the regulatory processes developing “a hospital proprietary solution” in which two out of three cases received appreciated support from an Innovation Office. DeepMed was supported by DS Innovation and PATHFx by KI Innovations. Furthermore, early innovation funding was received from “Innovationsfonden” and “Vinnova” among others.

Nevertheless, in progressing to the "next stage" there are challenges described by both cases and stakeholders, indicating that there is insufficient support and no systematic way of working to progress towards implementation. One contributing factor, highlighted in stakeholder interviews was the lack of permanent, i.e. not project based, cohesive structure to facilitate collaboration for joint strategy and action plan between KI and Region Stockholm, especially Karolinska University Hospital.

"The sooner we get the dialogue going across Solna-vägen and the more concrete it becomes, the easier and smoother it will be to build a virtual bridge in the future." Patrik Georgii-Hemming,

"We should create more permanent structures and not just put them into projects that we currently think are important." Carl Johan Sundberg

Despite the above described "gaps" in the process, positive initiatives already out there should not be forgotten. The massive work of the I-AID project for example, mapped out the overall process and initiated the work of establishing structures for the development and implementation for AI within image processing.(59) Another example is "Spelplanen" that was a joint project initiated by Swelife 2020 in collaboration with Karolinska University Hospital, Region Stockholm as well as three other Swedish Regions within the SWEPER project. It aims to clarify how development and innovation can be conducted in collaboration between Regions and industry/private sector.(61) However, the Spelplanen report does not include academia in the development and implementation process.

Strengthened support and governance

Given the need for support and a more structured and systematic way of working with innovation to implementation on both the academic side as well as the health care side, described above, a need for strengthened support and governance appeared during the study.

Looking at *Figure 2B*, at the "Stockholm Region" side, it became evident that not only that the Heads of Clinics are key in a clinical implementation, but also need a great deal of support when decisions for new technologies such as AI are made, and new, untried laws are invoked. This support covers the majority of the "new skills" earlier referred to but primarily within legal and technical/IT as well as policy and current praxis.

Within Region Halland and their innovation driven health care initiative called "Leap for Life"; there have been efforts to develop and build the "receiving ability" within the organization by supporting the Heads of Clinic in their decision-making, for example with regards to new drugs but also medical technology devices and AI solutions. The support encompasses for example checklists and close cooperation with the regional procurement department.

Looking at the "Karolinska Institutet" side, it was highlighted that there is a similar challenge. A strengthened, cohesive support in areas requiring "new" competencies would allow researchers to focus on what they are best at doing and reduce time spent on

e.g. interpreting new laws or building own IT infrastructure. This would require that the new areas of competences needed for development are secured.

It was highlighted, that a strengthened support could potentially also facilitate governance to assure that efforts are made in prioritized areas and thereby ease the communication of the important approval of top management support and a successful clinical implementation.

"Because if they [the research projects] instead make contacts of their own and look for research funding or meet Microsoft's CEO, it does not matter because then the hospital management is not involved." Patrik Georgii-Hemming

Strengthened collaborations between academia, health care and industry

The new models evolving due to regulatory requirements earlier described, are dependent on industry collaboration. Their contribution will be key, mainly to achieve support in CE-marking, ensuring the financial resources, the commercialization process as well as competences such as IT-development and tender strategy.

There was a consensus among stakeholders about a strong need for increased industry collaborations but there is still a general view that the industry might represent a threat.

"Industry must be involved in developing better methods for care in collaboration with academia and health care providers as they are the ones that will develop the final product." Jan-Olov Höög

Based on case interviews, except the I-AID initiative, there were currently no industry collaborations in place. However, there were ongoing dialogues driven by the Innovator themselves to explore collaboration opportunities. With regards to KI Innovations there were no formal arenas for collaboration and dialogue with industry was purely ad-hoc and based on prior personal relationships.

Within Region Halland, a pioneer with regards to the development of AI solutions, there is a Regional platform for industry collaboration created with the Leap for Life initiative. Within Region Stockholm there are some efforts in the same direction as already mentioned. One is ”Vägen in i vården”, another is the strategic collaborations with major medical technology suppliers that Innovationsplatsen have established.(48) Additionally, within the I-AID project there was a formalized and structured collaboration with industry and great deal of documented learnings with regard to this.(59)

Most likely, the new stricter MDR regulations will lead to the development of commercial players that need to learn how to take care of these innovations and help them into clinical practice together with those who were involved in the process, i.e. both academia and health care.

"The most important thing we have is that the institutions talk to the industry and that the industry talks to the institutions – in square that will be I^2" Lars Lindsköld

4.3.2 Regulatory & Legal

The future will bring more clarity on regulations

Trust in the solutions by users was highlighted as a key facilitator for clinical implementation and furthermore for a successful scale up of the solution. The now increasing pressure from authorities with new, stricter regulation and with the following increased attention from regulatory bodies to guarantee compliance was mentioned to have a positive impact on the perceived trust of a solution and thus increase the chances of implementation and sustainable funding.

As expressed by one of the participants and reinforced by several; *"We have a huge learning journey ahead of us"*. This applies not only to the academia and health care organizations but also for the authorities and regulators (the wider context).

For example, will the European commission soon release a policy package, which will include a proposal for a "Regulation on a European Approach for Artificial intelligence". This will be the first attempt to define a comprehensive regulatory framework for AI, dealing with essential aspects such as the definition of high-risk applications, regulatory obligations for providers of AI systems, the post-market surveillance of AI, the conformity assessment of high-risk AI applications and the possible creation of a new AI Board.(62)

A more local example is a recent verdict with regards to the disclosure of data for the benefit of research. It will serve as an important precedence that will help to guide moving forward. In this case, the health care provider said no to give out data despite an ethical approval by the research group, but the health care provider was proven wrong.

Furthermore, a supervisory matter was initiated by Swedish Health and Social Care Inspectorate (IVO) in February 2020 at Danderyds Sjukhus for an AI solution that was integrated to the image archive and developed for clinical use but was not CE-marked nor filed as "a hospital proprietary solution". Swedish Health and Social Care Inspectorate (IVO) has stated in their yearly report that they will closely follow how health care is implementing and using new technical solutions, such as AI.(4)

Lastly, there will be more and more examples on how to design the clinical validation of AI in the real-world clinical setting, meeting the study design requirements of the regulations. One example highlighted in the AI@KI project (19), is an AI solution using Machine Learning in internet delivered psychological treatments that currently is under external validation regarding its clinical usefulness via a triple blind, randomized clinical trial. It is one of the pioneers within this field in Sweden, planning to close the first phase of the study late 2021.(63)

Joined forces on policy issues

As illustrated earlier, study participants express a need for increased cohesion and collaboration between academia and health care, not the least within the area of policy development.

One example mentioned several times in interviews, is the current limitations with regards to GDPR and the secondary use of data without an informed consent. To create an improved foundation for predictive analysis and ability to use clinical data in research, the perspective needs to shift to the one where it is considered of public interest to use clinical data for research. In Finland for example, a new regulation was created in 2019 where the secondary use of data also allows research.

5. Discussion

This study explores how to facilitate the process of going from an artificial intelligence-pilot to real-world use in clinical practice, by identifying the main barriers and facilitators described by study participants and in literature. The analysis applied the NASSS framework to identify determinants for implementation related to the different domains.(34)

The study contributes to the existing empirical evidence and generally confirms previous findings of the implementation challenges of medical technologies.(34) However, it also aims to contribute specifically with regards to AI and implementation in health care, an area much less explored. The current lack of evidence-based implementation studies of AI in health care should itself be considered as a barrier to successful implementation of AI solutions, as there simply is little empirical evidence and few learnings have been made so far. In line with earlier Swedish reports, this study confirms as mentioned, that there are numerous challenges connected to the implementation process of AI in health care (4-6, 19). However, it also aims to shed light on how the process could be facilitated and improved moving forward, both from a top-down ("decision maker") as well as from a bottom-up ("innovator") perspective.

As suggested by Greenhalgh 2017 it is not individual factors that make or break a technology implementation effort but the dynamic interaction, or lack of interaction, between them.(32) Considerations for adoption across the entire system is essential, ranging from the technology itself to the wider system in which it must be embedded. In this study several of the main barriers could be identified primarily within the Organization(s) domain (32), deriving from the identified themes of "Innovation culture & Competence" as well as "The innovation to implementation process". Similarly, the main facilitators were within the corresponding themes.

A question evolving throughout the work in this study was which barriers and facilitators only appear when implementing an artificial intelligence solution, i.e. to be considered "AI specific" and which could be considered more general in character and apply to most technologies implemented in a clinical setting. In line with Greenhalgh, most of the barriers and facilitators explored in this study are of more general character such as the collaboration and organization of academia and health care in the Stockholm area, thus not only attributable to the field of AI. Since Artificial Intelligence models are advanced and very complex solutions, most parts and domains of the innovation system are more challenged upon its implementation and issues and weaknesses more exposed than other implementations. Thus, AI implementations in health care could be considered a sort of early adopter that challenges the current system and highlights required changes moving forward.

From pilot to clinical practice - how do we make it happen for AI?

As suggested in the study, the innovation and implementation of Artificial Intelligence is enormously complex. Key for facilitating the process moving forward will be a common ambition from all stakeholders (academia, health care and industry) to commit to create

the best possible prerequisites for a cohesive process starting in an early research phase and finalized only when the solution is widely used in clinical care, adding value to patients.

Given the considerable amount of money recently invested into research of data and information driven life sciences (19, 21, 22) it will be fundamental to prepare the organizations for AI solutions in the future. Thus, the structure and the efficiency of the current "innovation and implementation support system" previously discussed needs to be considered. See *Figure 2C* for an overview of the current system, highlighting all current structures of the "innovation and implementation system" in Stockholm relevant to AI implementation. All were not mentioned in interviews but have come to the author's attention during the work of the study, marked in dark green in *Figure 2C*. To mention a few examples of the structures that are likely to become essential for the implementation of AI moving forward are the Center for Precision Medicine, PMCK, the Center for Health Data (CHD), the Stockholm Region Innovation as well as the Stockholm Region Informatics Council. Similarly, the newly established KI Clinicum, the Information Management Council and the Research Data Office will likely be important.

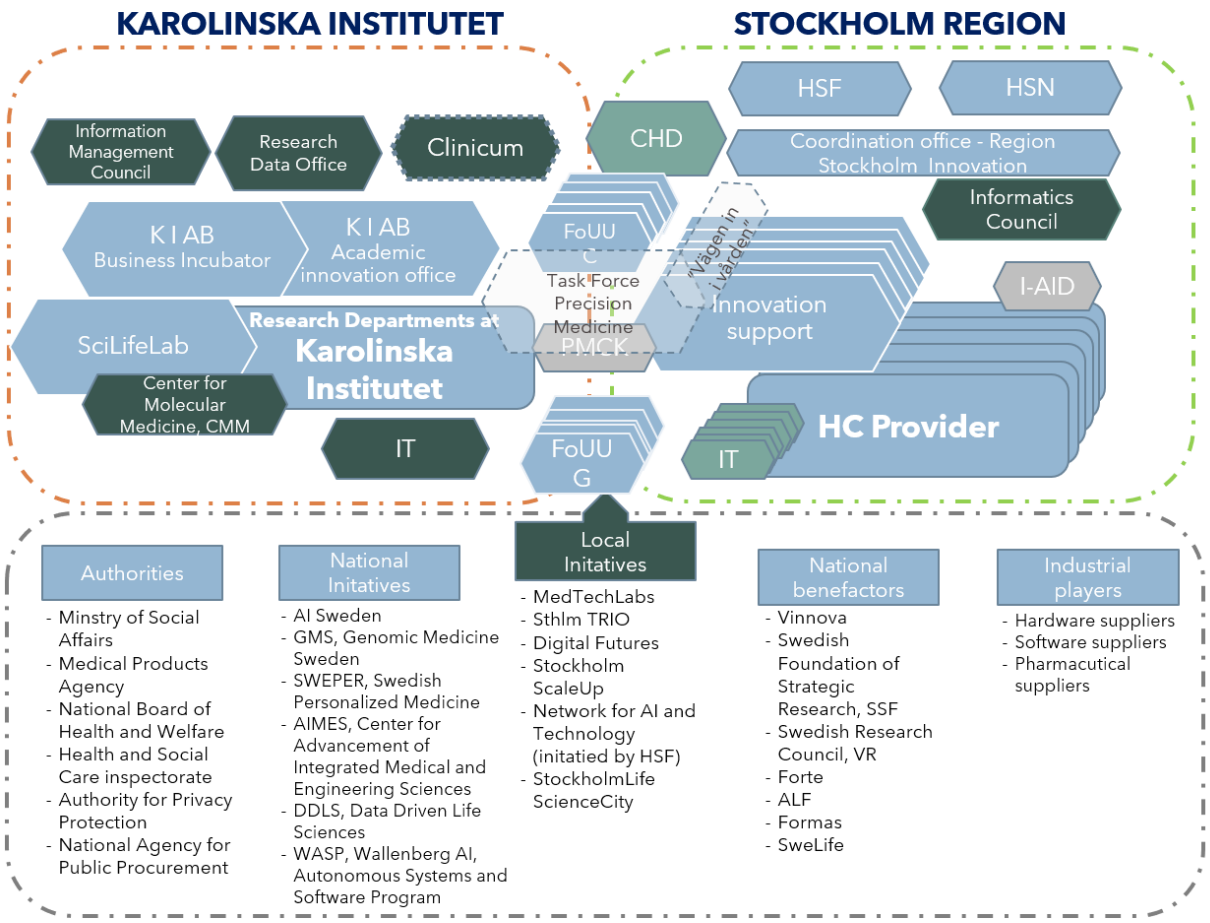


Figure 2C. *Graphical illustration that aims to highlight the current structures of the "innovation and implementation system" relevant to AI implementations in Stockholm*

From the study, it was clear that the current innovation structures are stronger in supporting the earlier phases and that there are challenges with handling complex implementation and commercialization processes for AI solutions. Currently, there is a high level of complexity in the system as a whole. There is a need to clarify who does what and when, in a "preferred path" towards clinical implementation of an AI solution. Even more important is to make sure that the "innovation to implementation system" is well-equipped for the task. This means to create platforms for dialogue and collaboration at appropriate levels and to secure the right competencies within the organizations. Additionally, the establishment of new partnerships and financial resources dedicated to the later implementation phases would be beneficial.

For instance, the current support and guidance provided to "organically grown" researchers and clinicians that all fight similar problems with legal, regulatory and IT problems, indicate that there is an opportunity for coordination, strategic alignment and naturally efficiency gains. By providing "top down" support and guidance another important prerequisite could be reinforced; trust.

Additionally, with regards to the structure, it needs to be noted that several of the initiatives highlighted as positive examples in which some of the above mentioned prerequisites actually are in place, like for example PMCK (Precisions medicinskt centrum Karolinska) are special solutions or project-based and thus risk to face major setbacks when making it permanent.

Lastly, as Cabitza 2020 suggests, the socio-technical elements are not be forgotten in creating prerequisites and a fundament for AI development but more importantly also for implementation.(10) Cabitza proposes that a focus is needed on the relatively neglected and underrated set of concerns regarding the quality of the data that is used to train and adjust the AI algorithms to fit the clinical real world.(10) This would require a full range of interventions, both organizational and technical and it is essential to cover the entire system, i.e. both academia and health care provider. These interventions, all referred to as "data hygiene", span from what data to record, standards, classification, data quality, data collection tools, data management and data governance requiring efforts in data governance practices and data awareness. This cannot be driven solely from an IT or Informatics perspective. In order to succeed in this transformation, it needs to be led by the profession themselves.

Limitations of the study and implications for further research

Due to the exploratory nature and qualitative empirical approach, some limitations of the study need to be taken into consideration. Firstly, given the complexity of the innovation system and the vast number of stakeholders, only some perspectives could be captured in this study. For example, valuable perspectives to include would have been the broader Regional perspective, specifically including the Innovation support units at hospitals and the Heads of Clinic. Moreover, industrial/commercial actors, policymakers and regulators as well as the political perspective (HSN) would have been valuable for more in-depth analysis.

This study only focuses on AI projects within the greater Stockholm region and the selection of study participants were affected by the geographical as well time limitations. Consequently, the results are based on the local innovation system in Stockholm and could not automatically be generalized to other regions or health care systems outside Sweden. Because of time restraints interviews were not fully transcribed, which could have an impact on the content analysis because of its lack of full transparency. Thus, as with all qualitative analysis, the risk of subjectivity of the author must be considered.

The exploration of barriers and facilitators in the implementation of AI in health care could help provide valuable insight and guidance on how to improve the future process. The findings highlight the importance of a broader approach, in parallel considering several aspects of the entire health care system in which it must be embedded. The study also adds to the growing information available on the NASSS Framework (34), by providing an example of how the framework supported both the creation of interview guides as well as the categorization of concepts into themes, barriers and facilitators. To perform a similar study of barriers and facilitators, but with a broader inclusion of AI projects, ranging from pure academic innovations (no combined positions) to industrial innovations would provide valuable insights for the future. Within some areas, such as radiology, AI-solutions have been integrated by the providers into already existing CE-marked equipment and implemented into clinical practice (64), which could serve as an interesting opportunity for an evaluation guided by the NASSS Framework (34).

During the study, the importance of the "data maturity" was highlighted as a key facilitator in the implementation of AI in health care. Thus, an assessment of the "data/AI maturity" of Karolinska Institutet as the one planned within the AI@KI project will provide very valuable insights into how to structure and organize for future implementations(19). For optimal effect, it would be beneficial to perform a similar assessment of the remaining key actors in the Stockholm area, as for example the Karolinska University Hospital.

To summarize, the field of implementation of AI in health care is unexplored but fundamental. It is only after implementation that the greatest values and benefits of the AI solutions can be realized. Thus, there is a great need for further empirical and theoretical analysis moving forward.

6. Conclusion

The numerous Artificial intelligence initiatives within the Stockholm region which are currently on-going emphasize the importance of gaining further knowledge of the implementation of AI in clinical practice. The aim of this study was to contribute to improving the process of clinical implementation of AI by identifying the key barriers and facilitators for an improved implementation process of AI projects.

It can be concluded that the implementation work of AI solutions in a clinical setting is complex and challenges the current structures for innovation and implementation. Essential prerequisites to facilitate an improved process from pilot to clinical practice are lacking or needs to be strengthened. Despite the complexity and the broad character of the research question in this study, a few humble proposals on how to improve the process from pilot to clinical implementation can be made.

First and most important is a joint, strategic direction and common ambition from both academia *and* health care to create the best possible prerequisites for an innovation process with increased emphasis on clinical implementation. This in turn requires a strengthened focus on:

- Strategic alignment and governance
- IT infrastructure for research *and* clinic
- Simplifying and clarifying the current complex system
    - a cohesive “preferred path” for clinical implementation
    - the roles of actors/structures in “the innovation system”
- Securing new competencies required
- Increased guidance and support to Heads of Clinic and Researchers
- Early industry involvement exploring new models of commercialization
- Facilitating a cultural shift towards interdisciplinary teamwork and “data maturity”

To conclude, several positive initiatives are already ongoing within the area of innovation and implementation and new forms of co-creation models are evolving. Moving forward it will be fundamental to strengthen some of the current structures of the system and create interactions for collaboration. At the same time, it will be crucial to avoid further complexity and to put the most important strategic collaborations into project format, as key structures and learnings will then be dissolved upon project finalization.

With a clarified and strengthened process and more formalized collaboration between academia and health care, there is a unique opportunity to take on an even stronger, leading position within Artificial Intelligence in health care. With a joint ambition to not only focus on proving the superior accuracy of AI, but more importantly demonstrating the value that AI can bring when actually used in clinical practice, Stockholm could become a showcase both nationally and internationally.

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Appendices

Appendix A. Interview guide Stakeholders

Total time estimation ~40 min. Note - used as guide only, conversation was tailored to each individual interview.

Researcher intro: (2 min)

- Name, Title, Role, Prior background
- Aim, objective, research questions and method of study
- Consent to record conversation? Check available time?

Participants intro questions: (3 min)

- Name, Title, Role, Organization
- Prior background

General view on AI (5 min)

- View on the potential of AI in health care?
- Within what areas in particular?
- What are the main priorities within this area?
- Experience from specific AI projects?

Domain 4: The adopter (10 min)

Implementation & Technology readiness

- Experience from implementation into clinical practice? To what degree - unit, department, hospital, region?
- What could have made the journey smoother?
- Does your organization work to facilitate this process in any way?
- How would you describe the capability to implement these solutions in general?
- Based on your experience - any learnings?

Disruption of current routines

- Does the technology itself disrupt/imply major changes in the health care delivery process (vårdkedjan)? (Work in a different way, admin, new competences etc)
- What would you consider to be the major barriers in the "adopter" perspective?

Domain 5: The organization (s) (5 min)

- From an organizational perspective, what would you consider to be the most important facilitators and barriers to smoothly being able to implement a project like this into a clinic?
- Are any of these barriers being addressed today by your organization?

Domain 6: The external context for innovation/ The wider institutional and social context (5 min)

- How would you describe the key stakeholders in this relatively complex ecosystem? / What external stakeholders/Groups/Organizations would you say you depend the most on?
- Could this relationship be further utilized/enriched?
- Are there currently informal collaborations or knowledge exchanges to facilitate the process? Which ones? Could you foresee others that could be beneficial?

Closing up (5 min)

- To summarize, what would you say were the main facilitators going from project to clinic? Barriers?
- Would you consider any of these "AI specific"?
- How would you like to address these challenges in the future? What is your wish list for the future?
- Given the aim of the study – would you like to add anything that you feel is valuable for me to consider moving forward?

Appendix B. Interview guide Project/Case interviews

Total time estimation; ~45 min. Note - used as guide only, conversation was tailored to each individual interview.

Researcher intro: (2 min)

- Name, Title, Role, Prior background
- Aim, objective, research questions and method of study
- Consent to record conversation? Check available time?

Participatant intro questions: (3 min)

- Name, Title, Role
- Time involved in AI project, Role
- Prior background

Domain 1: The condition/illness (5 min)

- Does the technology offer a solution to a well-known problem? Patient or Health care perspective? Elaborate on the future potential?
- Who is the target group to use/adopt the technology?
- Do you see other applications for this technology? Any interest for this?

Domain 2: Technology (5 min)

- Could you briefly describe the solution? Would you say it is unique?
- Is the technology CE-marked? Other regulatory requirements?
- How did you acquire the data? Did you have to define your own process for gathering the data, e.g. setting up a pipeline?
- (Would you say that the solution is difficult to define and explain? What is the "vague element"?)
- (What are the key priorities in the development of the technical solution moving forward? (performance or dependability concerns, supply chain etc))

Domain 4: The adopter (10 min)

Level of implementation:

- In what stage would you estimate the solution is right now?
- Is the solution applied now in a clinical setting? To what degree - unit, department, hospital, region?
- How long did this process take?
- What is the "next step"?

Learnings

- Looking back at the process of taking the solution from demonstration project to be used in clinical practice, could you/the project have done anything different that would have made the journey smoother?

Technology readiness:

- How would you describe the clinic capacity to implement your solution? (Innovationsdrivna?) Are they "ready" for this implementation?
- What is the current level of digital maturity?

Usability:

- If it the solutions has been tested – what were the reactions? Any learnings?
- What challenges do you foresee/have experienced utilizing the solution in clinical practice?

Disruption of current routines

- Does the technology itself disrupt/imply major changes in the health care delivery process (vårdkedjan)? (Work in a different way, admin, new competences etc)

Domain 3: The Value Proposition (10 min)

Funding

- Looking back at earlier phases, how did you perceive the process to get "funding" and other support to develop the solution?
- Collaborations outside organisation; Vinnova, KI Innovation, "näringsliv"/private companies?
- Have you considered setting up a Business around the solution?

Business case & Validation

- Is there a "commercial value" of the solution? For whom will it be most valuable?
- Has a "business case" been developed?
- And/or Has the cost/ benefit analysis or Health Economic cases been done?
- (Is there an initial investment in resources (time/money) or change routines /pathways before the benefit of the solution could be harvested?)
- How was the solution validated (internally only or also externally, e.g. RCT)?
- What is your thinking moving forward around validity (valideringsarbetet)?

Domain 5: The organization (s) (5 min)

Innovation climate

- Is there a vision and goal around innovation within your organization/organizations? Is there a difference between the two?
- Looking back, would you say this development had been possible without a true "Eldsjäl"/Local champion?
- From an organizational perspective, what would you consider to be the most important facilitators and barriers to smoothly being able to implement a project like this into clinic?
- Are any of these barriers being addressed today by your organization?

Closing up (5 min)

Learnings and summary

- To summarize, what would you say were the main facilitators going from project to clinic? Barriers?
- Would you consider any of these "AI specific"?
- How would you like to address these challenges in the future?
- What is your wish list for the future?
- Given the aim of the study – would you like to add anything that you feel is valuable for me to consider moving forward?

Appendix C. Study participants per stakeholder group

Stakeholder	Name	Organization 1	Title 1	Organization 2	Title 2	Organization 3	Title 3	Meeting details
AI project case	Forsberg, David	Paediatric Research Unit Department of Women's and Children's Health, Karolinska Institutet	PhD, Member of the DeepNEWS research group	The paediatric department; including NeoIVA, Karolinska University Hospital	MD			Zoom-meeting, 23/3 - 2021
	Gordon, Max	Founder and CEO of DeepMed AB	Research Leader AI, Karolinska Institute	Chief Physician	Orthopaedic unit Danderyd Sjukhus			Face-to-face meeting, 18/3 - 2021
	Janerot Sjöberg, Birgitta	Funktion och Teknik, CLINTEC, Karolinska Institutet	Scientific Director, Professor	Bild och Funktion, Karolinska University Hospital	Senior Physician, Head of FoUU			Zoom-meeting, 31/3 - 2021
	Wedin, Rikard	Co-developer of PATHFx, Chief Executive Officer	Prognostix AB	Orthopaedic surgeon	Karolinska University Hospital	Karolinska Institute	Associate Professor	Zoom-meeting, 17/3 - 2021
Academic innovation office	Kallas, Åsa	KI Innovations AB	Project Manager /Business Coach					Zoom-meeting, 24/3 - 2021
Health Care Provider	Georgii-Hemming, Patrik	Karolinska University Hospital	Chief Medical Information Officer	Karolinska Institutet				Zoom meeting, 20/4 - 2021
	Lindsköld, Lars	SweLife	Portfolio Manager, SWEPER	eHealth Unit, Department of Healthcare digitalization , Region Västra Götaland	Regional developer	Dept. of Applied IT, Division of Informatics, University of Gothenburg	Adjunct lecturer	Zoom-meeting, 17/3 - 2021
	Lingman, Markus	Region Halland Hospital Group Sweden	Chief Strategy Officer	Region Halland Hospital Group Sweden	Senior Physician, PhD	Leap for Life, Region Halland	Steering Group Member	Zoom-meetings, 4/3 - 2021; 19/4 - 2021
	Skyttberg, Niclas	Chief Medical Officer	Aleris Health care provider	Karolinska University Hospital	Former Chief Medical Information Officer	Karolinska Institutet	PhD, Health Informatics	Face-to-face meeting, 31/3 -2021
Karolinska Institutet	Höög, Jan-Olov	Karolinska Institutet, Department of Medical Biochemistry and Biophysics	Professor	EIT Health, European Institute for Innovation & Technology	Member of Supervisory Board			Face-to-face meeting, 4/4 - 2021
	Sundberg, Carl-Johan	Coordinator Science & Society at the President's office, Karolinska Institutet	MD, PhD, Professor	Dpt of Learning, Informatics, Management & Ethics (LIME), Karolinska Institutet	Chair	Dep. of Physiology and Pharmacology, Karolinska Institutet	Group leader	Zoom-meeting, 12/4-2021
SciLifeLab	Wirta, Valtteri	Head of Unit, Clinical Genomics Facility, SciLifeLab / Karolinska Institute	Facility director	Genomic Medicine Center Karolinska, Karolinska university hospital, SciLifeLab	Head of unit	Genomic Medicine Sweden and Genomisk medicincentrum Karolinska	Co-chair Informatics	Zoom-meeting, 8/4 - 2021
The Health and medical care administration, HSF	Laporte Castro, Ruth	The Health and medical care administration, Region Stockholm	Coordinator Digitalization and Strategic Planning					Zoom-meeting, 30/4 - 2021
	Ulvstedt-Stadius, Katja	The Health and medical care administration, Region Stockholm	Senior Project Manager		Author of "Långtidsutredningen 2040" Perspective report Development of care and Digitalization			Zoom-meeting, 30/4 - 2021

Appendix D. E-mail templates used in communication with study participants

Template, e-mail 1

Subject: ***Contact regarding Barriers and Facilitators of AI in Health care***

Hi XXXX,

My name is Sophie Lerenius and I am currently writing my Master Thesis at Karolinska Institutet within the Health Informatics Master Programme within the context of the AI @ KI work (https://ki.se/en/lime/artificial-intelligence-at-karolinska-institutet).

My focus is on the challenges of implementing AI in Swedish healthcare. The title is "From pilot to clinical practice: Barriers and facilitators to the implementation of artificial intelligence in healthcare - A multiple case study of Swedish AI projects".

Given the exciting journey you have made with XXXX, it would be very interesting to have XXX as a "case" in the study. / Given you extensive experience within this field, I therefore wonder if it would be possible to book a conversation with you (about 45 min) either via a link or in person?

I would be extremely grateful if you could come back with times that would suit you, for example X, X, X or X March?

Kind regards

Sophie

Template, e-mail 2

Subject*: Before the interview "Barriers and facilitators to the implementation of artificial intelligence in healthcare"*

Hi XXXX,

I am very much looking forward to our meeting tomorrow XX at XXX via Zoom/Personal! Here is the link to the meeting: xxxxxx.

During our conversation, I will focus the discussion on which main enablers and which barriers you see in the process from going from pilot projects to getting the solution used in everyday, clinical work. Preferably specific experiences from projects or more general reflections. What potential solutions do you see that could facilitate the process in the future?

Practical questions to think about, that I will follow up when we talk;
• In order to be able to make the best use of the information during our conversation, I would like to record an audio file that I save locally on my computer and then delete when I finish my work by the summer of 2021. *Do I have your consent for this?*
• In my report, I would like to inform the reader which are the cases I have used and which people have been interviewed as a basis for my conclusions. *Do I have your consent for this?*
• Is there a request from you to review the information / text before completion?

Sincerely

Sophie

Template, e-mail 3

Subject*: Thank you for your participation*

Hi XXX,

Hope all is well with you!

I would like to once again express my gratitude that I had the opportunity to interview You in connection with my Master Thesis work "From pilot to clinical practice: Barriers and facilitators in the implementation of artificial intelligence in health care". It has been a very exciting and rewarding work that is now in the final phase. I will give feedback via email as soon as I have a final version of the work.

To be able to complete the work, *I need your help in giving approval for the use of quotes and control of title and workplace.* Therefore, you will find attached a preliminary version of abstracts (to give a context), your name, title and workplace (it is possible to enter more) and the quotes I used from our conversation (under the barrier / enabler where I have including the citation).
I would like to ask you to answer the questions below. If possible, I would appreciate feedback on the above two points before Thursday, June 4th. Thanks!

• *Is the quote correct and do I have your consent to use the quote? Would it also be ok to include your name under the quote?*
• *In addition, I want to check that I have understood your title / titles correctly. See the last page of the attached document.*

Sincerely

Sophie

Template, e-mail 4

Subject: ***Happy summer!***

Hi XXX,

Thanks again for your participation in my Master Thesis "From pilot to clinical practice: Barriers and facilitators in the implementation of artificial intelligence in health care". Attached, you will find the essay in its entirety and a small "executive summary" - hopefully something to skim through in the hammock this summer?

As I said, if there is interest, I am happy to present the results before the holiday or later this autumn!

Sincerely

Sophie