Designing a new software system for the NHS: Applying Action Design Research work in an Institutional Setting.

by

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A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Business Administration

Warwick Business School

University of Warwick

September 2021

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List of Abbreviation

4IR	Fourth Industrial Revolution
ADR	Action Design Research
AHSN	Academic Health Science Network
AI	Artificial Intelligence
AKI	Acute Kidney Injury
AR	Action Research
AWS	Amazon Web Services
BIE	Building, Intervention, Evaluation
C21	Anonymised name for company involved in Main Case Study
CDR	Clinical Data Repository
CDS	Clinical Decision Support
CIO	Chief Information Officer
CPOE	Computerized Practitioner Order Entry
CSSM	Cyber Security Support Model
CT	Computerised Tomography
CVE	Cyber Vulnerability and Exposure
DBA	Doctor of Business Administration
DR	Design Research
DSR	Design Science Research
ECG	Electro-cardiogram
ED	Emergency Department
EDR	Endpoint Detection and Response
EMAR	Electronic Medication Administration Record
EMR	Electronic Medical Record
EPR	Electronic Patient Record
ERP	Enterprise Resource Planning systems
FDA	Food and Drugs Administration
FYFV	Five Year Forward View
GP	General Practitioner
ICS	Integrated Care System
IE10	Internet Explorer 10
IM	Instant Messaging

IMOT	Internet of Medical Things
IS	Information Systems
ISD	Information Systems Design
IT	Information Technology
HIMSS	Health Information and Management Systems Society
LSPs	Local Service Providers
ML	Machine Learning
MRI	Magnetic Resonance Imaging
MVP	Minimal Viable Product
NASPs	National Application Service Providers
NCSC	National Cyber Security Centre
NICE	National Institute for Health and Care Excellence
NICCS	National Initiative for Cybersecurity Careers and Studies
NHS	National Health Service
NPfIT	National Programme for IT
OBS	Output Based Specification
OEM	Original Electronic Manufacturer
OGC	Office Government Commerce
PAC	Public Accounts Committee
PACS	Picture Archiving and Communication Systems
PC	Personal Computer
PCN	Primary Care Network
PFI	Private Finance Initiative
SME	Small, Medium sized Enterprise
SOAR	Security Orchestration, Automation and Response
TS	Anonymised name for company involved in Pilot Case Study
VMS	Vulnerability Management System

Acknowledgements

The process to produce this document would not have been possible without the support and guidance from my academic supervisor Professor Eivor Oborn. Her insight, encouragement and advice on the framing, language, and lens to use for the research helped to complete the educational stages but also the completion of the product.

A DBA journey covers over four years of work, and in that time, there have been many supporters and helpers. Firstly, the team working on the project as designers, developers, managers, and the NHS contributors who gave their time and insights. This project set out to help the NHS be better protected from cyber threats, and I hope we are making a difference on the front line.

I would also like to thank my cohort; the journey would have been very lonely without the encouragement and support even when COVID stopped us from meeting face to face. The WBS professors who opened new ideas and concepts, and Professor Christian Stadler, whose enthusiasm for the DBA and welcome at the outset kept me going when the process was getting challenging.

Finally, I would like to thank my wife Karen for having the patient whilst I selfishly worked on this thesis and Ruth and Nicola for their encouragement to keep going.

I dedicate this thesis to Karen.

Declaration of Originality

I declare that this thesis ‘Designing a new software system for the NHS: Applying Action Design Research work in an Institutional Setting?’ is my own work, and no part of the dissertation has been previously submitted to any other university for any degree, diploma, or other qualification. Previously submitted work by the author in the form of reviews and conference presentations is drawn on for parts of this thesis. When reference is made to the work of others, the extent to which it has been used is indicated in the text and bibliography. Any errors or omissions within this thesis are the sole responsibility of the author.

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Signature:

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Name of Supervisors: Professor Eivor Oborn

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Research Question

‘How can a new software system be successfully designed for the NHS? How can the Action Design Research method be applied in a complex setting where institutional behaviour has a significant impact?’

DESIGNING A NEW INFORMATION SYSTEM FOR HEALTHCARE IN THE 4IR

Abstract

At the juncture of new technologies becoming available with the Fourth Industrial Revolution. Global healthcare need for new technologies to support improvements in efficiency and effectiveness. Combined with the historical failures of healthcare to adopt new technologies, a different approach is required.

This thesis explores how a new Information System (IS) artefact could be designed using Action Design Research (ADR) within a complex organisation – the NHS. The qualitative case study follows the design and implementation of a new IS artefact to address the threat poised from cyber-attacks on unpatched IT systems that are vulnerable. This is a field inspired problem following the WannaCry attack on the NHS in 2017. The research uses the lens of Institutional Theory to help frame the findings for how complex organisations react to new artefacts and what can be learnt from the process for designers of new artefacts.

The findings from the study show how ADR can support the design of a new artefact even as the environment in which it is being developed changes. I identified three areas where ADR could be improved, including focusing on stakeholder and competitor analysis at the problem initiation stage. There was also an additional step for imagining the use of the artefact in its environment and any impact this would have on the design to achieve the original design objective established.

The outcome from the project was an artefact successfully deployed and in use, supporting 27,000 NHS staff and recommendations on areas to enhance the ADR methodology.

1. Introduction

This chapter presents the background, aims and objectives of this research. It provides an initial overview of the drivers for the research and the environment in which the research project was set. It also outlines the structure of the thesis.

1.1. Research Background

1.1.1. The New Technology Paradigm

Digital technologies are transforming every aspect of our lives. What was seen as science fiction a generation ago is now becoming a reality in new products and services fundamental to the way we live today (Schwab, 2017). The onset of the Fourth Industrial Revolution (4IR) and its embedded diffusion of technology are expected to exponentially grow the impact of technical and socio-economic change (Morrar, et al., 2017). The 4IR is seen as a differentiator from the previous technology systems and uses due to the integration and interoperability between hardware, software, robotics, biology, and humans (Schwab, 2017). The impact of these capabilities is only just being realised. Maynard (2015) forecast the effect would be from

> *'Eliminating disease, protecting the environment, and providing plentiful energy, food and water, to reducing inequity and empowering individuals and communities'*

(Maynard, 2015, p. 1005)

The 4IR is, in the same way, the Second Industrial Revolution built upon the First Industrial Revolution, innovating upon the digital foundation of the Third Industrial Revolution. Philbeck and Davis (2019) described this as an "epi-digital" revolution. Their paper identified four fundamental principles to consider when investigating changes driven by the 4IR.

Firstly, focus on the system and not the technology. For instance, AI and machine learning are the current key terms used, but these may change as new developments are made. The discussion should not be on the technologies but on how they fit within a broader landscape. The requirement here is an understanding of the complex local issues and the broader social and political impact.

Secondly, focus on how the new ideas and concepts empower the users rather than direct them. The third area is to collaborate on the design by default. Finally, the fourth principle was to include values and ethics as a critical part of the design and not treat the technology as a pure tool.

The literature is clear that we are at the early stages of the 4IR, and the actual capabilities provided by the new technologies are still being identified. The 4IR tools and abilities will have a dramatic impact on our society, economy, and industry. The challenge will be to design the new technologies to benefit the stakeholders in the broadest sense and not just for technologies sake.

This project was established to investigate how a new Information Systems (IS) artefact could be designed using tools from the 4IR and understand if the process was different to other IS developments in previous digital technology developments, i.e., the Third Industrial Revolution and digital adoption. This is an extensive scope, and in the following few chapters, I will narrow the project’s focus to an environmental setting, healthcare, and specifically the NHS. Also, from a technology perspective, the focus was the area of cyber security.

1.1.2. The Healthcare Delivery Challenge

Within the healthcare sector, there are global challenges, including escalating healthcare costs, increased need for healthcare coverage, and the question of who pays for the service (World Health Organisation, 2017, George, et al., 2017). These are seen as drivers for adopting and using new digital technologies in healthcare. They enable efficiency and quality improvements that have already been seen in other industries (Zillner & Neururer, 2016). Work has already begun in seeking to define the objectives for healthcare that technology will need to support with Don Berwick setting out his "Triple Aim": improving the individual experience of care; improving the health of populations; and reducing the per capita costs of care for populations (Berwick, et al., 2008). These aims or objectives underpin the USA approach to health improvements for the last decade. More recently, a fourth aim of improving the work-life of health care providers, including clinicians and staff, was suggested by Bodenheimer and Sinsky, (2014)**.** This additional aim recognised the impact of change on the system users as well as the system itself.

As the National Health Service (NHS) celebrated its 70th anniversary in 2018, the Topol Review (2018) called out how digital technologies, robotics, and artificial intelligence will have an enormous impact on patients and the workforce over the next two decades even if it is difficult to predict the future.

Different reports claim the inefficiency in healthcare delivery in the USA alone could be measured in the $trillions and is the most significant sector opportunity for improvement compared to other industries (Zillner & Neururer, 2016). Healthcare does, however, have a poor record of realising the benefits of new technologies and services. Berwick and Hackbarth estimated that over U.S.$100billion was wasted as the best practices hadn't been adopted (2012).

1.1.3. Healthcare and Technology

The need for healthcare to invest in and adopt new technologies has been made. Over the last two decades, healthcare has undertaken large-scale technology implementation programmes. The UK through the National Programme for IT (NPfIT) and the USA through the

Hightech Act. However, there is clear evidence that these previous investments in technology, precisely IT in healthcare, has not only failed to deliver but, in many instances, caused harm (Wachter, 2015).

IS technology doesn’t have a good track record of successful delivery in healthcare. The latest technology investments are starting to impact health and social care, but Darzi Field (2018) claims we will need a more radical ‘tilt toward tech’ to deliver the fundamental change. The NHS Long Term Plan shows a clear need for healthcare technology adoption and expansion (Department of Health and Social Care, 2019), but this comes with the challenge of ensuring the technology is fit for purpose and used by the relevant staff.

1.1.4. The Focus of the Project

This project is set at the juncture of two interconnected phenomena: An exponentially increasing technology capability in the 4IR and health industry with a clear need for the technology. This research project's challenge and context sought to address the historical problems of designing and deploying new technology, specifically IS, into healthcare settings. At the same time, understanding the impact on IS design using the new capabilities from the 4IR. For this thesis, the scope and scale of the macro problem couldn’t be addressed as a case study action-orientated project. Instead, I have identified a subset of IS technology, cyber security, as the focused project area. I examine how to design a new artefact focused on the digital capabilities of machine automation in healthcare organisations. Within cyber security, vulnerability management was identified as a real-world problem for the NHS with significant impact, as the WannaCry attack demonstrated. This research project will investigate the specific area where these three elements overlap, as shown in Figure 1 below.

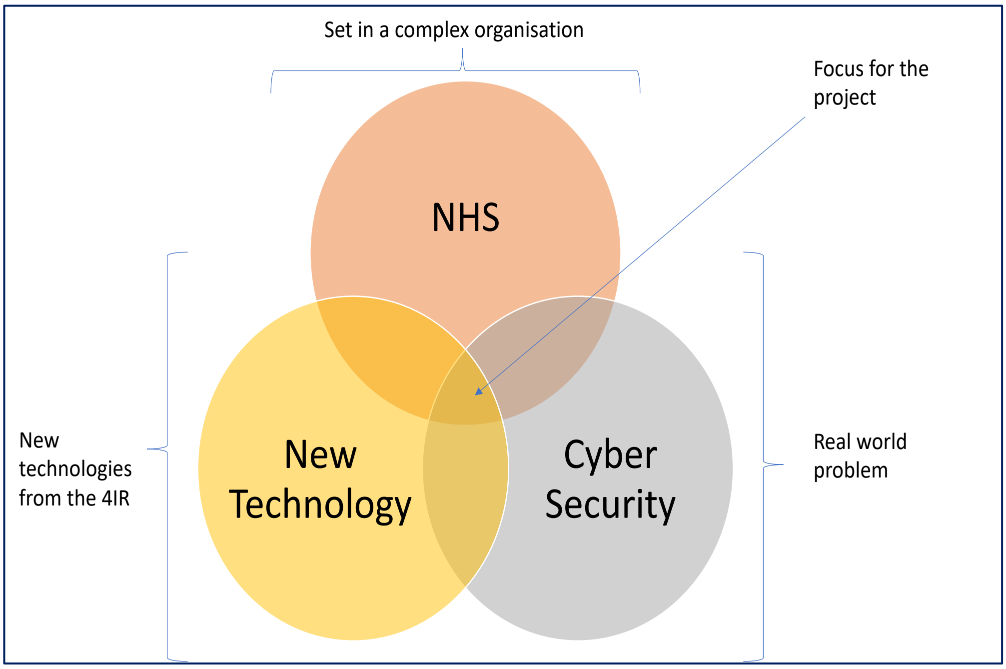


Figure 1 Focus Area for the Project.

Through this focused approach, I set out to develop a new artefact that would have a real-world impact on the NHS. The project would also consider the design approach for new IS artefacts based on the capabilities from the 4IR, such as machine learning and AI.

1.1.5. Healthcare as an Institution

One research lens that provides insight into the complexity of adopting new technologies into healthcare organisations and systems is Institutional Theory. Healthcare and Institutional Theory has been used to explain the resistance to change in healthcare and pinpoints 'the taken for granted rules' governing how healthcare organisations operate (Scott, 2001). Healthcare has undergone fundamental shifts in its new rules, new accountability systems, governance, and delivery models. In particular, the NHS in the UK has progressed from its original clinically lead autonomy from the 1940s through to the early 70s before managerialism. Then market dominance replaced these belief systems (Currie & Guah, 2007).

When the National Programme for IT failed, Currie drew on an Institutional Theory framework to investigate what went wrong. Institutional Theory provides a set of concepts that can investigate, analyse, and understand the macro and micro level environmental changes (Currie, 2012). Her key findings indicated that the technology being designed and implemented wasn't adopted and normalised by the key stakeholders and users in the institution because of the inter-organisational complexity that was interwoven within the NHS (Currie, 2010). Currie found the current habits of the institutional actors may block the innovation, and the taken for granted rules and beliefs, coupled with the complexity between the multiple organisations involved in the sector, rendered the relationships irrational and difficult to govern.

As such, mistrust and disjointed decision making made integration of the planned IT almost impossible to achieve. Integration of technology within a more comprehensive IT infrastructure is critical for its success (Oborn, et al., 2020). If a new solution takes a too narrow view on just the technology, there is a considerable risk it won't win the hearts and minds of the users and stakeholders, and it will fail (Constantinides & Barrett, 2006).

Using the Institutional Theory framework as a lens on which to investigate this project provides an opportunity to utilise the findings from Currie's and others earlier work to shape the current operating beliefs and norms in the NHS today as it engages with the 4IR.

1.1.6. Cyber Risks and the NHS

The 4IR, with its emerging landscape of rapidly developing technology, offers significant potential to solve challenges in the 21st century. However, it is also driving a steep change in cyber security risks as more global digital networks provide access to many operations and connected systems. The risks of cyber 'insecurity' increase by orders of magnitude as the processes move from traditionally securable environments (Maynard, 2015).

In 2017 the NHS and many other organisations suffered a significant cyber-attack, referred to as the WannaCry ransomware attack. This particular cyber-attack locked out computers and impacted 48 NHS trusts resulting in operations and outpatient services being cancelled (Ehrenfeld, 2017) with an estimated financial impact of £92m to the NHS for lost activity and also the recovery work (Department of Health and Social Care, 2018).

The company I manage provide IT and consultancy services to the NHS. My team provided support to the NHS to deal with the ransomware attack. During a post-event review, we identified a need for a new cyber vulnerability IS artefact that could have stopped the WannaCry attack from ever happening. This opportunity to solve a real-world problem was the basis for this research project.

1.2. The Research Question

Set against the backdrop of failed IT projects within healthcare (Wachter, 2015, Currie, 2014). The scope and scale of addressing the broad set of IS challenges outlined above and how new technology can be designed and implemented successfully in healthcare were too broad in scope for an action-orientated case study research project. The DBA seeks a practical, real-world impact building on existing theoretical work. Hence this project focuses more narrowly on how to design IS successfully for cyber security.

I have identified a specific IS problem that has adversely affected the NHS and sought to find a solution for this problem using tools from the 4IR. The project was to research, design and build a new IS artefact for the NHS using Action Design Research (ADR) methodology. The project used tools from the 4IR and would also investigate the generalisability of the project’s outcome for the design basis for other

IS products in the future. In doing so, I draw on a recent academic design method ADR (Sein, et al., 2011) as the model and methodological framework adopted. I also informed this research process with an overarching lens of Institutional Theory.

The research question was iteratively developed as:

> ‘How can a new software system be successfully designed for the NHS? How can the Action Design Research method be applied in a complex setting where institutional behaviour has a significant impact?’

This project was initiated to investigate the challenge of designing and deploying a new IS into the NHS, one of the largest organisations in the UK and arguably globally. As an organisation, the NHS displays institutional behaviour where the constant change of power base, roles, legitimisation, and politicisation are taken for granted (Currie, 2012). The NHS and healthcare organisations generally have a poor track record of adopting new information systems, technology, and the associated benefits from these investments (Wachter, 2015). Given the financial and service demand pressures on healthcare, the use of new technology is seen as one of the solutions that must be utilised (HM Government, 2017) to address these pressures. The outcome of this project aimed at helping to minimise the risk of failure and maximise the return on investment in new technologies used in the NHS. As such, the contribution of this research is to develop a robust method for designing IS artefacts in complex healthcare organisations and develop such an artefact for the specific cyber vulnerability problem identified.

1.3. Research Gap

The dichotomy between the advances made through the 4IR capabilities and the poor historical success of new IS technologies in healthcare must be closed. This project wasn’t seeking to add conceptually to Institutional Theory. Instead, the project focused on deploying the Action Design Research methodology (Sein, et al., 2011), an approach within the design science area to design and develop a new artefact. The research investigated the effectiveness of this approach in developing a new IS artefact within the environment of the NHS as a complex organisation. The project also assessed what other factors needed to be considered when designing new IS products with tools from the 4IR, such as machine learning.

The aim from a research perspective was to consider any additional steps, processes, or tasks that would enhance the use of ADR when designing new IS artefacts for complex organisations using tools from the 4IR.

1.4. Methodological Approach

This project adopted a case study approach observing the design, build and implementation of a new cyber vulnerability product (IS artefact) for the NHS drawing loosely on the framework of Institutional Theory to inform its analysis of being attentive to the 'taken for granted' rules that govern action within an NHS hospital. The project investigated how, using ADR, to design, build, test, and implement a new IS artefact for the NHS and what lessons could be learnt.

ADR was developed by Sein et al. (2011) to combine the researcher / practitioner involvement of an Action Research method using a Design Thinking academic approach. This combination worked well with me as both researcher and leading the team of practitioners working on the project. The final aspect of ADR is the requirement for the IS end-user's early engagement and continuous involvement. This last part addresses the critical elements of the 4IR, with the users being central and fully involved in the design process.

The research utilised a case study approach over three years working with C21, an IT technology and consulting company I founded and four NHS partner organisations.

1.5. Project Objectives

The project worked with four NHS organisations in a close collaborative model as required by ADR. As ADR is based upon an action-orientated method, I was both a researcher and a team member on the project. Over the course of three years, I observed, engaged, and oversaw the development of the new system from concept through to implementation in the NHS and was thus able to develop novel insight into the overall design process.

The project had a set of specific objectives, as shown in Table 1 below.

Objective	Description	How measured
1	Design, build, test, and implement a new system that would stop another WannaCry type cyber vulnerability attack	The new IS artefact is successfully deployed to the NHS
2	Observe and consider how the impact of designing new IS artefacts can be understood within a complex organisation using Institutional Theory as a lens on the project	Additional steps to be taken when working with complex organisations
3	Identify any additional steps that could be utilised with ADR when working	New areas / tasks or steps identified that would add value to the ADR

Objective	Description	How measured
	with complex organisations such as the NHS	method when used in a complex organisation
4	Generalisability of the findings	Will the outcomes from this project be useful to other IS challenges in the NHS or other complex organisations? What can be learnt about designing new IS products with tools from the 4IR.

Table 1 Research Project Objectives.

These objectives are reviewed in Chapter 5. Overall, the project was successful with a new IS artefact successfully delivered and is currently the only automated system for matching NHS issued CareCERTs to network scanned results and is in use by six NHS organisations supporting over 27,000 staff. This demonstrated an impactful contribution to practice, and the additional theoretical tasks and learnings discovered shows a theoretical impact.

1.6. Key Terms and Definition

Several technical terms and jargon are used throughout this thesis; a list of key terms and definitions is outlined in Table 2 below to aid the reader.

Algorithm	A series of instructions for performing a calculation or solving a problem, especially with a computer. They form the basis for everything a computer can do and are

	therefore a fundamental aspect of all AI systems.
Artificial intelligence	An umbrella term for the science of making machines smart.
Bayes' theorem	A theory that specifies how to handle uncertainty by updating the probability for a particular event, phenomenon, or hypothesis in response to data.
Bias (sampling)	Selection of data or samples in a way that does not represent the true parameters (or distribution) of the population. Bias in training data leads to bias in algorithms: machine learning is a data driven technology and the characteristics of the data are reflected in the properties of the algorithms.
Big data	Large and heterogeneous forms of data that have been collected without strict experimental design. Big data is becoming more common due to the proliferation of digital storage, the greater ease of acquisition of data (e.g., through mobile phones) and the higher degree of interconnection between our devices (i.e., the internet).
CareCERT	An alert issued with details of systems that have a known cyber vulnerability or exposure issued by NHS Digital to NHS organisations.
Chatbot	A chatbot (also known as a talkbots, chatterbot, Bot,

	IM bot, interactive agent, or Artificial Conversational Entity) is a computer program which conducts a conversation via auditory or textual methods.
Convolutional neural networks	Artificial neuro networks which have been inspired by the organisation of the animal visual cortex.
Data	Numbers, characters, or images that designate an attribute of a phenomenon
Deep learning	A machine learning method which composes details together to obtain more abstract, higher level, features of the data through composition of mathematical functions. Powerful modern deep learning algorithms often involve many levels.
Expert System	A computer system that mimics the decision-making ability of a human expert by following pre-programmed rules, such as 'if this occurs, then do that'. These systems fuelled much of the earlier excitement surrounding AI in the 1980s, but have since become less fashionable, particularly with the rise of neural networks.
Feed forward neural networks	A common artificial neural network where information moves in only one direction, forward, from the input layer, through hidden layers, to the output layer.

Gaussian	A probability density which adopts a ‘bell curve’ shape (and its generalisation to higher dimensions). It is widely deployed due to computational advantages and the tendency of independent data corruptions, when added, to be distributed according to this density.
Generative adversarial networks	Usually, 2 neural networks contesting each other in a zero-sum game framework.
Governance	The institutional configuration of legal, ethical, professional, and behavioural norms of conduct, conventions, and practices that, taken together, govern the collection, storage, use and transfer of data and the institutional mechanisms by and through which those norms are established and enforced.
Intelligent Agent	Any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals
Machine intelligence	A general term for machines that have been programmed to be smart, or otherwise artificially intelligent.
Machine learning	One form of AI, which gives computers the ability to learn from and improve with experience, without being explicitly programmed. When provided with sufficient data, a machine learning algorithm can learn to make predictions or solve problems, such

	as identifying objects in pictures or winning at games, for example.
Metadata	'Data about data', contains information about a dataset. For example, this information could include why and how the original data was generated, who created it and when. It may also be technical, describing the original data's structure, licensing terms, and the standards to which it conforms.
Model	A mathematical description of a system.
Neural network	Also known as an artificial neural network, this is a type of machine learning loosely inspired by the structure of the human brain. A neural network is composed of simple processing nodes, or 'artificial neurons', which are connected to one another in layers. Each node will receive data from several nodes 'above' it and give data to several nodes 'below' it. Nodes attach a 'weight' to the data they receive and attribute a value to that data. If the data does not pass a certain threshold, it is not passed on to another node. The weights and thresholds of the nodes are adjusted when the algorithm is trained until similar data input results in consistent outputs.
Petabyte	1,000 terabytes or 1015 bytes of information.
Programme	A set of instructions given to a computer to allow it to carry out a task.

Recurrent neural networks (RNNs)	A type of artificial neural network whose connections between neurons includes loops.
Reinforcement learning	An approach to machine learning in which an agent learns to interact with its environment, receiving inputs, and making sequential decisions to maximise future rewards. An important feature in this context is that it is often only after the agent makes several decisions that it learns of the payoff resulting from the set of choices. One challenge in reinforcement is thus to work out which of the decisions were “good” and which less so.
Sensitive (data)	Sensitivity has strict definitions under the Data Protection Act, but for the purposes of this report it refers to data or information that an individual would not wish to be widely and openly known or accessible.
Supervised learning	An approach to machine learning which relies on training data that has been labelled, often by a human. A label could be a categorisation into one or more groups: this is known as classification.
Test data	Data that is used to test the functioning of a machine learning system or verify its outputs.
Training data	Data that can be used to train machine learning systems, having already been labelled or categorised into one or more groups.

Unsupervised learning	An approach to machine learning that uses data which has not been labelled. Commonly it will seek to determine characteristics that make the data points more or less similar to each other and will attempt to represent the data in a summary form, such as through clusters or common features.

Table 2 Key Terms and Definitions.

1.7. Structure of the Thesis

This thesis is presented in separate chapters with a summary of each chapter, and its intention is given below in Table 3. As a DBA thesis, my objective wasn't to add conceptually to Institutional Theory. The research was to develop a new practical solution for a real-world problem generated by and using tools from the 4IR that would make an impact. In so doing, I aim to add further insight to the ADR methodology when deployed into complex organisations.

The project follows these stages:

Chapter	Overview
1: Introduction	The introduction chapter sets out the background and context for the project. It identifies the broad opportunities that the 4IR is providing. These are then set within the context of healthcare's needs for new technology to support service delivery and demand. Finally, contrasting the need in healthcare with the poor track record of adoption. This is the research gap that the project investigates; how to design a new IS

Chapter	Overview
	artefact for healthcare within the context of the 4IR. The scope at the macro level is broad, and so the project will focus on addressing a specific real-world problem of cyber security risks in the NHS.
2: Background and Context for the Problem	The research is positioned against the dichotomous position of revolutionary technology being developed yet poor adoption of new technology in healthcare. This chapter provides the background to the 4IR and the opportunities available. It includes the challenges healthcare has in meeting citizen expectations with costs and productivity. The resulting dichotomy between need for new systems and reality of delivery of new technology in healthcare is outlined. The case study is based on these broad needs but is focused on a specific cyber issue within the NHS to address a practical impact and seek generalisations from the outcomes.
3: Literature Review to the Theoretical Framework	A systematic literature review was undertaken covering the background to Information System Design and the selection of Action Design Research for the project methodology. The chapter then reviews Institutional Theory as a framework informing the research. This review covers the broad field of institutionalisation in

Chapter	Overview
	healthcare and the specifics of IS and technology developments through the lens of Institutional Theory.
4: Solution Design	The solution design chapter details the methodology used for the research – ADR and the application of this methodological tool in this setting. The chapter then presents a pre-liminary (pilot) case study where I test the proposed approach of data collection using semi structured questionnaires. The pilot case study is based on another company I was working with that had developed IS artefacts to the NHS already. The outcome from this pilot case study also provided insights into areas to explore on IS design in the main case study. The chapter finishes with the main case study and follows the design, development, and installation of a new cyber security product into an NHS setting that was developed by my company. I acted as both researcher and participant in the case study through an action orientated approach.
5: Solution Evaluation	Within the ADR process the methodology includes reflection on the outcome, impact and lessons learnt. This chapter provides my personal assessment along with additional input from the design team

Chapter	Overview
	members on their assessment of ADR as an appropriate tool for IS development in a complex organisation.
6: Discussion	The discussion section explores the key topics that set the agenda for the research project: Is ADR an appropriate methodology to help design new IS artefacts for the NHS and what could other researchers learn from this study. What was the practical impact of our design, and did we evidence any learning from other industries in the 4IR setting? How well did the context of a complex organisation and Institutional Theory framework explain the study outcomes? Finally, can we generalise from this study regarding the process for designing IS for complex organisational settings.
7: Conclusion	The thesis concludes with the key findings and identifies several areas for further research including technology debt in the NHS, the concept of imagined used and using ADR in other complex organisations.

Table 3 Thesis Layout.

2. Background and Context of the Problem

2.1. Introduction

This chapter provides the background and context for the research. The review starts very broadly with the onset of the Fourth Industrial Revolution and explores some of the capabilities that come from these developments. A key area is the use of machines to undertake tasks that would typically have required a human brain and perception to undertake, also referred to as cognitive behaviour. Machine learning, artificial intelligence and robotic automation are used interchangeably to describe this phenomenon, and a review of its history and use shows the risks and capabilities available. This initial section provides the basis for this project from an Information System (IS) perspective, recognising that modern IS development can pose a threat through cyber-attacks as well as a benefit through new solutions. Tools from the 4IR will significantly impact our lives and on healthcare delivery.

The chapter then describes the current challenges that healthcare is facing. The exponential growth in demand and expectations are being met with an ever-increasing reliance on technology. The section also explores the healthcare environment's poor history in designing, adapting, and implementing new systems to their maximum benefit, a challenge that Institutional Theory can inform. Other industries have overcome this challenge of poor design and implementation, and I present examples of how these industries have developed and deployed tools successfully to provide real-world impacts. These provide ideas and concepts that I considered in the design of the IS artefact in this project.

The dichotomous position of rapidly developing new technology, an industry in need of the latest technology but plagued with a poor track record on benefit realisation, provides the challenge that this project sets out to investigate. This scope is broad for a case study, and I identified a real-world problem of cyber-attacks in the healthcare sector as an area to narrow down and focus on. This final contextual dimension of cyber risks, attacks and vulnerability in the healthcare sector is presented. The tools of the 4IR can be seen from a cyber security position as a threat to and an opportunity to protect the healthcare sector.

Due to the nature and speed of change in the development of new technology in the current industrial revolution, 'grey literature'[1] has been adopted. This approach of going beyond the systematic review to include contemporary material and its use to inform practice better (Adams, et al., 2017) meets the criteria for this project.

2.2. Fourth Industrial Revolution and Healthcare

The Fourth Industrial Revolution (4IR) was described by Klaus Schwab at the World Economic Forum in 2016 as 'the inexorable shift from simple digitisation (the Third Industrial Revolution) to innovation based on combinations of technologies (the Fourth Industrial Revolution)' (Schwab, 2016). In his book released the following year, the concept was refined as the culmination of emerging technology fusion (artificial intelligence, robotics, the internet of things, autonomous vehicles, 2D printing, nanotechnology, biotechnology, materials science, energy storage, quantum computing, and others) into the physical and biological worlds that will fundamentally change the way we live, work and relate to one another (Schwab, 2017).

The concept wasn't new, and there are references to similar notions as far back as 2008 with Helen Gill's Cyber-Physical Systems (Gill,

[1] Grey literature has been defined as 'anything that has not been published in a traditional format or, in library parlance, lacks bibliographic control' (Levin, 2014)

2008) and the German Governments Industrie 4.0 (Jasperneite, 2012). In 2014 Brynjolfsson and McAfee called developments the ‘second machine age’ (2014). There are arguments that this is just an extension of the 3rd Industrial Revolution (Das, 2016), and as Rifkin suggests, the third revolution hasn’t yet reached its entire potential (2016). However, Schwab bases the development of a distinct fourth revolution on three key areas; velocity of change which is exponential rather than linear; the breadth and depth of the emerging technologies that are building from the third revolution but creating a paradigm shift in the economy, business, society, and individually. Finally, the impact on systems results in fundamental changes in how society engages and uses the technology (Schwab, 2017). This view is supported by Topleva, who proposes that for each industrial revolution (First and Third), there has been a subsequent technical revolution (Second and Fourth) which drive innovation and new models of delivery (Topleva, 2018).

This position and basis for 4IR are now accepted, and the emphasis is shifting to understanding the impact that this revolution will have on business (Skilton & Hovsepian, 2018). The challenge that everyone needs to address is ensuring that the Fourth Industrial Revolution is empowering and human-centred rather than divisive and dehumanising (Schwab, 2017).

2.2.1. Previous Industrial Revolutions

The First Industrial Revolution occurred around the second half of the 18th Century when man moved from muscle power to mechanical power through the invention of the steam engine (Schwab, 2017, Skilton & Hovsepian, 2018). Although this was the First Industrial Revolution, mankind had seen many revolutions going back to change from foraging to farming.

The Second Industrial Revolution started in the late 19th century to early 20th century. This was led through the use of electricity to make comprehensive scale mass production possible. The Third Industrial Revolution, referred to as the computer or digital revolution, began in the 1960s and followed the development of semiconductors, mainframe computers (1960s), personal computers (1970s and '80s) and the internet (1990s) (Schwab, 2017).

One aspect consistent throughout the industrial revolutions is that the time from initial innovation to widespread use and adoption is diminishing. For instance, the core component of the First Industrial Revolution, the spindle, took 120 years to spread outside of Europe (Schwab, 2017), and it took over 200 years from the first steam engine (Newcomen in 1707) to the mass-produced Fords in 1908 (Makridakis, 2017). It took more than nine decades from the discovery of electricity to widespread use in manufacturing to improve productivity (Makridakis, 2017). However, today 17% of the world's population have not experienced the second revolution with no access to electricity (Schwab, 2017). The Third Industrial Revolution took only twenty years from the ENIAC (the first computer) and IBMs 360 computer system that was mass-produced for smaller businesses. By the time Motorola released the first commercial mobile phone, the gap was only ten years since the invention, which was surpassed when the first smartphone was released in 2002. Its capabilities increased every couple of years (Makridakis, 2017). An example of this would be the rapid development of the app economy that Apple created in 2008 when it opened up its mobile platform to developers; in under ten years, the global app economy had grown to over $100billion in revenues and surpassed the film industry, which had been in existence for more than a century (Schwab, 2017).

Skilton and Hovsepian (2018) tracked the trends through the industrial revolutions, as shown in Table 4 below.

1780's – 1870's	1880's – 1930's	1950's – 1990's	2000's – 2030's
1st Industrial Revolution	2nd Industrial Revolution	3rd Industrial Revolution	4th Industrial Revolution
Mechanical production equipment	Mass production	The internet	Social-technology governance
	Electrical energy transformation	Automated production	
Mechanical energy transformation	Chemical / petrol energy transformation	Mechanical, analogue electronics to digital electronics transformation	Physical-biological technology Transformation
			New techno-materials
Start of globalisation	Electrification	Electronics, Information Technology	Cyber-physical systems

Table 4 The Four Industrial Revolutions.

Technology innovation has always underpinned economic change and disrupted how we do things. According to Dobbs et al., (2014), we are now entering into a new era of disruption and change and what they describe as the 'second half of the chess board'. This reference was related to a story told by Ray Kurzweil (futurist and director of engineering at Google) where he describes the inventor of chess asking a Chinese emperor to pay him one grain of rice for the first square on the board, two for second, four the third and so on doubling the quantity for each square, by the time the payments had reached the second half of the board the cost bankrupted the emperor.

2.2.2. Implications of Fourth Industrial Revolution

Schwab (2017) argues that the 4IR will need to learn from the previous industrial revolutions. The extent that society, government, public and private institutions engage in the process will determine the long-term benefits. He does, however, also highlight concerns that could limit the benefits of 4IR. Firstly, the required levels of leadership and understanding of the changes already underway are low compared to the impact that the 4IR will have. Secondly, the world doesn't have a consistent, positive, and standard narrative describing the available opportunities and challenges. This will be critical as the phenomenon of the 4IR will see human and machine intelligence becoming increasingly intertwined (Skilton & Hovsepian, 2018).

Industries have already benefited from applying tools from the 4IR, including advertising, retailers, and video gaming, for example, (Meeker, 2017). For her 2018 report, Meeker identified the change in perception globally of how data is captured and used and specifically the use of personal data or its improper use and the challenge of regulation (Meeker, 2018). The adoption of digital technology has led to an explosion of data. Turner et al. predicted that by 2020 there would be over 16 zettabytes of data (Turner, et al., 2014). Data has become as necessary to industry and production as labour, capital, or land (Miller, 2016). The challenge for businesses is that having the right technological and organisation capability to exploit the data is essential (Cavanillas, et al., 2016; Cavanillas, et al., 2014). This supports the view of Brynjolfsson & McAfee (2014), who argued that computers are so dexterous that it is virtually impossible to predict what applications may be used for in just a few years with AI is transforming our lives. This results in a significant shift in how businesses engage with their users, increasing transparency, consumer engagement, and new behaviour patterns. This will force companies to change how they design, market, and deliver existing and new products (Schwab, 2017). A shift from the simple digitisation of the Third Industrial Revolution to the more complex innovation of multiple technologies of 4IR (ibid).

Schwab proposed four main effects of 4IR for business:

- Customer expectations are shifting.
- Products are being enhanced by data, which improves asset productivity.
- New partnerships are being formed as companies learn the importance of new forms of collaboration; and

- Operating models are being transformed into new digital models (Schwab, 2017).

This result can be seen in the shift from analytical to predictive and prescription powers through AI, which will impact how humans will need to evaluate the values and norms of society (Skilton & Hovsepian, 2018). The impact on business is described as standing on a precipice of considerably more significant shifts in these areas. This will have tremendous implications for global leaders as the acceleration in scale, scope, and economic impact of technology and AI while shaking up business in unimaginable ways (Dobbs, et al., 2014). From an individual's viewpoint Manu (2015) offered three areas of development for the Internet of Things:

- Enhancing our experience of current products or services
- Expanding our relationship and engagement with existing products or services providing new benefits
- Redefining our relationship through new products or services.

Or another way of looking at this is that many things will change; people's personal lives, the productivity of the workplace and consumption patterns and behaviours of people will change.

For healthcare, Manyika et al predicted the positive transformation of clinical decision support systems using the health datasets to change how healthcare will be delivered as well as advanced analytics and research and development into predictive modelling and algorithms (Manyika, et al., 2011). Schwab argues that healthcare will be challenged with numerous advances from physical, biological, and digital technologies arriving as new models of care are delivered. The attempt to digitise a historically paper-based industry will collide with the wealth of new data from wearable and implantable devices (Schwab, 2017). This situation of information overload was described many decades ago by Herbert Simon "a wealth of information creates a poverty of attention" (Simon, 1971). The challenge for the healthcare profession will be maximising the benefits but minimising the risks of AI and new technology in healthcare.

Skilton and Hovsepian (2018) describe the transformation of the interaction between human to machine and machine to machine under 4IR as a key difference from previous revolutions. Where the nature of the change can be exerted at all levels, macro, micro and nano. This is leading to complex system relationships forming between physical, biological, and digital domains. This new model summarised in Figure 2 will allow new forms of responsive care and lifestyles, but in doing so will require new governance for personal data privacy ethics and security.

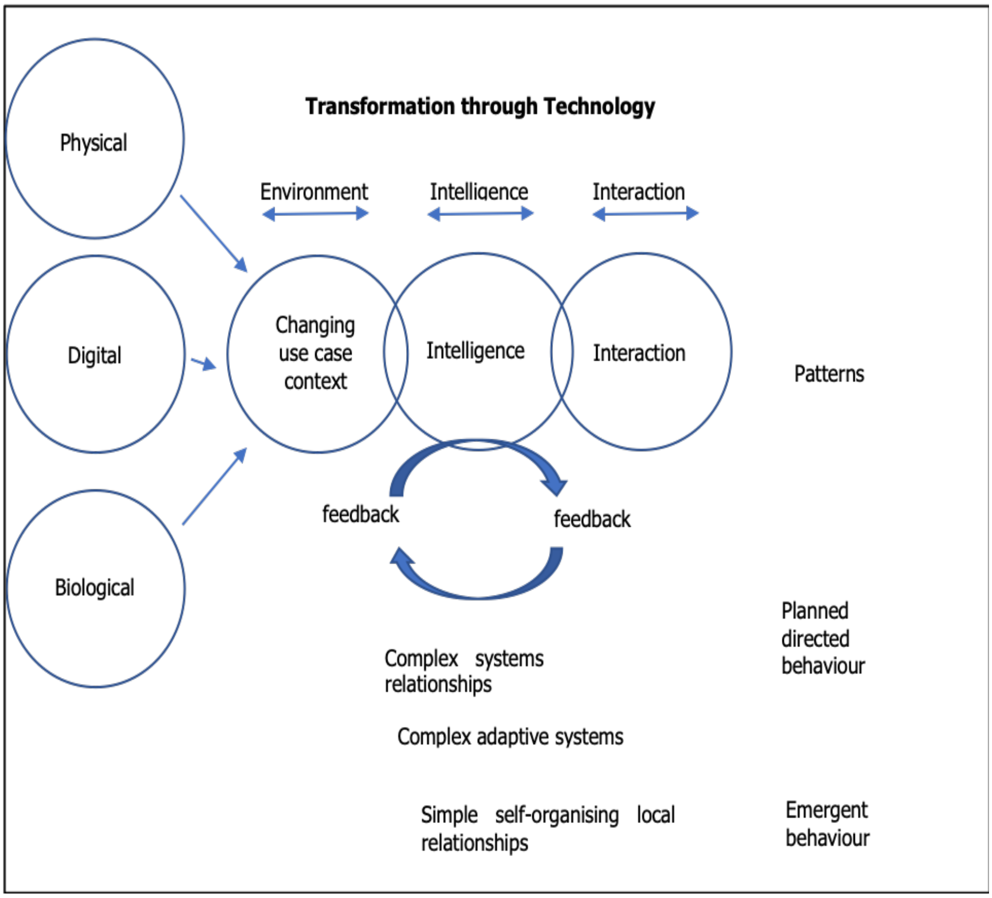


Figure 2 Fusion Feedback and Control the Rise of Intelligent Systems (Skilton & Hovsepian, 2018).

While this model was positioned as generic, it closely matches how healthcare could be delivered in the future and areas that need to be considered when AI and new technology are introduced to the healthcare domain.

Not everyone agrees that the 4IR and AI in particular is all good news, as Hawking et al (2014) raised "*Whereas the short-term impact of AI depends on who controls it, the long-term impact depends on whether it can be controlled at all….all of us should ask ourselves what can we do now to improve the chances of reaping the benefits and avoiding the risks*".

2.2.3. Artificial Intelligence the New Driver for More Technology

This section provides a summary of the background and development of Artificial Intelligence (AI), a more detailed review can be found in Appendix A. AI though is just one of many terms used to describe computers that learn, another being machine learning, the meanings are expanded on below but for the purpose of this report I will use the terms AI and machine learning interchangeably.

There isn't a precise definition for the term 'artificial intelligence' hasn't and examples of descriptions used include:

> "*Artificial Intelligence is a science; it is the study of problem solving and goal achieving processes in complex situations"* (McCarthy, 1973)*;*
>
> *"[…automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning…"* (Bellman, 1978);
>
> "*The art of creating machines that perform functions that require intelligence when performed by people*." (Kurzweil, 1992);
>
> "*The study of computations that make it possible to perceive, reason, and act.*" (Winston, 1992);

> "*The branch of computer science that is concerned with the automation of intelligent behaviour.*" (Luger & Stubblefield, 1993);
>
> "…*that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment*." (Nilsson, 2010);
>
> "*Is artificial intelligence real intelligence? Perhaps not, just as an artificial pearl is a fake pearl, not a real pearl. "Synthetic intelligence" might be a better name since, after all, a synthetic pearl may not be a natural pearl, but it is a real pearl. However, since we claimed that the central scientific goal is to understand both natural and artificial (or synthetic) systems, we prefer the name "computational intelligence*." (Poole, et al., 1998).

As can be seen, there is no clear definition of artificial intelligence or machine learning, and many claim that the definition changes as people become accustomed to previous advances (Bughin, et al., 2017). Larry Teslar has even been credited with a theorem that AI is whatever machines haven't yet done (Hofstadter, 1979), originally stated as whatever hasn't been done yet.

If the term artificial intelligence is used to broadly describe the science behind machines being smart then machine learning has been described as the technology that allows computers to learn to do a task intelligently through learning by example (The Royal Society, 2017).

AI isn't some sci-fi droid from the future; it is right here, right now and changing the world one smartphone at a time (Polson & Scott, 2018). The complexity of AI can also be viewed by its areas of use, Jeremy Wyatt (Professor of Digital Healthcare, Wessex Institute of Health Research) devised the following Table 5 as a model for differentiating AI usage in healthcare setting:

High Complexity AI applications	Middle Complexity AI modules or components	Low Complexity AI reasoning methods
• Autonomous vehicle • Machine translation tool • Care companion robot • Chat bot • Surgical or pharmacy robot • Mammogram interpretation system • ECG interpreter • Diagnostic decision • support system • Speech driven radiology report tool with SNOMED coded output	• Natural language to SNOMED code processing module • Image processing module • Text to speech module • Knowledge based or • expert system module • Signal processing & classification module • Recommender module	• Deep learning module • Ensemble methods (e.g., Random Forest Models) • Neural networks • Object segmentation algorithm • Signal processing algorithm / filter • Generative adversarial networks • Time series analysis • Graphical models • Decision trees, rule induction e.g., CART • Clustering algorithm • Classification algorithm • Regression – linear, multiple, logistic • Inference engine for rules or frames • Argumentation, temporal, or

High Complexity AI applications	Middle Complexity AI modules or components	Low Complexity AI reasoning methods
		spatial reasoner e.g., QSIM • Text generator using DCGs • Case-based reasoning algorithm

Table 5 Models for AI Differentiation (The AHSN Network, 2018).

This clearly shows AI is real and impacts a broad range of areas within healthcare. The challenge IS developers will need to address is what factors must be considered when using the tools of the 4IR. What and why is this different from the previous industrial revolutions.

2.2.4. Implications of Using Machine Learning / AI

There are several areas that need to be considered when machine learning is applied to healthcare. These need to be addressed (The Guardian, 2017) deliver any benefits safely and securely from the technology including:

- Data governance - For machines to learn they require access to data for training and testing purposes (Polson & Scott, 2018). As has been shown data is being acquired at an exponential rate (Jacobson, 2013). The question of how the data was acquired and what is its intended use must be considered. As opposed to what it is being used for in the realm of AI, raises governance issues that need to be addressed (The Royal Society, 2017).

- Data interoperability - In order to maximise the ability to extract and understand data that would be useful for machines to learn and act there are several key requirements including:
    - Data scientists need to understand what the data represents, how it was created and how it should be used.
    - The users of a new service may wish to know what data has been used to create / train an algorithm and what data was used for testing.
    - Was the data approved to be used for AI research? (The Royal Society, 2017).
- Limitations of AI - Several limitations of AI have been identified, Chui et al, (2018) identified five areas for consideration:
    - Firstly, the need to label training data from which the machine is 'taught' through supervised learning. This is often a manual process and involves a large quantity of manual labour and specialist skills (De Fauw, et al., 2018).
    - The second and connected limitation is access to the dataset in the first place to train that is both sufficiently large enough and comprehensive to allow the machine to learn and this isn't always available with clinical trial data given as an example.
    - Thirdly, is the challenge of explaining how the machine has generated an outcome from the large quantity of data so that a human can understand the output. In healthcare, if you cannot explain the answer how it can be certified through current regulations (De Fauw, et al., 2018).
    - Fourth from the team was generalisability, or the challenge of taking learnings from one setting to another (Silver, et al., 2016).

  - Finally avoiding bias in the data and algorithms. this has caused embarrassing issues for some early systems. For example, the COMPAS (Correctional Offender Management Profiling for Alternative Sanctions) system was used to predict the level of risk of reoffending to a judge. The system was trained explicitly without knowing the race or gender of the input data. However, when it was tested in a real-world setting it clearly had a racial disparity. The bias was clearly there but as the algorithm was kept secret researchers were unable to identify the cause (Polson & Scott, 2018).
- Data security - Arm's (2018) survey found that one of the areas of most concern to the public is security through hacking and loss of data being the key areas with 85% (n=3938) of those surveyed raising this as an issue.

These aspects could be seen as limitations of the current approaches or challenges to overcome. This project considered these in its design stage if appropriate and the wider generalisation of them in designing IS products in the 4IR in the discussion section.

2.3. The Expected Impact of New Technology in Health

In recent years numerous reports, presentations, and commercial claims have been made on both the opportunities and benefits that the technologies of the 4IR should deliver for healthcare. This section addresses the need for these tools and technologies in health, the expected benefits, and early demonstrators as well as the issues that need to be considered.

2.3.1. The Need for New Technologies in Health

The case for why healthcare needs new technology from the 4IR, and emerging technologies comes from many different perspectives including the following drivers.

- The cost of healthcare globally has reached 9.9% of Gross Domestic Product in 2014 (World Health Organisation, 2017), and has increased 1-2 percentage points since 2010 driven by aging populations and inefficiency in healthcare provision (George, et al., 2017). In 2016 two-thirds of British hospitals ran a deficit and without major reform the NHS may see a £30 billion funding gap over the next three years (Blackwood, 2018). If AI can achieve the same level of benefits seen in other industries, it would reduce the cost of healthcare significantly.
- Doctors are under increasing work pressure and compared to nondoctors are 40% more likely to abuse alcohol or drugs and twice as likely to commit suicide (Polson & Scott, 2018, Dzau, et al., 2018).
- Only 20% of available trial-based knowledge when diagnosing cancer patients and prescribing treatments is used by doctors, AI could sift through millions of medical evidence papers to provide a diagnosis and treatment plan in seconds.
- In imaging, AI based recognition systems can see details on MRI and CT scans that human eyes may not register. For example, the Mayo Clinic has already developed a programme that can recognise the different types of glioblastomas and identify different genetic abnormalities to ensure the correct treatment is selected (Matthews, 2017).
- To improve clinical decision making through joined-up care and current knowledge that drives out unexplained variation we must stop pretending that the human brain can remember everything when medical knowledge doubles every three years (Obermeyer & Lee, 2017, Carter, 2017).

- 250,000 Americans die each year from treatment-related mistakes, which is the third-leading cause of death in the USA (Woodson, 2018). Healthcare professionals need technology they can trust in to guide them, and early studies have shown AI enabled technologies can help provide more accurate treatment plans and create the learning health system (ibid).
- Trainee doctors spend up to 70% of their time on paperwork (Donnelly, 2015). Wachter (2015) reported finding junior doctors spending most of their time moving information from one place to another, known as a simple transfer in computer science. According to the Royal College of Nursing, 17 to 19 per cent of nursing time is spent on non-essential paperwork (Royal College of Nursing, 2013).
- Healthcare is an information intensive industry, in the USA a large healthcare system will process about 10 million computerised transactions a day, twice what the NASDAQ achieves (Wachter, 2015).
- Policy drivers, the Five Year Forward View (FYFV) (NHS England, 2014) recognised the essential role that technology will need to play to improve health and care. The Wachter report (2015) found that the NHS would fail to deliver the FYFV without addressing the successful use of technology.

For evidence of earlier use of data analysis and medical statistics that significantly improved healthcare performance and patient outcomes, Florence Nightingale provides a path to follow through the three steps she had to overcome in the 19th Century:

- Institutional commitment to change – you must want to change the field of work.
- Overcoming the entrenched status quo of how things are done today.
- The tenacity and leadership to drive through the change needed (Polson & Scott, 2018).

Through her work, she modernised nurse training and education, showed how detailed analysis of health data could be used to improve outcomes (for example she shamed the army into improving sanitary conditions in hospitals and barracks that immediately dropped the number of disease related mortality). Finally, she was credited with professionalising the data collection and analysis of medical data (Polson & Scott, 2018).

The same challenges that Nightingale faced remain for today's moderniser to implement the change needed so that new technology can deliver its full potential. Two-thirds of respondents to a HIMMS report (105 senior IT respondents) feel AI is transformative. Nearly half feel AI is relevant to patients' health and wellbeing at their own organisation (HIMSS , 2017). University College Hospital in London see AI as a 'Game Changer' and has signed a three-year research agreement with the Alan Turin Institute aiming to bring the machine learning revolution to the NHS in an unprecedented way (Devlin, 2018). Wachter declared that the rise of genomics and precision would make AI essential for future clinical practice, as clinicians would not be able to store all that knowledge in their head (Heather, 2018).

It is worth noting that this isn't the first time that AI is seen as revolutionising healthcare, Maxmen (1976) predicted that the 21st Century would be the post physician era with paramedics and computers treating us. We aren't there yet but progress suggests the combination of new technology and new clinical models of healthcare delivery need further investigation.

2.3.2. Expected Benefits of New Technology in Health

The new era under the 4IR, where large quantities of personal information are collected through connected devices and the Internet of Things. When combined with health data should, although not yet available, lead to new wellbeing services (Skilton & Hovsepian, 2018).

Healthcare should be a prime receiver of benefits from new technologies and provide more accurate diagnosis and efficient and effective healthcare services (The Royal Society, 2017). This potential will be realised through machine learning algorithms assisting medical staff with extracting features from complex data sets and inferences drawn from them as well as pattern recognition in imaging. Using these to identify or predict alerts for the staff to act on (Bughin, et al., 2017). Polson and Scott (2018) see a world where doctors don't spend a third of their time manually entering data, instead, they just talk and systems such as Amazon Echo update the medical record automatically, analyse the conversation and using predictive algorithms help the doctor look for hidden signs of trouble.

New technologies could support the NHS in delivering the Five Year Forward View (NHS England, 2014) through reducing the gap in healthcare provision in three areas:

- Address health and wellbeing – through predicting which individual or groups are at increased risk of illness and target treatment more effectively.
- Care and quality gap – through AI tools providing cutting edge diagnostics and treatment tailored to individuals (personalised care).
- Efficiency and funding gap – through AI automating tasks, triaging patients for the most appropriate services and self-treating (Harwick & Laycock, 2018).

AI was called out in Personalised Health and Care 2020 (Department of Health and Social Care, 2014) and the 2017 Industrial Strategy: Building a Britain Fit for the Future (HM Government, 2017) as helping to deliver an NHS fit for the future. This reinforced the expectations of Professor Sir John Bell's earlier report on life sciences in the UK and the expected benefits of AI to healthcare (Bell, 2017).

Radiology has been sighted as a priority area for AI due to its increasing demand for radiology services and availability of complex datasets that the new technologies used in radiology can generate (Joshi & Morley, 2019). Some have gone as far as to say AI and machine learning could entirely automate analysing radiology images, although in the same report Jia Li, Google Cloud AI Research and Development lead, believes that doctors will not be wholly replaced any time soon. The technology will assist doctors in making better decisions (Knight, 2018). These new statistical modelling capabilities will identify what patient is most likely to be affected by a disease or deterioration and deliver precise interventions with maximum effectiveness (Fiahult, et al., 2017).

However, Bughin et al (2017) caution on the speed of adoption, that it may not be as fast as other industries with concerns over patient acceptance of a machine diagnosing them. The large-scale integration challenges of multiple sources of data and systems, and the regulatory requirements that would need to be met. The AHSN Network in conjunction with Department of Health and Social Care carried out a survey of healthcare managers and professionals in late 2018 and identified that to release the expected benefits of AI and transform healthcare there were several barriers to overcome including:

- Ensuring that the AI solution is grounded in real problems as expressed by healthcare users.
- Engage healthcare professionals to develop an ethical and trusted approach.
- Build capacity and capability.
- Ensure the regulatory framework is fit for purpose.
- Explore new funding and commercial models.
- Build a sound data infrastructure, quality data sets and interoperability.

(The AHSN Network, 2018)

These were the key areas to be addressed in this research project and reflects the areas expressed by the Royal College of Physicians as needing to be addressed (Royal College of Physicians, 2018).

2.3.3. Early Reports of AI in Health

There are early reports on new technologies including AI and machine learning making advances into the healthcare industry by assisting medical staff across a range of disciplines. The following Table 6 shows examples of these early reports:

Company	Area	Use of AI
Microsoft	Cancer treatment	There are more than 800 medicines and vaccines to treat cancer, however with so many choices it is more difficult to select the correct drug for the patient. Microsoft is working on a project to develop a machine called "Hanover". Its goal is to memorize all the papers necessary to cancer and help predict which combinations of drugs will be most effective for each patient (Bass, 2016).
Epic	Predicting deteriorating patients	In a 90 day pilot at Oschner Health in the USA the organisation managed to reduce the numbers of codes (a patient suffering a cardiac arrest or needs immediate medical assistance) by 44% by the system using AI to 'pre-code' and alert the

Company	Area	Use of AI
		medical staff in advance for earlier intervention and have integrated the alert into the clinicians workflow (Ho, 2018).
IBM Watson	Diagnosis	Successfully diagnosing leukaemia with AI (Ng, 2016).
Arterys	Imaging	Analysing cardiac images and approved by FDA for clinical use (Insights, 2018).
Bablyon	Primary care	Digital health app for triaging primary care (ARM, 2018).
Triggr	Addiction	Tackling opioid addiction (ARM, 2018).
Zebra	Imaging	CE marked AI for diagnostic imaging (George, et al., 2017).
Stanford University	Skin cancer detection	Using 129,450 images that has been classified against 2,032 taxonomy of skin lesions they created a mobile app that could using the mobile camera and a deep neural networks could make two inferences from the image, it could distinguish between the two most common types of skin cancer and between a benign mole and deadliest type of skin cancer with accuracy comparable to 21

Company	Area	Use of AI
		board certified dermatologists (Polson & Scott, 2018).
DeepMind	Octane	A joint project between DeepMind and Moorfields Eye Hospital that demonstrated performance in referral recommendations following a 3-dimensional eye scan that reached and exceeded that of experts in a real-world clinical pathway using AI to interpret and recommend next steps in the care pathway (De Fauw, et al., 2018).
AliveCor	Mobile heart monitor	Approved by National Institute for Health and Care Excellence (NICE) as a mobile heart monitor using AI to detect, monitor and manage atrial fibrillation (Harwick & Laycock, 2018).
Eve	Drug discovery	'Eve' is a robot scientist that makes drug discovery faster and more economical (Wiliams, et al., 2015).

Table 6 Early AI Adoption in Health.

El-Kareh et al (2013) concluded that there are few demonstrable clinical impacts from health information technology on diagnostic errors at this stage, and further research was needed. By 2018 the CB Insights (2018) reported that healthcare was the hottest area of AI start-up investment, with specific focus on imaging and diagnostic companies. The report also draws on the concerns over responsibility for misdiagnosis and how current systems in use are aimed at assisting radiologists and physicians rather than delivering a definitive diagnosis. The new systems won't in the short term, replace doctors and in-person care. Still, the combination of humans and machine intelligence could have dramatic implications for the delivery of healthcare, especially in the developing world (Polson & Scott, 2018).

The early evidence of AI and machine learning adoption for the NHS is sparse. The approach is to leave individual organisations to introduce the new technologies resulting in a piecemeal approach to both adoption and commercial models (Harwick & Laycock, 2018).

The use of AI in health isn't without its challenges. Professor Fox, in providing evidence to the House of Lords Committee, suggested that many of the claims for healthcare AI may well be overblown (House of Lords, 2018). IBM has also had challenges with its AI oncology claims not delivering the expected benefits for the clinicians or patients (Ross & Swetlitz, 2017). The challenge of implementing new technologies and AI into healthcare should not be underestimated or associated with just technical issues but focus on the behaviour of the end-users (Emanuel & Wachter, 2019).

This rapid growth in computerised devices that historically would not have come under the management of governance of healthcare IT departments raises further risks for cyber security. The proprietary nature of medical devices and the Internet of Medical Things (IoMT) means that the healthcare IT teams may not even know or be able to patch the operating systems and software the manufacturer is using (Coventry & Branley, 2018).

2.4. Healthcare and Technology

The review to date has shown that there should be some clear benefits from the 4IR for healthcare, given its impact in other industries.

However, the history of technology adoption within healthcare hasn't always delivered what was expected (Wachter, 2015). This section explores some of these issues.

2.4.1. A Brief History of Technology Adoption in Healthcare

Healthcare is now at its digital inflexion point. A century ago, healthcare and medicine were very much a human touch industry, 25 years ago analogue machines were beginning to provide assistance and today there has been an eruption of digital-enabled technology (Meeker, 2017). This rapid growth has seen changes including, analogue x-rays to now digital 3D PACS (Picture Archiving and Communication Systems). Paper based analogue ECG machines to wearable digital readers and computers deployed everywhere. The application of technology in other industries has seen a step-change in areas such as productivity, efficiency, and value yet in health this hasn't been the case (Chui, et al., 2018). The challenge of why new technologies and innovations don't deliver the expected benefits has been investigated through multiple lenses. Greenhalgh et al (2017) looked at how innovation must be embedded into existing workflows. Scarbrough and Kyratsis (2021) refocused the discussion on how innovation was implemented at scale and embed the innovation through learning, adopting, and institutionalising the innovation. The research shows there is no one answer to address the challenge.

From an IS perspective one response to address this has been the creation of maturity models depicting the steps need to reach the goal of digital maturity. Appendix B provides an overview of three examples of the digital maturity model provided by the leading healthcare IT association (HIMSS), the UK healthcare digital agency (NHSx) and a leading academic healthcare provider from the USA (Cleveland Clinic). All three of the maturity models are seeking the same goal of providing a pathway or roadmap that shows healthcare organisations what steps in terms of systems or products they should deploy and in what order.

Maturity models proposed for healthcare IT adoption have been used since the early 1970's (Carvalho, et al., 2019). The aim of the models was to focus attention on the key areas that will drive digital and IS adoption. However, healthcare hasn't widely achieved these levels of maturity. Wachter, (2015) undertook a detailed review of why, when computers were introduced to front line medicine, the expected benefits were not delivered. Wachter provided a detailed timeline of healthcare digitisation in the USA and identified several key issues and mistakes made by the technology industry and the supporting change management programmes, he summarised it as:

> "While someday the computerization of medicine will surely be that long-awaited 'disruptive innovation', today it's often just disruptive: of the doctor-patient relationship, of the clinicians' professional interactions and workflow, and of the way we measure and try to improve things."
>
> (Wachter, 2015, p. xi).

In the UK the National Programme for IT was deemed 'a fiasco' and the bulk of £12billion of investment written off with the view that the programme was run like a military procurement programme whose leadership under Richard Granger was 'just do it' which placed him at logger heads with the physicians and almost everyone in the health service (Wachter, 2015, p. 17).

This poor level of satisfaction with new technology in healthcare has been attributed to the lack of user-centred design. The EHR systems were great business tools and met the needs of the hospital administrators, but they didn't meet the need of the customer – the doctor (Wachter, 2015, Docherty, et al., 2018, Campion-Awwad, et al., 2014). Without considering how technology and the social system of its use interacts and is embedded in a contextual setting, the benefits opportunity will be minimalised. The focus should be on the people and not the technology (Greenhalgh, et al., 2017). Or, as Adner and Kappor state, '*explicit consideration to the challenges different actors will need to overcome in order for value to be created in the first place'* (2010, p. 307).

It could be argued that the entire approach to how systems or products are defined is grounded on the wrong principle. As Christensen et al, proposes we actually 'hire' the product or service to 'get a job done' (Christensen, et al., 2016). The proposition is that instead of focusing on knowing the customer. The question should be on finding out what job the customer is trying to do. This is an essential aspect used in this project to work with the end-users / customers from the outset to ensure that the product does deliver the job required.

2.4.2. Healthcare IT Complexity

Healthcare organisations have multiple IT systems all focusing on certain aspects of the overall care model such as patient imaging, requesting systems, pathology results, medical notes, and drug charts. These combine to create significant day to day challenges in integration and management (Docherty, et al., 2018). The authors' personal investigation identified over 800 separate systems at a large USA academic medical centre and over 200 different systems at a London NHS hospital.

The quantity and diversification of systems deployed in healthcare is one of the major challenges IT managers and healthcare executives face (Carvalho, et al., 2019). This complexity is driven from the historical perspective of clinicians and individual departments buying the IT systems they wanted with no overall central control. The National Programme for IT sought to address this but failed (Currie, 2012). The issue with multiple systems of varying age is the management and need to integrate and control them and the increased cyber risk they poise (Ghafur, et al., 2019).

Regardless of size, most organisations do not have a defined process for integrating new technology solutions into the business processes or clinical workflows (HIMSS , 2017). Zillner and Neururer (2016) found that clinicians seek a more automated and less administrative process when dealing with technology to have more time available for and with the patient. In addition, they seek aggregated, analysed, and concisely presented data that can inform their decision making and quality of decisions made.

In her report on the four critical steps to digitising healthcare, Carter (2017) stated technology-enabled care isn’t about the hardware; it’s about the people, the elements of the system infrastructure, technology, data, skill and leadership must all be there. The fundamental changes happen because people make them happen. In solving the challenge of successfully designing and deploying new IS technology, people aspects will be a crucial consideration.

2.4.3. Regulatory Barriers for New Technologies in Health

New technologies face challenges in adoption for all industries (House of Lords, 2018). In healthcare, the number of barriers and challenges to overcome appears significantly higher than other sectors due to healthcare delivery's ethical and safety aspects. This should be, according to Harwick and Laycock (2018), a central matter for the regulatory bodies to tackle now, not least to ensure that the regulations are updated to meet the current technology in use. In the USA the Food and Drugs Administration (FDA) is defining “software-as-a-medical-device” and is developing a pre-cert programme to allow a flexible approach to specifically support AI developments (CBInsights, 2018). The EU has recently released its latest regulations on new technology certification and provides a large amount of the evidence needed on the design process used for the new artefact and cyber safety built-in from the outset (EU, 2020). Healthcare technology is becoming increasingly monitored and controlled through government bodies. However, the speed for these regulations to change and meet the new technologies will be tested in the coming years.

Despite these regulatory approaches, there is a significant risk that the multitude of new technologies and devices will increase the cyber risk through unauthorised access to the medical device, which could access the data, re-programme the device or even launch a new cyber-attack from the device (Safaei Pour, et al., 2019).

2.4.4. Implementation of New Technology in Healthcare

One of the challenges of introducing new technology is even when it can be lifesaving or clinically ground-breaking. There is a high risk that bureaucratic procedures, low morale, hard-pressed funding, rising levels of demand and expectation compounded by risk aversion and the scars left by failures of the past need to be managed (Carter, 2017). According to Wachter (2015), the root cause of healthcare's lack of change can be traced back to how the leadership tackled problems in healthcare. Referring to Ronald Heifetz description of two types of problems: technical and adaptive. Wachter believes that to date healthcare has approached its need to change by taking a technical approach which is solved with new tools, new practices, and conventional management as 'follow the recipe' approach. In contrast adaptive problems are where people themselves need to change. As Wachter puts it, healthcare is the 'Mother of All Adaptive Problems' (Wachter, 2015, p. xiii), yet it has been approached through a technical solution of buy more computers and switch them on and wonder why they have failed. Then look for someone or something to blame rather than take a step back and consider that we had used the wrong prescription based upon the wrong diagnosis.

Chen et al, noted the importance of professional and social networks in communicating new innovations (2021). The implementation, adoption and change management success questions are other areas of research that new IS artefact needs to consider when being deployed into healthcare settings. This current study focused on the design of a new artefact (cyber security product) and if ADR can reduce the adoption barriers.

I recognise that many other factors that can influence why a new technology project is successful or not. These include implementation and change management aspects where the findings from other researchers focused on the need to include end-users in the team and not treat it as a pure technology problem (Austin, et al., 2016, Heath & Porter, 2019, Deokar & Sarnikar, 2016). These areas are out of scope for this project as standalone investigation areas. These factors, implementation and change management, are however, key parts of a successful outcome from a technology investment perspective and will form part of the design approach.

2.4.5. Summarising The Issues

This section has provided an insight into the history and challenges healthcare has faced when deploying new technology, specifically IS and IT systems. The need for new systems in healthcare is clear. The question is how to avoid the failures of past IS programmes in delivering real benefits to the end-users. Other industries have overcome this challenge, and the next section explores if any lessons can be learnt.

2.5. What Can New Healthcare Technology Learn from Other Industries

2.5.1. Introduction

The literature review has shown that successful companies drive value creation from 4IR, and new technologies operate on a different model to traditional businesses. Manu (2015) associates the success of the new companies (for example, Google, YouTube, Amazon) with their approach of engagement through experimentation. He argues that the best engagement happens in experimentation by creating behaviour platforms that allow the user to be involved with product development alongside the company. Another view of the new value creation is how companies are using software to orchestrate people and resources to make intelligent decisions and create value (Choudary, 2015). An example of such a behaviour platform is Uber whose business model could only exist once mobile phones had become mainstream for its two customer groups, riders, and drivers. Manu argues that Uber's success is down to its ability to answer the value question '*what is the question* to which *your product is the answer to*?', by providing clear answers to a number of parties (see Figure 3 below) Uber disrupted the taxi market globally.

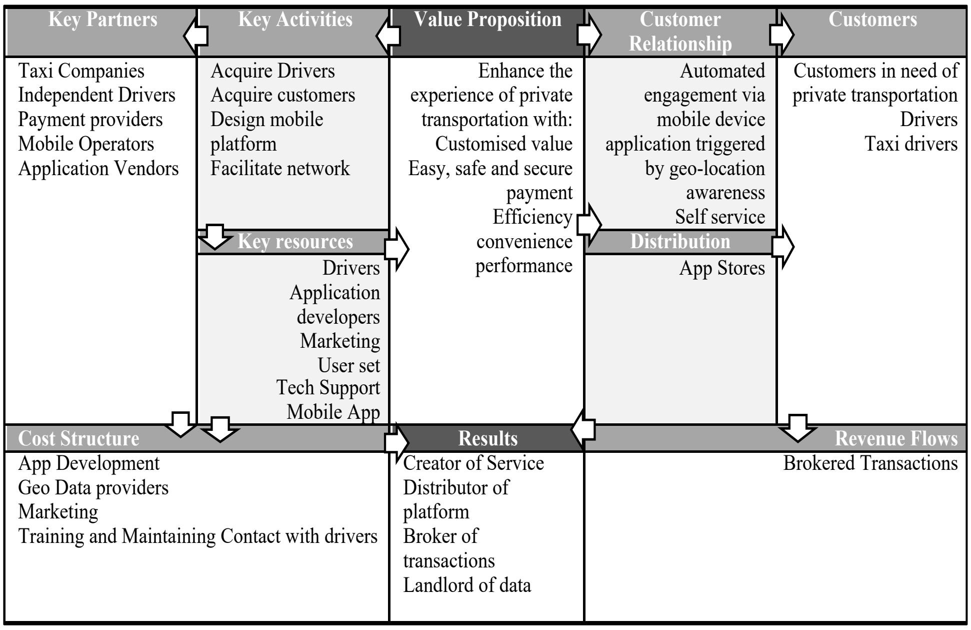


Figure 3 Uber Business Model (Manu, 2015, p. 94).

The ability for new start-ups to invade mature markets and disrupt them in short timescales, for example Airbnb in accommodation, demonstrates the power of the platform model (Parker, et al., 2017). The platform approach connects people, organisations, and resources within an ecosystem to drive value. It also meets the challenge provided by Chesbrough (2010) of how a novel technology requires a novel business model (Baden-Fuller & Haefliger, 2013).

2.5.2. A Platform Technology Approach

A platform model is different to the traditional pipeline model of value production. In the pipeline model the value is created through a step-by-step process. Each step adding value in a linear way. This approach is associated with long timescales and slow changes through the inefficient gatekeepers at each stage. This approach delivers value upstream that is consumed downstream creating a linear value (Choudary, 2015). A platform model however seeks to allow and encourage users and producers to enact in a way that allows rapid interaction and feedback that can unlock the value more efficiently (Parker, et al., 2017). This is driven by the increased connectiveness of society, the decentralised production of goods and services, and the rise of AI (Choudary, 2015).

The key exchange on any platform is information, and as such, the platform should be designed to facilitate this as its core characteristic and provide the infrastructure to support and allow this to happen (Parker, et al., 2017). As information is the core exchange and driver for platforms, the information being exchanged must be of value to both producer and consumer. In healthcare, clinicians often feel they are collecting data with little reward for themselves, and it has low value (Wachter, 2015). As the platform doesn't produce any information, it acts more like a factory floor allowing the producers to create the value proposition or information. However, good platforms can encourage a culture of quality control through the design and experience of the interaction (Parker, et al., 2017).

Therefore, the key to a promising technology platform is the design that encourages users to undertake the core interaction. Time and effort must be invested in this design and user experience to pull, facilitate, and match the producers and consumers of the information (Parker, et al., 2017). The challenge is to ensure you are testing the correct hypothesis with the design before optimising. The specific areas that need to be tested should be identified by laying out the overall architecture that identified the key points of failure to be tested (Choudary, 2015). Key considerations should be given to areas including:

- Multiple user roles – how does the platform deal with different users.
- Open architecture – the platform design must encourage regular use to keep the cycle of creation going.

- Quality control and relevance – the challenge of an open architecture but ensuring quality especially in a healthcare setting; and
- User-generated values – the platform needs users to generate value so must be designed with users in mind (Choudary, 2015).

The design also needs to learn from desktop-based systems that it doesn't become too expansive and complicated through the accretion of features that users stop using or find a hindrance. Parker et al (2017) termed this 'bloatware' and can be seen in many of the issues faced by doctors using complex EPR systems (Wachter, 2015). Baldwin and Woodard (2009) proposed that the platform should be partitioned into a set of 'core' components with low variety and a complimentary set of peripheral components with a high variety. The platform model is then built around this core interaction, and edge interactions should reinforce the core purpose (Choudary, 2015). This project will need to ascertain which components are core and peripheral within the platform to succeed.

From a commercial aspect or how you generate money from a platform, Parker et al (2017) identified four broad value categories:

- For consumers: access to value created on the platform – for this research project, what values are healthcare professionals seeking?
- For producers or third-party providers: Access to a community or market – what tools are needed for other apps to want to operate on the platform?
- For both consumers and producers: Access to tools and services that facilitate interaction – what are the tools and services needed to support a modern healthcare platform?
- For both consumers and producers: Access to curation mechanisms that enhance the quality of interactions – what

enhancements do the users want, and how can these be delivered?

If a platform cannot attract producers and consumers to engage consistently, it is highly likely to fail at creating value (Choudary, 2015).

For the platform to be seen as meeting the needs of its user's, behaviour design should be included to address and encourage user interaction as a sequence of events – trigger, action, reward, and investment (Eyal, 2014). The platform should also create new habits of behaviour by pulling producers and consumers together, facilitating interactions between them and matching supply and demand (Choudary, 2015).

This research project needed to establish what these drivers were for the healthcare users. An alternative view to addressing the same issue was the reward I am getting for my effort or involvement, worth it, often referred to as the social currency (Parker, et al., 2017).

For healthcare, Parker et al (2017) identified this market as a challenge for a platform model driven by resistance based on three factors:

- High regulatory controls – these favour incumbents and can be seen as a blocker for a new model.
- High failure costs – the cost of making an error in healthcare is high, and trust in the platform by the professional would be essential.
- The resource-intensive industry has been the last to be affected by the internet and ensuring that all participants are engaged is a challenge.

These factors should not be seen as a blocker but as a challenge to be overcome and the benefits delivered when one or more platforms emerge that can integrate a wide range of health data from multiple sources and address the issue raised by Vince Kuraitis:

"*Many healthcare value propositions will be dependent on broad networks and platforms. If you had high blood pressure and needed to manage your own care with support from your physician, what good would it be if your lab values were on one platform and your medications were listed on another non-interoperable platform?"* (Kuraitis, 2014, p. 2).

A typical platform architecture is made up of three layers as shown in Figure 4.

Figure 4 Platform Stack (Choudary, 2015).

The platform stack is consistent across all platforms with the variance being on the utilisation of each element that reflects the configuration and positioning of the platform (Choudary, 2015). Examples showing this variation are:

- Craigs list – very large community network but very limited infrastructure play and minimal data leverage.
- Android - very large infrastructure play but with a community for the apps to be resold through and access to consistent data; and
- Airbnb – large play on the data layer holding all the information on properties and recommending actions. (Choudary, 2015)

One factor associated with rapid platform scaling is the 'network effect' where positive network effects drive more users to the platform and the value created for each user. Whereas negative network effects can drive users away and create poor value for the users (Parker, et al., 2017). It should also not be forgotten that when building network effects, you are not designing a technology first approach but an interaction first approach (Choudary, 2015).

Another way of looking at platforms is through its relationships and how information flows:

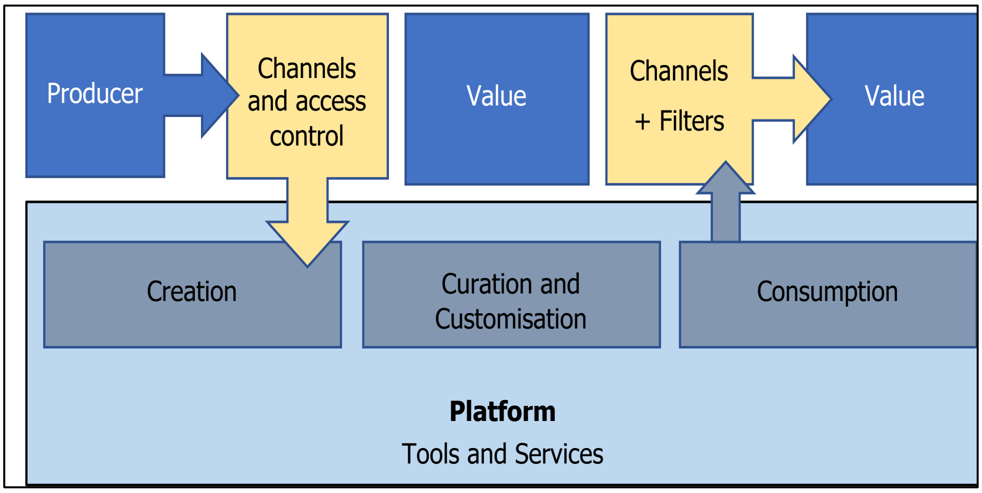


Figure 5 Platform Canvas (Choudary, 2015).

This approach shows the key component parts of a platform as the information flows through it and creates the value. For this project the research needed to identify what each step involved, and the core interaction and values added. Equally the tools and rules applied needed to support the core interaction and processes without creating blockers or boundaries.

2.5.3. Designing Technology Systems

Adoption of new technology in healthcare has had mixed success, diagnostic equipment (for example Computerised Tomography or Magnetic Resonance Imaging) has been very quickly accepted and adopted into workflow as well as some computerised systems i.e., PACS. However, there are more examples of where IT has failed healthcare (Wachter, 2015). For healthcare professionals, managers, and patients to ultimately gain the most from the 4IR and new technology applications in health a new approach to system design, build, test, and implement the systems must be created. There are numerous reasons why adoption has been poor (Wachter, 2015). One of the most significant differences between successful consumer systems and healthcare applications is the approach to user interface and user experience of using the system (Parker, et al., 2017). This isn't suggesting that all healthcare IT companies have been developing systems in isolation but that the approach taken hasn't addressed the core aspect of what the user is trying to do. As Christensen et al (2016) put it, we need to know what the *job to be done is;* we need to understand what progress the customer [user] is trying to make in that given circumstance. This approach follows that we hire a product to help us do a job and the company's aim is to make the experience such that we would 'hire' the product the next time we need to do the same job.

Through this approach, it is vital that we are precise in understanding 'what is the job to be done'. Then tackle it from what the individual task perspective in each circumstance. In doing so, a good innovation will solve a problem that only had inadequate solutions or no solution whilst recognising that it must also fit within the processes and culture of the organisation (Christensen, et al., 2016).

2.5.4. Components for a Successful Application

To deliver a successful application requires a set of components to come together interoperable. For healthcare, algorithms have been used over the last few decades based upon manual calculations originally on paper. As we move into the 4IR and AI and other technologies such as mobile devices can be deployed a new operating model is needed. In section 2.3.1 I explained how Florence Nightingale had used data collected manually from paper records to investigate and understand how disease was progressing and improve outcomes. Roll forward two centuries and the data that was on paper is now in multiple systems not always connected and interoperable. The tools of the 4IR that have collated data from different systems, used that data to train a computer and then used that output to make a recommendation show how this application model operates. Appendix A provides multiple examples including amazon shopping, Netflix video streaming and Uber taxi service using this approach.

Jeremy Wyatt (Professor of Digital Healthcare, Wessex Institute of Health Research) provided the model shown in Figure 6 as an example of the components required for a successful platform play in healthcare.

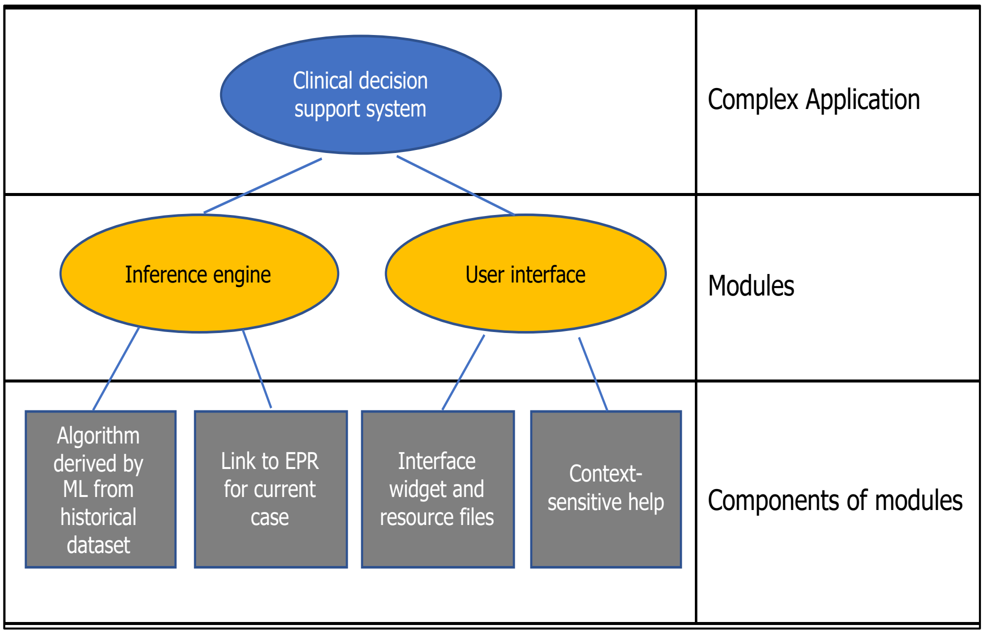


Figure 6 Components Required for a Successful Platform Model in Healthcare (The AHSN Network, 2018).

In this example, three layers are presented that work together provides a complex application outcome – clinical decision support recommendation to a doctor. To achieve this output requires the modular components to provide the input. In this example, there are two elements supporting the automation steps. The patient health data that is held on the Electronic Patient Record (EPR) and an algorithm that has been trained on previous historical data to interpret and understand the EPR data. This process drives the inference – i.e., what can the trained machine infer from the data that is held on the EPR. The second module is the user interface. This requires two modules, one displaying the information and supporting resources. The second module provides advice or help based on the context that the algorithm is operating in. When these are combined the output is advice on a clinical decision driven by the algorithm that has read the data and presented this in a useful way to the clinician with advice on what to do.

An example of this would be alerting for Acute Kidney Injury (AKI) in a hospital. AKIs are common in many admitted patients to hospital affecting up to 20% of admitted patients (Connell, et al., 2017). An AKI is where there is an abrupt disruption to normal kidney function detected through a urine test in a laboratory. In this example the flow would be as follows:

1. The EPR would hold data on the patient including their urine test results from the laboratory (component module 1).
2. The algorithm would look at the results and interpret if they are outside of the expected normal range for that patient (component module 2).
3. If the results are abnormal, it would generate an alert (module 1 output).
4. The alert would be sent to the mobile phone of the on-call response team with the relevant patient data and context (component module 3).
5. The alert system would also hold the relevant information on what to do and how to treat the patient (component module 4).
6. The output (alert and what to do) are presented in an easy to access and use interface (module 2 output).

The combination is a clinical decision support system for the doctor or nurse treating that patient. They receive an alert based on an algorithm reading the data. The alert is presented in context and with advice on what to do.

The development of the cyber vulnerability product for this project looked to follow a similar pattern in its design.

Other industries are utilising the new capabilities and technologies that 4IR is making available. The literature has shown that healthcare is often behind the curve on adopting and utilising these capabilities. Through this research project, I looked to learn from these models and approaches used in other industries and their fit for this specific cyber problem. The objective was to investigate if the approach to the platform model of modules and components works at the specific level for the cyber product. Also, can any generalisations be developed for wider use? These approaches and tools were assessed against the final IS artefact developed to compare the functional layers and uses for this case study.

So far, I have shown the capability of the tools from the 4IR and their potential impact on healthcare. The need healthcare has for new technologies and the key factors that need to be considered. I have selected a specific area within IS and healthcare domains for this case study: cyber security. This is a focused area that uses the tools from the 4IR to deal with threats often driven by tools from the 4IR used for illicit purposes.

2.6. Cyber Security and Healthcare

The literature review has shown that the 4IR will result in a step-change in new technologies deployed to the healthcare industry, whether these are systems, infrastructure, or connected devices. With this increase in digital technology reliance, there is a clear risk that the industry will be exposed to increased cyber threats. Cybercrime is the fastest growing industry globally. The subject of defending against these attacks is the hottest topic on the planet, according to the opening statement by Mario Vello at the foreword to Managing New Cyber Risks (Pogrebna & Skilton, 2019). Luna et al (2016) undertook a systematic review of published literature on cyber threats in healthcare and identified themes for threats, including data breaches, internal and external threats, cyber-squatting, and cyberterrorism. They concluded that current health cyber-security systems do not rival the capabilities of cybercriminals and there is a real risk of denial of service and data breaches in healthcare. This is a real-world problem directly affecting the healthcare industry.

2.6.1. What is Cyber Security

Cyber security has been defined by the National Initiative for Cybersecurity Careers and Studies as:

> *'The activity or process, ability, or capability or state whereby information and communication systems and the information contained therein are protected from and/or defended against damage, unauthorised use or modification or exploration*.' (NICCS, 2019).

Despite this clear definition, there is still confusion within industry and specifically healthcare as to what is and isn't cybersecurity. In the USA the Health Information Trust Alliance states that cybersecurity does not address human errors or mistakes (2014). Coventry and Branley (2018) identified three common threats from their research:

- Hacking – defined as unauthorised access to a computer system.
- Malware (malicious software) – refers to programs designed to infiltrate computers without users' consent - i.e., viruses and ransomware; and
- Insider threats – where staff make mistakes or through deliberate action such as phishing emails being opened or sharing passwords

Pogrebna and Skilton (2019) took a different approach to understand the label of cyber-threat. They separated the definition into two component parts the chance or probability of something happening and then the harm that would be realised. Recognising that although the harm will be to a computer or network, the real impact will be to users and individuals involved. This key concept is that when harm is considered it is the wider impact and not just the systems that need to be considered. Their research also identified a wider assessment of the threats seen from cyber. The ‘periodic table’ of cyber threats (see Table 7), Pogrebna and Skilton (2019)) they identified shows the breadth, depth, and complexity when it comes to developing a solution to cyber risks. For IT and technology staff seeking to develop a strategy to address the broad spectrum of risks there is a need to focus on the areas where there is a high chance and a high harm level. For this project we had to consider the elements that could threaten the NHS and for which the individual organisations could address the risk.

Many of the vectors identified they are protected through existing tools such as anti-virus or drive-by-download through Wi-Fi security protocols. For others the chance is very low such as blockchain majority attack. There are some vectors that need human training as well as technology. Phishing is an example where an email is sent asking the receiver to click on a link to allow the cyber threat to enter the organisation. This vector requires both tools to try and identify the email and block it at the edge of the organisation and staff training not to click on the link.

Many of these threats mapped out in Table are single instance attacks or highly unlikely in the NHS. The key aspects that we considered that are highly likely and have proven to impact the NHS are ransomware attacks. These can impact multiple devices, spread very quickly, and cause real harm. What isn’t available from the periodic table approach is the delivery vector used to open the cyber-risk. This could be emails attachments, weak security, or unpatched software. It is the latter that this research project identified as an area where a new technology developed artefact could make a difference.

			Monomers		Polymers		Composites			
Executable File				Basic monomers		Malware polymers		Composites		
Macro				Malicious monomers		Hybrid polymers		Complex composites		
Exploit						Email or messaging polymers				
Web Crawler						Technical stealth polymers				
Adware										(Cyber) Harassment
Backdoor	Virus	Worm	Trojan	Wiper	Brute force	CAPTCHA Bypass	Payload	Hacking	Advanced Persistent threats (APT)	(Cyber) Theft
Rootkit	Bootkit	Malicious Mobile code	Malicious crypto miners	Malicious bot	Denial of Service (DOS) attack	Man-In-The-Middle	Botnet	Network Attack	Hijacking	(Cyber) Fraud
Logger	Browser Hijacker	Spyware	Point of Sale (POS)	Ransomware	Voice Fabrication	Data dibbling	Unwanted programmes /Apps	Drive-by Download	(Cyber) Extorsion	Cyber Terrorism
Social Engineering	Crimeware	Phishing	Spear-phishing	Whaling	Spam	Water-holing	Malicious Research	E-mail crime	(Cyber) espionage	Cyber Warfare
	Cyber squatting	Stolen Devices	Software piracy	Malicious Insider	Deceptive Callers	Phone Phreaking	Blockchain Majority Attack	Blockchain Price infliction		

Table 7 Periodic Table of Cyber Security Threats (Pogrebna & Skilton, 2019, p. 16).

In looking at how you can gain assurance, the National Cyber Security Centre (NCSC) identified ten steps for cyber security assurance shown in Table 7 below. Whereas the Pogrebna and Skilton model defined the actual attack vectors, the NCSC approach guides the management and executive on actions to minimise and reduce the risk.

Network Security	Protect your networks from attack. Defend the network perimeter, filter out unauthorised access and malicious content. Monitor and test security controls.
User education and awareness	Produce user security policies covering acceptable and secure use of your systems. Include in staff training. Maintain awareness of cyber risks.
Malware prevention	Produce relevant policies and establish anti-malware defences cross your organisation.
Removable media controls	Produce a policy to control all access to removable media types and use. Scan all media for malware before importing onto the corporate system.
Secure configuration	Apply security patches and ensure the secure configuration of all systems is maintained. Create a system inventory and define a baseline build for all devices.
Managing user privileges	Establish effective management processes and limit the number of privileged accounts. Limit user privileges and monitor user activity. Control access to activity and audit logs.

Incident management	Establish an incident response and disaster recovery capability. Test your incident management plans. Provide specialist training. Report criminal incidents to law enforcement.
Monitoring	Establish a monitoring strategy and produce supporting policies. Continuously monitor all systems and networks. Analyse logs for unusual activity that could indicate an attack.
Home and mobile working	Develop a mobile working policy and train staff to adhere to it. Apply the secure baseline and build to all devices. Protect data both in transit and at rest.
Set up your Risk Management Regime	Assess the risks to your organisation's information and systems with the same vigour you would for legal, regulatory, financial, or operational risks. To achieve this, embed a Risk Management Regime across your organisation, supported by the Board and senior managers.

Table 7 NCSC Identified 10 Steps for Cyber Security Assurance (NCSC, 2019).

The broader research into cybersecurity risks has shown that the scope of the subject is complex and even bewildering from a layman's view. Given the breadth, depth, and complexity of the potential cybersecurity risk vectors, NHS Digital has published its framework for cybersecurity to support NHS organisations. The approach adopted doesn't define parameters but states 4 parts of its cyber security support model (CSSM):

- Onsite assessment - To help your organisation identify issues and provide initial guidance on how to overcome areas of high risk and expose vulnerabilities.
- Technical remediation - To fix the issues identified in your on-site assessment, focussing on existing technology and systems.
- Unified cyber risk framework - To embed security into your existing organisation.
- Cyber operational readiness support - To help embed good cyber security practice into your policies, processes, and culture.

(NHS Digital, 2019).

These varying approaches (and there are many more) to baselining the scope of cyber shows the challenges that people tasked with cybersecurity must understand. This research shows this is both a technical and human challenge, and any artefact designed to address this subject needs to consider both elements.

For this project, the fundamental principles identified by NHS Digital in its CSSM approach formed part of the development for the specification for the new artefact. The objective was to build an artefact that addressed the risks identified in the wider industry setting but embedded within the operational model for the NHS.

In designing a new artefact, the key is to be clear on the expected scope of its use. One challenge with focusing on cybersecurity is that the potential scope that cyber threats cover isn't suitable for a single artefact to address. As discussed, these risks cover everything from email training, faulty software code, direct human threats, and vulnerabilities through out-of-date software. The project had to be achievable and grounded so that a clear definable artefact was delivered, and benefits realised for the NHS. The real-world problem the case study addressed was based on cyber vulnerability, which is explained in the next section.

2.6.2. Cyber Vulnerability

It is useful to understand the difference between a cyber vulnerability and a cyber threat when considering cyber vulnerabilities. A threat is associated with the general probability that a malicious cyber act will be realised. A cyber vulnerability is a specific probability due to a gap in the system that could be exploited (Pogrebna & Skilton, 2019). This difference is key in that the threats are very broad and difficult to define. For a vulnerability this is a known issue or a gap in the systems in use that can be addressed. Managing cyber vulnerabilities allow for a clear objective to be established – identify and remove any known vulnerability on a software application. Adopting this approach for the case study allowed a clear focus to be set out and an evaluation of success monitored.

The most common model for dealing with cyber vulnerabilities is patching with a technology solution (Ashden & Sasse, 2013). This requires several steps; the system supplier or a third party to identify the vulnerability. The system supplier to develop the patch or confirm the system won't be updated. The end-user environment needs to determine if it has the system version that has the vulnerability and, once identified to then patch to the new version or remove the system. There is another dimension that would also need to be considered and may impact on the approach to resolution - what is the 'harm' that would occur if the vulnerability was realised. This last aspect will determine the urgency to apply any patch or if no patch is available the risk assessment to continue to use the system accepting the known risk and potential impact if realised. The scale of the risk from a cyber vulnerability being realised is shown in the next section and demonstration the real-world impact.

2.6.3. Cybersecurity Breaches

Despite the significant increase in cybersecurity awareness within the industry and wider user base there are still clear gaps that have led to many security breaches. Examples include Carphone Warehouse in August 2015, TalkTalk in October 2015, Vtech in November 2015, and inadvertent email disclosure by the Bank of England in May 2015 (Evans, et al., 2016). In the NHS there was 7255 data breaches between 2011 and 2014 (Big Brother Watch, 2014). In the UK, Northern Lincolnshire and Goole Hospitals NHS Foundation Trust had to cancel almost all appointments and operations for 4 days with no IT systems running after an attack in 2016 (Evenstad, 2016). The WannaCry breach in 2017 significantly impacted 48 NHS trusts (Ehrenfeld, 2017). This attack was estimated by the Department for Health to have cost the NHS £92m for lost activity and also the recovery work (Department of Health and Social Care, 2018) .

The Ponemon Institute found that 90% of healthcare organisations interviewed had suffered a security breach in the last two years, with 64% reporting a successful attack targeting medical files in 2016 (Gordon, et al., 2017). In 2015 the FDA in the USA issued an alert for an infusion system that could allow an attacker to remotely control the device (ICS-cert, 2015). In January 2017 the FDA issued a similar warning against St. Jude medical radio-frequency-enabled implanted cardiac device (Gordon, et al., 2017). These attacks referred to as Medjack (Medical Device Hijacks) are specifically looking for ways to exploit vulnerabilities in medical devices (Coventry & Branley, 2018).

The WannaCry breach offers a unique insight into some of the challenges faced by the NHS and the impact of not patching a known vulnerability. The following timeline provides an overview into how this cyber-attack occurred (O'Dowd, 2017):

April 8th 2014	Microsoft stops supporting Windows XP as an operating platform
March 14th 2017	Microsoft released a ‘critical’ patch and issued an alert to a known vulnerability (this would have stopped WannaCry if applied)
May 12th 2017	The WannaCry cyber-attack was launched targeting the known issue addressed by Microsoft in its March 14th update
May 13th 2017	48 NHS hospitals in England and 13 NHS organisations in Scotland are infected with the WannaCry virus
May 14th 2017	Microsoft takes the unusual step of releasing a security patch for older unsupported platforms – including XP
May 15th 2017	United Lincolnshire Hospitals NHS Trust had cancelled all routine activity at its hospitals over the weekend.
May 16th 2017	Barts Health NHS Trust (at the time the largest in the UK) had to cancel appointments whilst it worked to address the issue
May 16th to 26th 2017	48 NHS organisations had to work to recover and fix the computer machines infected with WannaCry and recover lost data

The WannaCry Ransomware attack wasn’t targeted at the NHS and over 200,000 computers in approximately 150 countries were affected including FedEx, Renault, and Germany’s railways (O'Dowd, 2017). Whilst in the past cyber security may have been seen as an administrative problem the impact from WannaCry and other ransomware such as ‘Petya’ have made this a public health issue (Gordon, et al., 2017). These types of attacks highlight that even after implementation the software needs to be kept up to date with the latest releases. The dichotomous position is that healthcare organisations are spending large sums on new technology but not sufficient money or time on keeping existing software updated (Kruse, et al., 2017).

2.7. Summary of the Need for a New Cyber Security Artefact in Healthcare

The research background has highlighted at the macro level two interconnected phenomenon: An exponentially increasing technology capability in the 4IR and a health industry with a clear need for the new technology. The challenge and the context for the research is seeking to address the historical problems of designing and deploying the new technology, specifically IS, into healthcare settings. For this thesis the scope and scale of the macro problem were outside that of a practical project focused on delivering an IS artefact. Instead, I identified a subset of IS technology, cyber security as a focused project area, within which I examined how to design new IS artefact for healthcare organisations. Within cyber security vulnerability management was identified as a real-world problem for the NHS with significant impact as the WannaCry attack demonstrated. This research project investigated the specific area where these three elements overlap as highlighted in Figure 7.

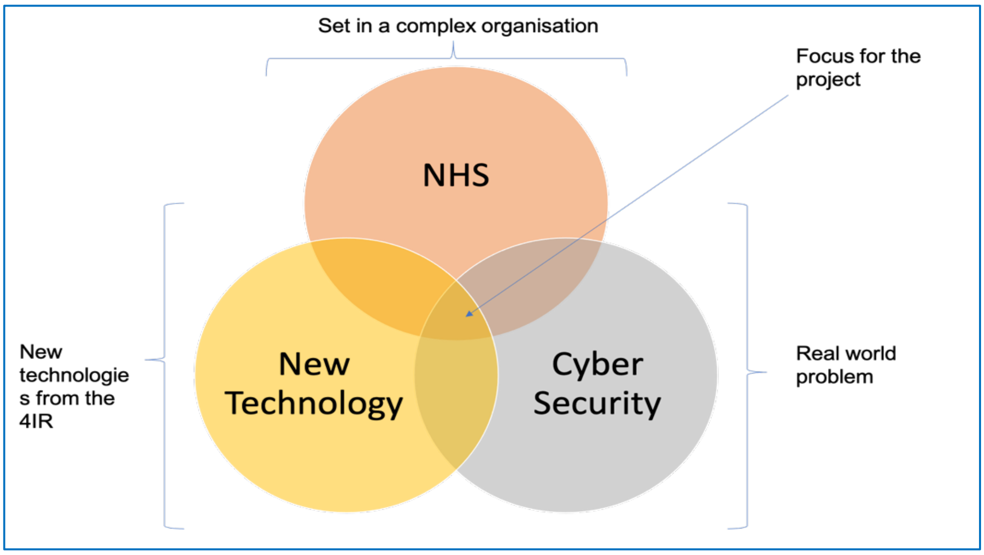


Figure 7 Research Project Focal Area.

The project set out to investigate using ADR to design and implement a new IS artefact through a case study approach. The research sought to investigate how designing a new IS artefact with technology from the 4IR was different (if it was different) from previous IS artefacts designed using technologies of earlier eras. How using machines that can imitate and learn like humans alters the design and outcome process will be an area reviewed in the discussion and outcomes in Chapter 8.

The focus was on the design aspects of a new artefact and not on the implementation and change management of an existing product which is a separate research area.

3. Literature Review and the Theoretical Framework

3.1. Introduction

The literature review is broken down into two parts. The first section reviews the background to Information System Design (ISD). This section considers the relatively recent changes in ISD as both the use of Information Systems (IS) and the academic rigour of design models have been developed and expanded.

The second part of the chapter considers the theoretical framework of Institutional Theory as the lens being used to understand the organisational complexities of the NHS as the background for this project.

3.2. Information System Design in a Complex Environment

The context for the project is the convergence of the 4IR technology capabilities, the threat of cyber vulnerabilities and the complexities of the NHS as the largest organisation in the UK. To design and build a new information system to meet the cyber threats in this context required a methodology that can be proven to address these challenges. This section looks at the background of information system design and supporting literature for this as the basis for the research method for this project.

3.2.1. Introduction to Information Systems Design

The study on IS design as an academic subject began to gain traction in the 1970s and 1980's. Information systems were significantly advanced with the developments that came through the Third Industrial Revolution. The early studies focused on how systems were designed by the early practitioners. During the 1980s, evidence showed that IS design followed a checklist approach of the definition of requirements captured from system users, using narrative language to describe the needs (Hawryszkiewycz, 1988). The outcome of this process was a highly technical document that couldn't be easily followed or maintained (Baskerville, 1993). This approach was associated with the early development of computers whereby the manufacturer had to provide detailed technical documents to the users and built these on the design documents. The next version of system design was based on the mechanistic engineering system development (Baskerville, 1993). This method was based on partitioning the elements of a complex system into smaller component parts and then merge them into the whole solution. The belief behind this approach was that the focus on the smaller more detailed elements was more effective than trying to solve the issue as a single solution. This approach was based on the mechanical model of input, storage, and output (Baskerville, 1993). This model was often referred to as bottom up or waterfall approach. The issue with both early approaches was the weak connection between the solution design being undertaken and the actual need and benefits to be realised by the organisation. Baskerville (1993) believes this is due to the technical aspects that the approach focuses on in the early stages. This results in a poor connection between the original requirements captured and the eventual design specification.

This mechanistic approach has been associated with developing new methodologies based on the introduction of new tools and techniques using software to drive the development. Nandhakumar & Avison (1999) argue that this approach separates the execution and control, and the IS development is essentially programmable. The alternative model Nandhakumar & Avison found in literature was based on the functionalist paradigm. This approach sees the project's outcome achieved by the technical developer taking the requirements and developing the new system through a rational process.

At this stage in the IS theory development, there had been limited research into the process for IS development in their social and organisational setting and their wider impact (Nandhakumar & Avison, 1999). Nandhakumar & Avison, set out to investigate the impact that the actors had to the process, intentionally and unintentionally within the context of the project Their research demonstrated that IS design needed to progress from the fictional belief that everything can be controlled within the design. IS designers needed support where the actors and environment do impact the design process. They summarised their findings as indicating

> *'That the development process is characterized by a continuous stream of intervention, bricolage, improvisation, opportunism, interruption and mutual negotiation as much as by regularity, progress milestones, planning and management control'*
>
> (Nandhakumar & Avison, 1999, p. 188)

Recognising that process will still be critical in a design methodology, the need to understand the impact of the actors and the environmental context will be essential for an IS design study in a complex organisation.

3.2.2. Design Science Research

Henver et al (2004) described two paradigms characterising IS research: behaviour science and design science. With design science emerging from its engineering roots as a problem-solving paradigm. This compares to behavioural science with its roots in natural science research. Henver et al (2004) argued that combining these two paradigms would lead to new design-science research in the information systems framework. The concept was built around the convergence of people, organisations, and technology and was seen as a pivotal moment for the development of Design Science Research (DSR) (Rossi, et al., 2013). The framework itself provided researchers with a way to conduct, evaluate, and present, DSR (Hevner, et al., 2004). Figure 8 shows how the two paradigms come together, and the juxtaposition that derives from IS research.

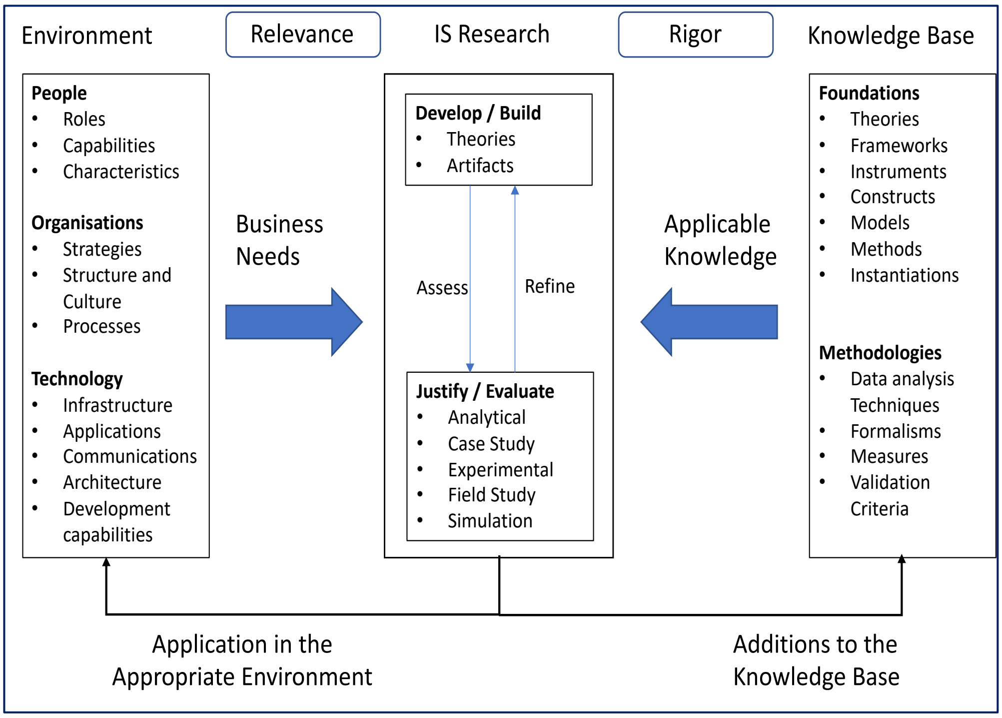


Figure 8 Information Systems Research Framework (Hevner, et al., 2004, p. 80).

This framework helps design researchers visualise how the knowledge coming from reference disciplines provides the rigor. Behaviour science provides the environment to test the truth of the design outcomes. The combination of the two paradigms is the application of information system design research in a business setting. The challenge for researchers is to ensure the approach is used for 'wicked problems' (Buchanan, 1992) and not routine design. The Information Systems Research Framework was developed into seven guidelines for researchers to follow that underpin DSR. Table 8 below summarises these.

Guideline	Description
Guideline 1: Design as an Artefact	Design-science research must produce a viable artefact in theform of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to developtechnology-based solutions for important and

Guideline	Description
	relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact.
Guideline 6: Design as a Search Process	The search for an effective artefact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Table 8 Design-Science Research Guidelines (Hevner, et al., 2004).

As DSR has matured over the last 20 years one of the challenges has been the recognition in the mainstream research publications (Rossi, et al., 2013). The focus during this time was on the actual system and not on what the system was trying to do and how it was developed. The recognition of the need to change to a more naturalistic approach (Orlikowski & Iacono, 2001) has driven an alternative perspective and several different approaches have been proposed. These include more rigor in the approach (Venable, 2006) or an action research approach (Sein, et al., 2011). Rossi et al, stress the need for the focus to be on doing design science research and not on theorising about design science research (2013). The argument being that the knowledge is generated when an artefact is designed – the two are intertwined. Once an artefact has been developed as viable it must be recognised that it is only viable if the environment in which it operates doesn't change. DSR must evolve as the environment changes (Rossi, et al., 2013). The 4IR has been presented as one of continuous change and DSR will need to adjust to an environment that is constantly changing and adapt for that. It is within this environment that DSR now needs to operate where the artefact and the social setting are bundled together (Orlikowski & Iacono, 2001). Examples of this approach include Sein et al (2011) and Purao et al (2013). There is a difference however, between a design theory-based approach (general solution concept) and pragmatic design approach (specific solution that can be generalised) these are explored in the next section.

3.2.3. Designing for Innovative Solutions in a Real-World Setting

Design Science Research has seen interest growing in how it can be used to provide new innovative artefacts to solve new problems (Peffers, et al., 2007, Vaishnavi & Kuechler, 2015). Iivari (2015) identified some confusion over how DSR was being developed through two distinct strategies. The first was based upon a researcher constructing an IT meta-artefact as a general solution concept. The alternative is a researcher attempting to solve a client's specific problem by building a concrete IT artefact in a specific context and seeking to distil knowledge for generalisation. The following tables show the critical aspects of these two differing approaches. Table 9 shows the differences in context and Table 10 shows the differences in outcomes.

Dimension	Strategy 1	Strategy 2
1. Researcher-client relationship	A client may be involved by not necessarily	Client involvement is inevitable

Dimension	Strategy 1	Strategy 2
2. Major problems to be addressed	1. A general problem (a class of problem), more or less informed by specific problems in practice	1. A specific problem encountered by a client (or a set of clients) 2.The general problem (The DSR problem) to be figured out during the DSR project
3. Typical uncertainty of a DSR project	1.Uncertainty about the new, innovative general solution concept to the class if problem 2.Uncertainty about the total complexity of specific problems and their solutions in practice	1. Uncertainty about the specific solution to the specific problem encountered by the client 2. uncertainty about the possible DSR contribution.

Table 9 Contrasting the Two Strategies of DSR-context (Iivari, 2015, p. 108).

Dimension	Strategy 1	Strategy 2
4. Artefacts built	1. Conceptual IT meta-artefact as DSR contribution 2. Possibly a real system implementation	1. A real system implementation as a specific solution to a problem encountered in practice

Dimension	Strategy 1	Strategy 2
	(instantiation) of the conceptual IT meta-artefact	2. Conceptual IT meta-artefact as a DSR contribution 3. Possibly a real system implementation (instantiation) of the conceptual IT meta-artefact
5. Primary role of the real system implementation	Instantiation as a proof of concept and possibly used in the evaluation	The real system as a specific solution to a problem encountered in practice implemented primarily as a source of inspiration Instantiation as a proof of concept and possibly used in the evaluation
6. Nature of target IT artefacts	A *priori* designable system	Emergent system
7. Typical nature of the IT meta-artefact	A new, innovative concept for a software-hardware system or a new innovative systems	New, innovative design principles

Dimension	Strategy 1	Strategy 2
	development approach, method, technique	
8. innovativeness	Innovativeness of the IT meta-artefacts as the DSR contribution varies greatly	Mixed tendencies + if an interdisciplinary team it may foster creativity +practical problems may challenge existing solutions, knowledge, and wisdoms -easily focused on client's current problem -clients may be reluctant to experiment with cutting-edge technology
9. Practical relevance	Varies greatly	A *priori* better equipped to address immediate practical problems

Table 10 Contrasting the Two Strategies of DSR-outcomes (Iivari, 2015, p. 109).

Using this as the basis for this project I identified:

- Direct client involvement – 4 development partner NHS organisations.
- We were addressing a specific problem – how can a technology platform better protect the NHS from a WannaCry type cyber-attack.
    - The ability to then apply these outcomes to the wider cyber threat.
- When we started, we had no certainty about the solution or possible wider consideration.
- The outcomes were a real, emergent system, designed through an interdisciplinary team and implemented for the clients.
- It was based on new innovative design principles to solve a practical problem.

This would align to strategy 2, and Iivari identifies three types of artefacts being developed:

- A real system implementation to address the specific problems of the client.
- Conceptual IT meta-artefacts as DSR contributions; and
- Their instantiation.

This process is seen as emergent and involved a substantial number of practical problems to be solved through action. To address the emergent challenge that DSR generates Sein et al (2011) proposed Action Design Research as a methodology that achieves the dual mission for information system research of:

- Making theoretical contributions; and
- Assist in solving the current and anticipated problems of practitioners.

To achieve this and even extend the relevance of the research the method must explicitly recognise IT artefacts based on the Orlikowski and Iacono definition of:

> '*Shaped by interests, values, and assumption of a wide range of communities of developers, investors, users'.* (2001, p. 121)

Sein et al (2011) argue that this must be achieved whilst still delivering design research through innovation and dealing with a class of problems and systems. This is achieved through a new methodology called Action Design Research – combining Action Research (AR) with Design Research (DR) (first proposed by Iivari (2007)). Through this approach, the researcher can combine building, intervening, and evaluating in a research project.

The attractiveness of this methodology for this project was how it addressed the issue identified by Wachter (2015) that healthcare IT systems appear to be built without the end-user and the setting in mind, and then stakeholders wonder why they fail. From a research perspective, this shows the failure to address a class of problems and intervene in authentic settings (Sein, et al., 2011) and avoids the build then evaluate cycle. The combination of a DR approach with the researcher intervention from AR has been considered before Sein (2011), see (Iivari, 2007). However, Sein et al goes further and propose the new methodology must:

> *'Recognise that the artefact emerges from the interaction with the organizational context even when its initial design is guided by the researchers' intent*.' (2011, p. 40)

There have been limited published papers of ADR in use. A recent case study using ADR by Mullarkey and Hevner (2019) identified four extensions to the ADR method. Firstly, they reviewed and appended the ADR stages with a Diagnosis stage at the outset to enhance the problem formation into a complete diagnostic process. This was combined with the extension of the BIE cycles into full ADR cycles.

The evaluation at each BIE stage allows for enhanced learning and feedback. Secondly, they suggested that each stage be made more transparent for the researcher to follow. The third area is a proposal on how to publish the results from various phases of the ADR cycle. In responding to these extensions, Sein and Rossi (2019) accept and support these additions and enhancements as the ongoing development of the process. There was, however, a fourth extension that the different authors could not agree on. Mullarkey and Hevner (2019) argued that ADR has multiple entry points compared to Sein et al (2011) original and subsequent rebuttal position that ADR can only be entered from a problem formulation stage.

Mullarkey and Hevner (2019) case study research and paper were undertaken at similar time to this project. The objectives of their research aligned to the same desire as mine to test the ADR method. In their instance to provide a new social network system. This supports the use of the ADR method as a tool for developing a new artefact as a researcher and practitioner.

3.2.4. Evaluation in Design Science Research

Evaluation is a key part of any research process. For DSR this focuses on the design science outputs and the build evaluation (Venable, et al., 2012). Without the evaluation DSR can only theorise about the utility of the design artefacts but without evidence of its impact in a real-world setting (Venable, et al., 2016). The two aspects that drive DSR from Hevner et al (2004) original framework of rigor and relevance, then any evaluation must also address these two aspects. This ‘build and evaluate process’ for a new artefact in the environment and knowledge from the research of any evaluation needs to assess the impact of the artefact and the knowledge created (Venable, et al., 2016).

This project evaluated the outcome of the artefact in both its real-world impact – through its contribution to practice in the NHS and its knowledge outcome – through its contribution to theory via this thesis.

3.3. Introduction to Institutional Theory

This research project investigated the design of a new IS artefact for the NHS using the ADR methodology. To augment my research with a theoretical framework that informed my study I drew on Institutional Theory. Currie's investigations into the NHS use of IS systems (Currie, 2012) using Institutional Theory was most closely aligned to the project context and was therefore considered as a good basis for the project.

Currie (2010) positioned her research into NHS and new IS against the background of a continuous drive to modernise health services by adopting new technologies as a government policy. The NHS has been described as a battleground (Currie, 2012) with multiple drivers competing for control, including political, managerial, clinical, and more recently, patients and the public themselves. The outcome of these activities is a dichotomy between traditional management models and new disruptive practices (Scott, et al., 2000). The change over the last 70 years since the NHS was established has been from a professional clinician-led dominance to management practice and a market operating model (Bloomfield, 1991). This change is now continuing with the expectation that technology will revolutionise how healthcare is delivered and managed (Wachter, 2015).

Against these changes, healthcare is seen as a highly institutionalised environment, governed through regulations and directives from the centre (Currie, 2012). In seeking to identify a theoretical framework to study the impact of information systems and technology on healthcare Currie (2012) reviewed a range of approaches, including re-engineering, critical theory, social-technical systems, and cultural approaches. Studies published using these approaches often did not consider the historical significance that may impact any change – positive or negative (Scott, et al., 2000). Currie identified Institutional Theory as a framework that could provide the lens onto the subject recognising the need to capture cross-disciplinary, multi stakeholder and longitudinal input to generate the data that would allow insight (Currie, 2012, p. 237), and conceptual tools and techniques for understanding complex IS change management (Currie, 2009).

3.4. Theoretical Background

The ability of organisations facing political, regulatory, and technological changes to cope is seen as a key determinant of its survival and competitive advantage (Greenwood & Hinings, 1996). The behaviour of organisations is based on their ideas, values and beliefs driven by the context of the organisation (Scott, et al., 2000). This approach isn't unique to Institutional Theory, and the approach can be found in other frameworks such as Pettigrew's change management (Pettigrew, 1987). The uniqueness comes from the focus of institutional theorists on the convergence of the organisation to ideation templates created outside of the organisation (Greenwood & Hinings, 1996). This is when an institution attains a '*stable and durable state or property'* (Currie, 2009, p. 68). As such, the actors within the institution are following the social norms and behaviour without realising they are doing so (Mignerat & Rivard, 2009).

Institutional Theory has been studied for over 80 years with the original focus on influence, coalitions and competing values (Greenwood & Hinings, 1996). This focus was shifted in the 1990s to reflect the new theoretical framework of legitimacy, embeddedness of organisational fields, and how routines and scripts were classified (DiMaggio & Powell, 1991). Greenwood and Hinings (1996) had identified several arguments that Institutional Theory isn't seen as a framework for studying change as such but to focus on the similarities of an organisation. They countered this through providing the model of change linking organisational context and intraorganizational dynamics. They proposed three themes to explain the incidence of radical change in the context of evolutionary and revolutionary approaches:

- A major source of organisational resistance to change is derived from the normative embeddedness of an organisation within its institutional context.
- The incidence and pace of radical change will vary *across* institutional sectors – specifically where sectors are tightly coupled and insulated from ideas practiced in other sectors.
- The incidence and pace of radical change will vary *within* institutional sectors – because organisations vary their internal organisational dynamics.

(Greenwood & Hinings, 1996, p. 1023)

These themes support the concept of how organisations respond differently to stimulus and how quickly they adapt is a function of these dynamics. In so doing altering the archetypal template that has been built by the institution.

There are two types of change, convergent occurring within the existing template; radical where the organisation moves from the current template to a new template (Greenwood & Hinings, 1996). In the context of healthcare, a radical change would be seen as the movement from clinically lead governance to management lead. This change would have been affected by the mimetic, normative, and coercive processes within the NHS institution (Currie, 2012). The ability for any institution to adapt to radical change was summarised as:

- Organisations are structured in terms of archetypes which are institutionally derived.

- Radical change is problematic because of the normative embeddedness of an organisation within its institutional context (convergent change is the more normal occurrence).
- The greater the normative embeddedness of an organisation within the institutional context, the more likely that when change occurs it will be revolutionary rather than evolutionary (Greenwood & Hinings, 1996, p. 1028).

Acceptance is seen when the change gains legitimacy within the organisation (Mignerat & Rivard, 2009). For change to be undertaken it is therefore necessary to understand the internal complexities of an organisation and the associated interest and values of these groups and their complexity (Greenwood & Hinings, 1996). This requires the study of the irrationalities of the organisation and how decisions are made (Mignerat & Rivard, 2009). Yet Currie and Guah found that there was limited rigorous research into IT change management programmes being adopted and diffused in the NHS (2007). There were however studies on policy issues. This lack of research into how change can be affected by inter-organisational factors, the different constituent parts, and power plays without a robust theoretical framework to consider them through resulted in descriptive outcomes (Currie & Guah, 2007).

Scott et al. (2000, p. xii) work on Institutional Theory and healthcare identified that *‘the field of healthcare services .... presents a marvellous opportunity to examine an institutional arena undergoing rapid, even ‘profound’ change’*. Mignerat and Rivard (2009) reported two processes in Institutional Theory; institution effects where one institution is affected by another. The second, Institutionalisation is where the focus is on the formation of the institution and is the only focus. This project will focus on the NHS and how a new IS platform can be legitimised and institutionalised within the NHS.

3.5. The NHS as an Institution

The NHS is a highly institutionalised and complex organisation made up of over:

- 207 clinical commissioning groups
- 135 acute non-specialist trusts (including 84 foundation trusts)
- 17 acute specialist trusts (including 16 foundation trusts)
- 54 mental health trusts (including 42 foundation trusts)
- 35 community providers (11 NHS trusts, 6 foundation trusts, 17 social enterprises and 1 limited company)
- 10 ambulance trusts (including 5 foundation trusts)
- 7454 GP practices
- 853 for-profit and not-for-profit independent sector organisations, providing care to NHS patients from 7331 locations (NHS Confed, 2020).

For the first 40 years of the NHS clinicians had relative autonomy over how healthcare was managed and delivered as an institution (Currie, 2012). The operating model consists of a material resource environment and a set of beliefs, rules, and ideas (Constantinides & Barrett, 2006). The interaction between the two elements is determined by the institutional beliefs which can be seen through the way that template or archetype develops around the actors, governance, and social action of the healthcare systems (Scott, et al., 2000). To fully understand the healthcare environment from an institutional perspective Currie and Guah stipulate the need to *‘adopt a multi-level analysis that considers how societal, inter-organisational, and individual (agency) factors influence, both directly and indirectly, the material-resource environment and the prevailing belief system*,’ (2007, p. 236). The system organisation field includes a wide range of suppliers, resources and consumers seeking to provide on one level a consistent set of deliverables – a standard service to patients. At the same time, large variation in the quality of service, delivery model, administrative approach and use of information technology (Currie & Guah, 2007) across the 2000+ organisations that make up the NHS.

The NHS has traditionally been seen as a vertically integrated organisation where the central body (Department of Health) has worked with the wider key actors to develop the norms in areas such as governance, procedures, and practices (Currie & Guah, 2007). These field boundaries need not be geographical but defined by the interaction of the actors within each field as a community with a common meaning system (Scott, et al., 2000). Healthcare and specifically the NHS hasn't stood still over the last 50 years, and it has been argued the rate of change is increasing (Topol, 2018). Currie and Guah presented these changes into three main phases as shown in Table 12 below:

Institutional logics	Era of professional dominance, 1948-1971. Public sector ethos Professionalism Self-regulation	Era of managerialism 1972-1997 Private sector ethos Performance Government regulation	Era of market mechanisms, 1998- Patient centred ethos Patient choice Public value

Table 11 Three Eras of NHS Institutional Logics (Currie & Guah, 2007, p. 244).

The result of these pressures and drivers for change is an inevitable conflict between the systems' actors, the material-resource environment, and the beliefs legitimising the system. This has led to new policies, practices, targets, and conflicts between politicians, medical professionals, suppliers, managers, and patients (Currie & Guah, 2007). Examples of these changes include:

- The move of the NHS and the wider public sector to adopt private sector practices in areas such as IT procurement and implementation.
- The emphasis on patient involvement and choice as opposed to the previous era where the clinical professional dominance was seen as the norm; and
- The increasing bureaucracy in management and reduction in professional freedom (Currie & Guah, 2007).

Practical examples of these can be seen in the development of the internal market driving the focus on cost management. The increasing user of private sector actors such as Private Finance Initiatives (PFI) for building and running hospitals and the outsourcing of care delivery to private sector providers. All these changes caused confusion in the workforce as NHS staff struggled to manage the new institutional logics against the current logics (Currie & Guah, 2007). The change from a care and compassion behaviour to a cost and efficiency logic.

3.6. Positioning the Institutional Perspective in NHS

The NHS has a poor track record of introducing new information systems and technology (Wachter, 2015) (National Audit Office, 2006). The organisation has been transformed from a paper-based intensive information organisation to one with tens of thousands of computers and systems (Currie & Guah, 2007). It is against this background of change that the concept of Institutional Theory is used to address the value systems within healthcare. Institutional Theory provides a way of observing and capturing the belief systems that influence how individuals respond in an organisational field and provide a '*meaning to their activities'* (Scott, et al., 2000, p. 20). Given the scale and scope of the NHS and its multiple actors and complexity, it is no surprise that it shows institutional behaviours that form the fabric of the organisation. Scott (2001) conveys the significance and need to investigate the belief systems of the field members as they see and understand them. Examples of the institutional behaviour are seen from the political manifestations embedded in policies and directives, through the various stakeholders who interpret and reinterpret these behaviours depending on their impact personally. This process isn't linear with new and old behaviours often conflicting (Currie & Guah, 2007). The institutionalising mechanism shouldn't always be seen as negative or a blocker to innovation. They can in fact *'motivate professionals and organisations to adopt innovations more extensively but also implement more deeply'* (Scarbrough & Kyratsis, 2021, p. 5). The process legitimises the new technology into the organisation and increases the adoption and spread. The reverse is however also true, if a new technology is seen to be forced onto an organisation and there is no proven legitimacy then token adoption could be seen which would not lead to the technology and change being deeply imbedded or spread (Scarbrough & Kyratsis, 2021).

3.7. Institutional Perspective in NHS Information Systems

Currie has undertaken several studies of information systems and the NHS through the lens of Institutional Theory (Currie & Guah, 2007, Currie, 2009, Currie, 2012). The work was focused on the National Programme for IT (NPfIT). NPfIT was at the time seen as the largest information systems transformation programme in the world (Wachter, 2015) and initiated following a number of government reports on the future of the NHS; the NHS Plan in 2000, Building the Information Core – Implementing the NHS Plan in 2001 and the Wanless report in 2002 (Currie & Guah, 2007). These all provided guidance and recommendations on IT for the NHS. This resulted in the establishment of the National Programme (a more detailed report on

NPfIT can be found in Appendix C). Currie's work over several projects investigated areas including:

- *'How can we identify and delineate the key organisation groups and individuals' actors which comprise the organisational field of UK healthcare?*
- *What are the defining institutional behaviours prevailing within and across the NHS in relation to the NPfIT and change programmes generally?*
- *Who are the key players in determining the governance system underpinning the NPfIT?'*
  (Currie & Guah, 2007, p. 239)

Currie's (2010) paper used the Tolbert and Zucker's model of key concepts; innovation, habitualisation, objectification, and sedimentation to interpret the NPfIT as an IS study. At each of these stages, the key is to ensure that the study is placed in the wider social context and not as an isolated unit of analysis. Examples would include:

- Innovation is going beyond the concept of a technical champion to understand all the constituent members, i.e., government, hospitals, patients, and suppliers.
- The challenge for innovation is to progress from the pre-institutionalised state to being fulling habitualised. However, the current habits of the institutional actors may block this process if they can't easily adopt and see the benefits of the change.
- The next stage of objectification or where the value of the change is accepted by the decision-makers. For this to be achieved two tests must be satisfied; firstly, there is a common definition of a generic problem, secondly, the justification of the solution to the problem is on logical or empirical grounds.
- Finally, in sedimentation, the change or innovation is taken for granted across the organisation.

Currie's works have identified several key aspects that formed part of the review on this project and shape some of the learnings from the process. These form the basis of the discussion on how ADR dealt with IS artefact design for a complex organisation.

3.8. NHS Information Systems Changes Over the Last 25 years

The NHS IT strategy has undergone several national directional changes over the last 25 years. The pre-1980s period had limited use of computers in the NHS outside of finance, most patient health records were paper based (Price, et al., 2018). Through the 1980s as computer usage increased the Health Information Support Systems (HISS) programme was initiated (Jones, 2004). The first national IT strategy was released in 1992 and focused on a patient-centred approach with national guidance and local choice (Price, et al., 2018). Since then, the NHS has been through several changes from central guidance, central control, local control, and the latest change back to central control. These changes can be seen in the following Table 12 showing these 'era's:

Era	1990 -2000	2000-2012	2012-2020	2020+
Intuitional behaviour	Central guidance but local choice	Central control	Local control with resources and guidance	Central control returning
Strategic initiatives	• 1992 - Getting Better with Information • 1998 -Information for Health	• 2000 – NHS Plan • 2002 - Delivering 21st Century IT Support for the NHS	• 2012 – The Power of Information • 2014 - NHS Five year Forward View • 2014 - Personalised Healthcare 2020 • 2015 -Information and technology for Better Care • 2015 National Planning Guidance – Delivering the Forward View 2016/17 – 2020/21. • 2016 Lord Carter's Report – Operational productivity and performance in	• 2019 - NHS Long Term Plan • 2021 – Health and Care Bill

Era	1990 -2000	2000-2012	2012-2020	2020+
			English NHS Acute hospitals: Unwarranted variations. • 2018 The Future of Healthcare: our vision for digital, data and technology in health and care. • 2019 Topol Review – preparing the Healthcare Workforce to deliver the Digital Future	

Table 12 NHS IS Institutional Behaviour Changes (Price, et al., 2018, Department of Health and Social Care, 2018, Department of Health and Social Care, 2019, Department of Health and Social Care, 2021).

The significance of these changes is the level of control and decision making at a local level. During the national programme era control of all aspects of IS were centralised (Currie, 2012). This changed when the national programme was cancelled and was replaced with central guidance and resources (funding) but with control and choices at a local level (Price, et al., 2018). This change allowed a shift in power and control from a top-down dynamic to a bottom-up decision model. On a practical basis this allowed local hospitals, executives, and IT managers to select and deploy the technology they wanted with control held locally. In many ways this was the reaction to the failure of the central control model that hadn't engaged with the key local stakeholders and influencers – the doctors and nurses (Currie, 2014). The most recent change with the new Health and Care Bill creating more centralised control (Department of Health and Social Care, 2021). The establishment of central IT bodies such as NHSx and central funding control, there is a shift in power and control from the local hospital back to the central bodies. In a recent presentation the scope of the power shift was made clear when NHSx shared their plans and vision for controlling solution strategy and procurement routes for purchasing new systems (NHSx, 2021). This move reflects the changing dynamics and power base as a new era of more central control is developed.

3.9. Areas Identified from Previous Institutional Research for IS Systems

Currie's work on IT introduction into the NHS through an institutional lens identified several key themes which were used as a starter for consideration for this research project.

- Any IT change must be understood in the wider socio-political and inter-organisational environment, as opposed to just being an IT project delivered to the end-users. These findings match those found by Wachter (2016) where IT dominated change was not met with clinical acceptance and benefits realisation. Where there is a lack of alignment this is a further barrier to adoption (Mignerat & Rivard, 2009).

- The solutions shouldn't be focused on the narrow window of IT and technology, but to win the wider hearts and minds of the users who will be expected to adopt the technology. This was a key finding from Constantinides and Barrett (2006) study. Williams (2016) found the same issue of where vendors failed to match the product to the user's settings and practices.
- Communication is key between those leading the implementation and the intended users of the systems. The need and adoption of user engagement in all aspects of the process for implementation was advocated (National Audit Office, 2006).
- Any IT programme must be understood in the competing institutional behaviours of the history of NHS and its public ethos and professionalism versus the private sector supplier behaviour of efficiency and performance management.
- Explaining to the wider stakeholder why the investment in IT is a priority over the direct investment in staff and treatments, such as drugs. This conflict may be driven by the historical behaviour of professionalism and clinical decision and the prioritisation in short term spending at a local level by executives. If all stakeholders cannot see the benefit of the investment, then resistance will be found. Currie and Guah (2007) found some evidence to suggest that the conflict between these behaviours destabilised the NPfIT as CEOs moved money to different priorities.
- That one size does not fit all, and IT adoption and diffusion occur at a local level (Currie, 2009) You cannot legitimise the

innovation through coercive pressures alone from central government.

- Finally, that policy changes outside of IT often lead to wider institutional forces that can either fuel or prevent the change (Currie, 2012).

Currie's summary view is that healthcare is a highly stable organisation field, and change cannot be made through top-down policies alone. If you do not recognise the 'big picture and the powerful and regulatory forces working at a local level that any study of technology change being made is futile (2009). Orlikowski and Iacono (2001, p. 122) described the 'web models' to ensure that IT is more than just the tools provided but understood within the wider, social context, including the history of commitments, social relationships and processes. Change through IT in organisations can only be delivered when the temporal and multilevel context of the interdependencies between institutional actors and practices are understood (Constantinides & Barrett, 2006).

3.10. Summary

The use of Institutional Theory within the project isn't to test or even add to current literature on institutional research. The rationale was to adopt a framework in which the study could be undertaken on what should be considered when introducing new technology and systems to the NHS. This theoretical approach has limitations, including the criticism of vague and amorphous concepts (Hasselbladh & Kallinikos, 2000). Currie and Guah (2007) also identified the lack of 'agency' in this approach compared to the broader IS literature, which sees the role of 'technical champion' as a key to understanding the change agent role.

A final aspect of this approach is the need for clarity on the research project being focused on the entity (with institutional affects) or the process (institutionalisation) which will determine the environmental and organisational variables used (Currie, 2009). This project needed to ensure that it addressed not only the cause / effect of the relationship between IT related constructs but also the wider environmental inter-organisational levels. Orlikowski & Barley (2001) recommended using Institutional Theory to investigate the effect of design, use, and outcomes of technologies within and across organisations.

The use of institutional perspective allows a lens on the use of a particular system design method and how this would need to be adapted to support a healthcare environment. Through adopting this approach, the research is limited as I am only using the concepts of the Institutional Theory and not adding to the theory itself. The research is also limited in scope to two case studies and a limited number of organisations over a relatively short time scale. The study will seek to deliver a real-world impact that other researchers could build on to maximise the potential for IT to deliver real benefits to the NHS.

4. Solution Design

4.1. Introduction

The phenomenon-driven in-depth case study follows a technology company designing its first new system for cyber security following the WannaCry cyber-attack on the NHS in 2017.

The main research project was launched to develop a new technology platform designed to alert the NHS of a cyber-attack similar to the WannaCry. The case is bounded within the UK Small and Medium Sized Enterprise (SME) business (anonymised as C21 for which the researcher is the founder) that was initially focused on solving this problem for the NHS. The case study follows from an internal discussion in mid 2018 through the development of the new IS product to its installation in the NHS. The NHS was selected as the initial focus due to the public outcry following the WannaCry attack (BBC, 2017) and the level of knowledge and access to the stakeholders that C21 as a supplier to the NHS had.

Whilst the case study was set within a spatial phenonium of the NHS and UK the evidence shows that the research was addressing a global problem across multiple sectors and the generalisability of the solution found.

The case was based upon a descriptive typical approach as defined by Gerring (2017) and follows the development of the product with NHS development partner organisations.

4.2. Methodology

4.2.1. Introduction

The background to Design Science Research (DSR) was reviewed in section 3.2 and Action Design Research (ADR) was identified as the methodology for this project. This chapter focuses on the application of ADR for this project to design and build a new cyber security product for the NHS.

4.2.2. The ADR Method

The ADR method proposed by Sein et al (2011) used the following stages and principles shown in Table 13.

Stage 1: Problem formation	The problem can either be perceived in practice or anticipated by researchers. The output of this stage is the determination of the initial scope, the roles and scope of the practitioner and formulating the research question.	
	Principle 1	To ensure that field problems are seen as knowledge creation opportunities through practice-inspired research at the intersection of technological and organisational domains.
	Principle 2	This principle seeks to ensure that the artefacts created and evaluated are informed by theories and have the power to generalise.
Stage 2: Building, Intervention, and Evaluation	This stage builds the initial design of the IT artefact and is then updated with feedback from organisational use and design cycles. There is a cycle of build, intervention and evaluate as a continuous process.	

	Sein et al proposes for IT dominant artefacts the beta version is taken into the wider organisation and further intervention and evaluation ensues.	
	Principle 3	Recognises the two influences of the IT artefact and the organisation cannot be separated. To address these there must be an iterative process involving the two drivers.
	Principle 4	Reflects the value that all participants are involved in the mutual learning
	Principle 5	The key to the methodology is that evaluation isn’t a separate stage following build but are interwoven into the design process.
Stage 3: Reflection and learning	This stage transfers the learning from the instance to the wider class of problems. This is continuous with the first two stages and allows a conscious decision to reflect on the framing and theories chosen.	
	Principle 6	The principle of guided emergence reflects the combination of the emerging design (principle 2) and the updates to it from interaction with the organisation, participants, and users (Principles 3 and 4) and the demonstration of continuous evaluation (Principle 5).

Stage 4: Formalisation of learning	This stage transfers the problem from a specific problem into a general solution. The outcome from the artefact and the learnings are transferred to design principles and refinements to the theory.	
	Principle 7	The final principle is to move from a specific problem and solution to a generalised solution for a generalised problem and any derivation of design principles from the research outcome.

Table 13 Stages of ADR.

This can be seen diagrammatically as follows in Figure 9 ADR Method: Stage and Principles (Sein, et al., 2011, p. 41).

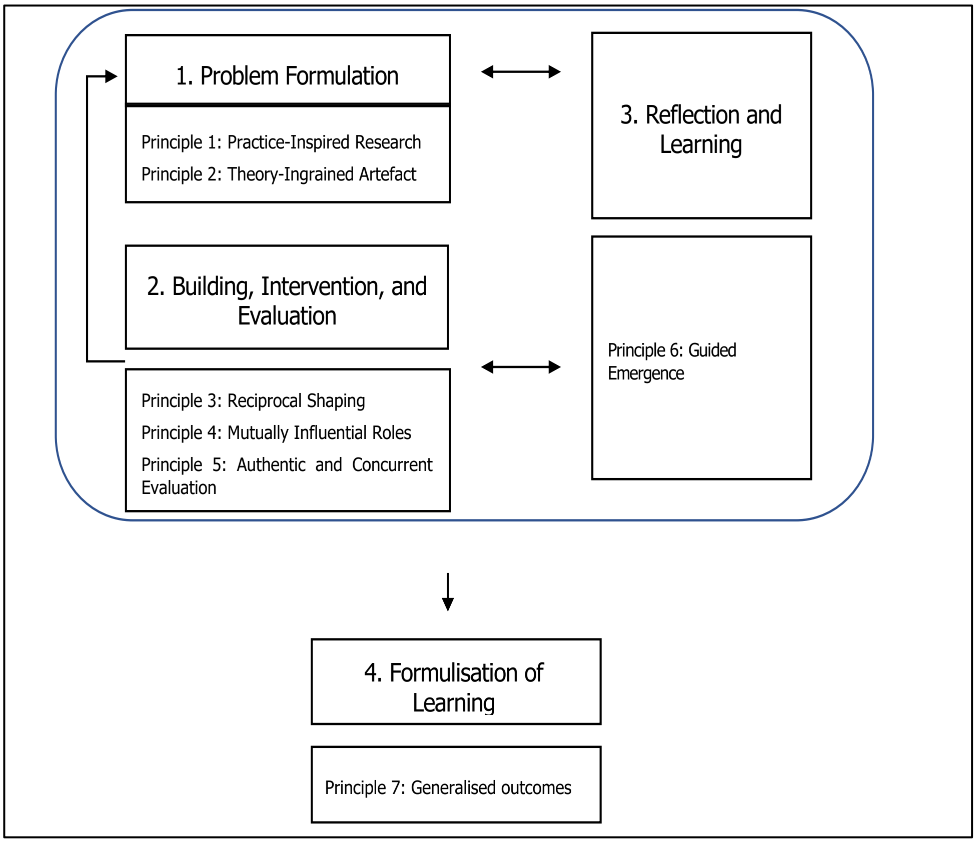


Figure 9 ADR Method: Stage and Principles (Sein, et al., 2011, p. 41).

4.3. Data Collection

I collected data from a broad range of sources throughout the research project. The main methods used were, interviews, workshops, conference attendances, research diary, and survey data. Table 14 Data Sources for the Project shows the data sources and the analysis approached used. The data was collected and analysed through an inductive approach (Currie, 2009).

Before commencing on the Main Case Study, I undertook a Pilot Case Study to review of an established healthcare technology business. The Pilot Case study would provide tentative theories that would form the basis for the Main Case Study research. The Pilot Case Study context is described in section 4.4.1 below. The Pilot Case Study was also a good testing and learning experience for my questioning, listening, and analysing capabilities before commencing the Main Case Study.

Data Sources for both case studies	Description, total and breakdown	Analysis Approach
Interviews	Pilot Case Study interviews with 5 TS staff	Axial coding through 3 stages (See Appendix D and E for the raw data collected)
	Main Case Study Interviews with 5 NHS staff pre-development	
	Main Case Study Interviews with 5	

Data Sources for both case studies	Description, total and breakdown	Analysis Approach
	C21 staff post-development	
Conferences	Attending 4 global conferences	Identify and use specific cyber security innovations to filter and categorise concepts based on open coding (Strauss and Corbin, 1998)
Workshops	Over 20 workshops with NHS	Identify and use ADR method to filter and categorise concepts based on open coding (Strauss and Corbin, 1998)
Survey data on ICT spend	Data spend over 5 years from 79 trusts	Map the data over 5 years and basic statistical analytics of data
Research Diary	Personal research diary covering 3 years of work	Identify and use ADR method to filter and categorise concepts based on open coding

Data Sources for both case studies	Description, total and breakdown	Analysis Approach
		(Strauss and Corbin, 1998)

Table 14 Data Sources for the Project.

4.4. Pilot Case Study: Existing Product Development Company

4.4.1. Purpose of Pilot Case Study

The literature review demonstrated the challenges of developing new technology and implementing this into the healthcare sector including lack of engagement, underfunding, and managing multiple stakeholders. Before commencing the Main Case Study of a new cyber security product for the NHS. I undertook a review of an established healthcare technology business to provide tentative theories that would be the base for the Main Case Study research. Specifically, I wanted to understand from interviewees their experiences and areas they considered key for technology design and adoption. This would help develop insight into what factors such as design, adoption, or implementation to investigate when companies are designing technology for the NHS. I wanted to understand, what in their opinion had worked and equally importantly what had not worked in their current development and implementation process? I was also keen to explore the challenges they have had working with the NHS as a large, fragmented organisation.

The outcome from this Pilot Case Study would then be used to provide the framework for the Main Case Study research questions in testing the ADR methodology for a new product. Through undertaking a Pilot Case Study, it also allowed me to practice the questions and overall approach to data collection. The Pilot Case Study was therefore useful in ensuring the process worked and the semi-structured approach allowed a wider set of data to be collected.

The Pilot Case Study identified 4 themes from the experience of TS (anonymised name for the company) that were then explored further in for the first-round interviews in the Main Case Study. The first theme identified the need for an engagement methodology when dealing with a complex organisation. Areas specifically noted included the power dynamics of senior managers and end-users of the technology. This was seen as the impact of decisions made by stakeholders who were not users of the technology and often resulted in negative outcomes.

The second theme identified governance and the issue of adhering to a process. TS staff clearly felt they had a process, but the evidence suggested this wasn't followed and led to issues with design and adoption. For this research project there was a clear methodology in ADR but how well did this apply within the institution of the NHS was an area explored.

The third theme centred around the feedback process from a complex organisation. Specifically, how can you maintain a relationship over time with the multiple stakeholders and decision-makers within a complex organisation. The findings identified challenges of consistency specifically on testing a product version and the feedback loop. The literature surrounding design methodology identifies the user feedback as critical to the design process and this is an area that was explored further in the Main Case Study research phase.

The final theme and the most interesting was that just delivering 'good' technology didn't always make the difference expected. This area was taken forward into the Main Case Study as a key question. I identified this as the 'so what' question, just having technology doesn't deliver a change and the need to fully understand what other aspects must be considered within an organisation like the NHS for a successful outcome was key.

The Pilot Case Study is structured through an initial background on the company and my role within it. This is followed by data collection approach and analysis, the results and discussion on key findings.

4.4.2. Background

The Pilot Case Study was undertaken at TS Ltd. I was appointed as the CEO of TS Ltd to prepare the company for sale through acquisition. This process was completed in late 2020. The business has over the last 10 years developed a range of data analytics and data visualisation products for the NHS. The company history is broadly broken down into three phases:

<u>Phase 1 research and development</u>: TS began following a review of the H1N1 flu pandemic that impacted the NHS in 2009. The company founders identified that there was no single trusted view of the data across multiple NHS organisations and established TS as a company to build a solution. The first 6 years were spent on various research concepts and ideas before a minimal viable product (MVP) was released in 2016.

<u>Phase 2 early use of the system:</u> following the release of the MVP the company scaled the product rapidly into the NHS and begun to develop new modules as NHS customers presented different use cases to be solved. This was a time of rapid change and product development in multiple areas, not all successfully. During Phase 2 TS developed over 10 standalone products for different NHS customers. The core product originally built on the learnings from the H1N1 pandemic was the product that achieved the most success with the NHS. Whilst other product ideas were sold to the NHS in smaller numbers, and some were never fully deployed at all.

<u>Phase 3 platform development</u>: the latest phase of TS has seen the product portfolio rebuilt onto a platform model. The platform model consists of a single data entry portal for NHS data, a single database holding all the data. Finally, a range of modules sit on that database

and display the data for specific use cases. The original standalone products were assessed against user needs and viability for the NHS – i.e., did the current NHS userbase want to pay for them as a going usable product. The outcome of this assessment was that some products were dropped, and the successful ones migrated to become modules on the new platform. The platform design also allowed new modules to be added when required.

TS products are used across 27% of NHS Clinical Commissioning Groups and have been awarded a place on the NHS National Innovation Accelerator's programme. This indicated good user adoption and acceptance of the technology and products into the NHS as a complex organisation.

4.4.3. Data Collection Approach

The data was collected through 5 semi-structured interviews. These were recorded and then transcribed. The base question asked are shown in the Table 15 below.

Question	Purpose
Introduction and Background	
1. What is your role and background?	Understand role and experience, relax the interviewee
Historical System Development Approach	
2. Could you describe how the early products were conceived and designed?	Experience of early product approach and learning from this model

Question	Purpose
3. Could you describe what worked well in this process	In the interviewees experience what worked well and what were the key attributes /models used
4. Could you describe some of the key challenges you have experienced from managing this process in TS?	In the interviewees experience what were the issues / challenges and why
5. Following this TS process have there been any failures to launch a product or for it to be accepted / or stopped etc	Understand any evidence of impact from the approaches taken
6. In your opinion why have some of these products failed to be accepted? a. Supplementary question based upon answer	Seek any views on why the products failed to be accepted.
7. What do you feel should be done differently?	Broad question seeking interviewees views on what could be done differently
NHS Involvement from TS Perspective	
8. Where all the products conceived around a	Seeking evidence of how and why products were

Question	Purpose
common theme or ad hoc as needs arose? a. How did this work? b. What research into the need was undertaken? c. What were the issues?	conceived and the impact of this approach.
9. In previous development cycles what has been the involvement of the end-user and at what stages? a. Has this caused any issues?	Seeking evidence of any end-user in the design and development stages of the products
10. What from your experience should be undertaken differently?	Seeking views on how the interviewees would undertake the work with the NHS differently now
11. Are there any other factors that should be considered for the next generation of the product portfolio and specifically the command project?	Wider question on future approaches for the next product / module that would be developed,

Table 15 Semi-Structured Interview Questions for Pilot Study.

4.4.3.1. Interviewee Selection

The interviewees were selected from the executive, management, and operational staff to provide input from the breadth and depth of the business and its design approaches. The interviewees included a company founder, two senior managers and two more junior team members. The roles included Chief Technology Officer, Head of Product Design, Operations Manager, Designer, and Systems Implementation Lead. The selection of these individuals ensured a balanced and broad selection of views was captured for the Pilot Study.

4.4.4. Analysis of the Interviews

The interviews were analysed following the established approach of open coding (e.g., Strauss, 1987, Strauss & Corbin 1998, Kaplan 2008). Each transcript was analysed, and a code allocated to each key feature. The features were then mapped through axial coding (Strauss & Corbin 1998) to generate the key themes reflecting the approach to product design for TS within the NHS setting.

This model adopted for this Pilot Case Study would identify through an induction process tentative themes for the Main Case Study to test. The following diagram shows the process followed from initial data being coded and key concepts induced. This was then followed by axial coding leading to the tentative themes being identified. These themes then formed the basis for the main research project and through a deductive process explored, modified, rejected, or verified as the key findings. This process can be seen in Figure 10.

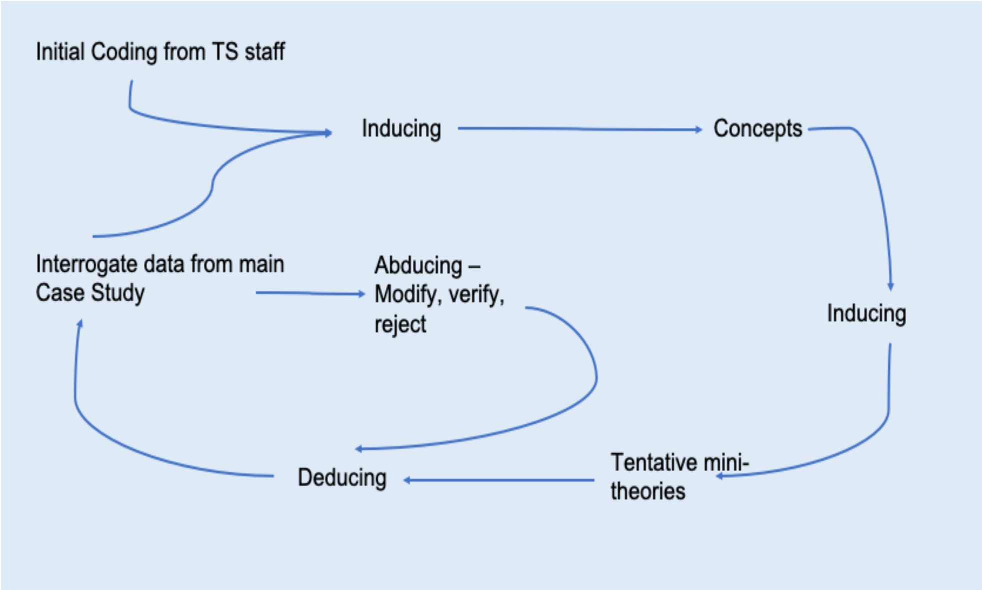


Figure 10 Interpreted from Analysis in Grounded Theory (Ward, Hoare & Gott, 2017).

4.4.5. Findings from the Interviews

The raw coding from the interviews can be found in Appendix D. A total of 82 codes were initially identified. These were then checked for commonalties and reduced to the following tables of summary codes and themes identified.

<u>Theme 1 Stakeholder Engagement</u>

The first theme I identified was appropriate engagement and requirements gathering through strong relationships with the key stakeholders. The development of this theme is shown in Figure 11 below.

Quote	Code	Axial Coding	Theme
where somebody has a really good relationship at a network level, the key stakeholder would be the executive sponsor'	Good relationship with stakeholder key	Engagement with senior staff	Relationship must be with wide base of end users and stakeholders to drive correct needs and requirements
'people in senior positions who can influence within that environment but the wider stakeholders that needed to be influenced to actually make this something that everybody was bought into'	Lead by senior staff only		
'We've not got to the level of stakeholders we've needed to gather requirements more fully or had enough partners to gather a broader set of requirements'	Influence of stakeholders		
In terms of the wider stakeholder engagement was lacking on some of the projects'	Lacking engagement with enough users	Engagement with end users	
'we requested those names of stakeholders and but they just never came through and they didn't give us an enormous amount of their time'	Amount of time available with stakeholders insufficient		
'because the people that were put into it were operational level'	People put in were not operational users		
'We lost the champions that we focused in on'	Lost the champion		
'it wasn't a socialised wide enough to to have been bought into by a wider stakeholder group'	Wasn't socialised enough		
'the requirements gathering wasn't with enough actors and therefore it got focused around again with individuals rather than a broader group of users'	Focused around individuals rather than broader groups		
'ensure that requirements were gathered, prioritized, categorized, signed off by the end users '	Right requirements gathered	Clear analysis and requirements gathered at outset	
'somebody to be able to do a full market analysis of across and gather the right information '	Business analysis		
'I think it's very important that we get the right personas in the room because different users have different viewpoints and utilize the system differently'	Right personas in the room		

Figure 11 Stakeholder Engagement Theme.

This theme seems obvious based upon personal experience and is stated as a key aspect for most models for user-based design (Norman, 2013). The evidence from these interviews reinforced the need for a wide engagement and not to base the design on limited input.

Engagement with Senior Staff

This code was generated from dichotomous views. There is a clear need to engage with senior staff who often hold the budgets and make final decisions on what products to purchase. However, if that is the only engagement then the input is stymied to their view. In complex organisations like the NHS there are many power dynamics in play and a significant difference between a senior stakeholder and a junior member of staff in their use of and engagement with technology. An example provided was TS spent a lot of time and money building 'Bills dashboard' as he (Bill) was a senior manager at a client site. However, once the dashboard had been built, Bill didn't use it. It transpired that Bill's interest moved to a different technology and with no wider NHS userbase for supporting the needs / requirements the product didn't meet anyone else's need and so was discontinued.

"There's been quite a lot of instances where we focused on individual problems instead of saying what's the real problem that we're trying to solve here?"

Head of Product Design

This statement highlights the frustration felt when a product was commissioned by a senior manager from a powerful base position who felt they knew what was needed and dictated the outcome. When in reality it is the wider stakeholders and users of the system that would have identified different issues and therefore different outcomes across the organisation. This conflict was evidenced in the findings from Currie (2009) when she reviewed the National Programme for IT. A decade later the same institutional power conflicts are being evidenced.

This balance and need to manage the different influences within an organisation were identified within these interviews and was explored in the Main Case Study research.

Engagement with End-users

This code was one of the strongest to come from the interviews. Despite the TS internal documented process showing the need for regular engagement with end-users of the product from a wide user base. The evidence from the interviews highlighted numerus cases where this was not followed and resulted in poor outcomes for TS and subsequently the NHS:

The Implementation Manager responding to a failed product stated:

> “It *was developed based on requirements, far too few people and not engaged wide enough for everybody to see the benefit”.*

And this was reinforced when the need for requirements was explored further:

> *“We've not got to the level of stakeholders we've needed to gather requirements more fully or had enough partners to gather a broader set of requirements”*

The consistent theme was not to build the product based upon a single or limited end-user input but to ensure all stakeholders involved in the service provision were included. For a complex organisation like the NHS this will also mean involving stakeholders from multiple different organisations. The NHS is not a single entity but as shown in section 3.5 made up of thousands of different pseudo-independent organisations. This area was explored further in the Main Case Study.

<u>Clear analysis and requirements gathered at outset</u>

The final code identified for this theme resolved around how the ‘need’ was documented that the technology was trying to solve. This code bridged the first two identified in this theme. It demonstrated the necessity for a consistent approach to capturing the needs or requirements of the problem. This is a core basis of many design methodologies and does form part of the ADR approach. The Main

Case Study considered how this would be affected within the NHS as a complex organisation.

Engagement with key stakeholders i.e., those that use the systems is critical. These could be called ‘real users’ or those impacted by the changes rather than the decision makers exclusively. The process must include a wide user base and not be limited to a few even if they are senior staff from a power base in the NHS. This can often be a challenge as the power base sits with senior staff and decision makers who control the access to stakeholders involved and decide who is or isn’t involved. This theme was used in the early engagement process for the new cyber product to explore the stakeholder engagement model for the Main Case Study.

Theme 2 Structured Governance Theme

The second theme developed from the coding was the need for a structured approach to the research, process mapping, development, and governance of the programme. The development of the theme is shown in Figure 12 below.

Quote	Code	Axial Coding	Theme
'you must have the steps and gateways to make sure you're making the right decision'	Governance gateways	Governance	There is a need for a structured approach to research, governance and process
'the problem of poor governance and projects '	Project Governance		
'the poor governance that happens around projects'	Poor governance		
'the developers and designer liaise together and did a lot of the development together in no particularly structured format'	No structured format		
'I don't think we have the resource again to do the business analysis properly to understand and process map '	Process mapping	Design Process	
it was going to solve the problem'	Map the solution		
'good governance takes time and effort and it's easy to bypass it and just jump on the nice shiny thing and do it.'	Bypass process and just jump to nice shiny thing and do it		
'there were little, or no processes'	Lack of process		
'I think it was an ad hoc approach was used to design, build and deliver products'	Ad hoc process for design		
'due to the lack of documentation and lack of fulling any processes'	Lack of documentation for process		
'the governance of our decision making around a new idea and how it gets decided to be commercially viable option hasn't been there.'	Commercial assessment wasn't undertaken	Research the problem, environment and markets fully	
full market analysis of across and gather the right information about who would actually buy this'	Full market analysis		
'we still don't really have a thorough time and motion study '	Time and motion study		

Figure 12 Structured Governance Theme.

Governance

This code came through from most interviewees. It appears to have been used generically to describe multiple areas where the agreed governance processes were not followed. The interesting area to note was that the company claimed to have governance processes in place. However, the adherence to following them or lack of them altogether, led to issues for the product development. Governance in this context was looking at the key decision points for the TS senior team to approve progress to the next stage. Examples of these decision points would be requirements gathering, internal business case to fund the development, design sign off, user testing, and feedback. All these areas it appears were at some point in the development cycle skipped or completely ignored by the TS senior managers.

As the Implementation Lead said:

> *"Good governance takes time and effort and it's easy to bypass it and jump on the nice shiny thing and do it."*

As a small and medium enterprise (SME) company that is seeking to be agile and reactive to customer needs, it is easy to understand why documented processes can be skipped on the belief that the outcome will justify the means. The evidence from this stage of the research shows the need for discipline on the key decisions stages is critical not matter what the size of company. Also, the review shoed the risk of chasing the next new idea without checking on the need and processes being followed. This aspect I believe is far wider than the scope of the current research project, to consider how SMEs manage the conflict between process governance often associated with delays and flexibility to meet perceived need. The use of an agreed methodology such as ADR provides a framework for governance. The ability to adhere to it was investigated in the Main Case Study project.

<u>Design Process</u>

TS has a well-documented and very detailed design process that follows an agile model of feedback loops at each stage of design and some clear gateways that must be passed. Through the course of the data collection there were several projects identified that in hindsight if the documented design process had been followed, would have avoided some costly errors.

"We had over 10 different products that never saw the light of day".

Product Manager

For a small company marketing a small range of products this appears to be a high failure rate. The products failed as key gateways were skipped and so the product continued to be developed even though in hindsight it was clear the products should have been stopped at earlier gateways. This would have avoided effort (time and materials) being spent and in most cases wasted. When these failures to follow the design process are combined with the earlier identified issues of inappropriate requirements gathering and the institution pressures from NHS changes, the outcome of wrong products being developed to solve the wrong need are martialized.

The learning here is that having a process or methodology isn't the key to success but implementing and adopting the methodology is. As the lead designer stated:

> *"I think a project has two Ps on the right processes on people. And you need to get both done right. But I would say almost more importantly, the people bit of it. I'd say 60/40, because if you've got excellent process and the people aren't aligned, it's almost useless."*

<u>Research the Problem Fully</u>

One final area that came through on several of the interviews was the lack of market research of the area that the product was trying to solve. Evidence from the interviews showed that in several cases an individual – often within a senior role in the NHS working with a senior director at TS would identify a problem that technology might solve. From this very limited and brief exchange TS went directly into development. In taking direct action of initiating product development a key opportunity to understand and research the current commercial and technical landscape was missed. Without this research TS wasn’t aware if the product would work for the wider NHS. Or if there were other products or solutions on the market that were already addressing the problem for the NHS.

> *“To be able to do a full market analysis of across and gather the right information about who would actually buy this, maybe we haven't had that particular expertise within the company to do that and build that and bring that information into that governance making decision.”*
>
> *Head of Product Design*

Overall, this section of the Pilot Case Study has identified the need to not only have a methodology or process for design and development. The key challenge is for a company often seeking to rapidly develop new solutions with internal and external stakeholders to adhere to the design process that will protect its investment. The data from the senior team has shown that TS had a good design process but weak governance in following it.

My personal experience has been in programme management and delivery based on stringent set of processes. When the ADR methodology was adopted for the Main Case Study research the adherence and compliance areas were reviewed based on this learning. Also, that consideration is given to a broader market research and analysis than the initial NHS stakeholders provide as direct input to the process to ensure a broader view is considered.

<u>Theme 3 Clear Engagement and Communications Theme</u>

The third theme identified the need for clear engagement and communications throughout the design and build process. This theme builds on the first two for engagement and processes. I have identified it as a new theme as the feedback from the interviewees separated these comments from the initial engagement (theme 1) and the design processes (theme 2) to need for an on-going engagement with the stakeholders. The development of this theme can be seen in Figure 13 below.

Quote	Code	Axial Coding	Theme
'Because I know that there have been meetings set up with user groups on a number of occasions. I've been a part of about three of those now for different products. And they were at late stages.'	Involvement of end users only at late stages of the process	End user involved in all aspects of the process	Maintaining clear engagement and communications throughout the process
'little or no testing with actual users in the process of development'	No testing of actual users		
'we've lost that concept of having user groups'	User groups have been lost		
'ensuring that we have in it we have those regular check backs and present them exactly where we are in the cycle of that development so that they may they stay engaged with what we're doing and they understand what the next step is at all times'	Regular check backs	Communicating during the design process is key	
'I think there is a wide gap in communication that can be very easily improved on. I think it's some biggest one of our biggest areas of biggest opportunities and gaps'	Communication		
'Communication processes and people. Those three things, because especially now things are particularly interesting with the recent events'	Communication, process people		

Figure 13 Clear Engagement and Communications Theme.

The data collected provided several examples of where the interaction with the end-users broke down during the development and then after installation.

<u>End-User Involvement</u>

End-user involvement came through in the interviews at different stages of the design process. The initial engagement at the beginning (theme 1) but also throughout the process. This was identified in the interviews through references to user groups where they would support development prioritisation. The need for end-users was also identified in product testing before the final release. Both prioritisation and testing, had in TS experience, occurred using TS staff only and not NHS end-users of the products.

The Lead Designer reported *"little testing with actual users in the process of development".* This lack of engagement was picked up through the Implementation Lead when reviewing why a product that on paper should have worked, failed:

> *"We didn't engage enough people around it*."

The Chief Technology Officer identified the impact of losing the user groups from the process:

> *"we've lost user groups, we've lost that concept of having user groups, whereas it was part of the whole process has now become an adjunct to everything else we do. And we need to come back to this is part of the process."*

One of the most common terms used throughout the interviews was 'user' being mentioned 42 times. The Lead Designer summed up the overall impression from the process:

> *"I mean, we're trying to be a user centred organization. And I don't think a lot of people fully understand exactly what that means."*

All the interviewees discussed the need for user engagement but little evidence of this activity being truly embedded in the process throughout the life cycle of a product. The evidence from the interviewees all agreed for the need of end-user engagement. The actual lack of this engagement appears to be due to the difficulties of the challenge of consistently engaging with NHS stakeholders. It was easier to work on the product internally and then deliver it as a completed product. This is a critical challenge to any design cycle, to engage early and maintain that engagement throughout the design process.

<u>Theme 4 The 'So What' is New Theme</u>

The final theme to be identified was the most interesting from a personal perspective and research concept. The interviewees identified that the 'use of technology in itself' isn't the end game but just another tool. The coding and thematic development was built from four key areas as shown in the Figure 14 below.

Quote	Code	Axial Coding	Theme
'And generally we'd only have a have one requirements	No requirement exercise undertaken	Be clear on what the problem is and how the technology will address it	What is different now the technology is available
'we've been too fast to rush in to try and solve it. Stand back and think about what it is we're trying to achieve'	Rush to solve the problem		
'we still don't really have a thorough time and motion study '	Time and motion study		
'I do think we need to spend more time now if we want to build a better case study of benefits	What Benefits do we provide		
'then it becomes a deployment problem.'	Deployment problem	Managing the deployment process	
'The project requires far more resource than they ever believe that they're going to have to provide'	NHS needed more staff than anticipated		
'I think people tend not to think about the change element '	Not thinking about the change element	Commitment to the associated change required with the technology	
'They need to commit to the change management part of that then to actually roll it out and make sure it's trained and get it out there'	They need to commit to the change management part		
'we need to really be careful about articulating the change plan for each of those steps'	Articulating the change plan for each stage		
'So what are they going to need to do humanly differently so that our customer understands what they would need to do to to make the change once we've built something that supports the change'	What are they going to do that is humanly different	Technology isn't the answer in itself	
'but there's not an appetite to pay for them or own them in a way that allows you to deliver	No appetitive to deliver them effectively		
'They think the tool will do solve the problem for them'	The tool will not solve the problem for them		

Figure 14 The What is Different Theme.

The analysis identifies that the overall process will only work if you truly understand the problem that the technology is trying to address. The new technology then needs to be deployed successfully. With complex organisations such as the NHS, this hasn't always delivered the success or benefits expected (Wachter, 2015). The final two areas identified were the most interesting to me as the researcher. The level of change management required to deliver the expected benefits and that the technology isn't the answer in itself. The challenge of change management and adoption is well documented in the NHS as a complex organisation (Currie, 2012). These are explored further below.

<u>What is the Problem</u>

The codes captured in the Pilot Case Study reinforced the need to avoid assumptions. This means being confident at the outset of the design process that the design team fully understands the problem for which the technology is trying to solve. It is easy to rush to build something based upon assumptions but as the evidence shows (TS built multiple products that were never used in the NHS) this can lead to failure. The time and effort spent specifying the requirements across a wider user base will provide a strong understanding on which to design and build a solution. This isn't a new theme and has been identified in almost all design processes and as a key finding from Currie's (2009) early work on the NHS National Programme for IT.

<u>Managing the Deployment</u>

This code was derived from several comments on the challenges of deploying new technology into the NHS. This is as well documented challenge (Wachter, 2015) and an area the main study considered further. This code was also associated with the change management code detailed below.

<u>Commitment to Change Management</u>

Change management, or more importantly the commitment to change what you do when the new technology is implemented, was identified by many of the interviewees. The Head of Product Design reflected on their experience:

> *"I think people tend not to think about the change element because I think it is assumed everyone's using software products nowadays, so you just build, package it and deliver. But I think for any products that we create, especially for the NHS, there should be a change element within that and involving the right people from the onset and not just delivering the well packaged product and saying here it is use it."*

This Pilot Case Study identified the proposition that goes beyond just change management and raises the question that just developing and deploying new technology won't necessarily deliver the outcome expected. This was seen most clearly when TS built an alerting tool for operational management. The tool was designed to replace the current manual escalation process for when accident and emergency wait times exceeded the set target. The manual process involved the on-call operations director being informed of the target breach and they then began to contact staff members and ask them to instigate the agreed process, such as opening more beds. The new system automated these alerts to the staff members phones as soon as the data has passed the agreed threshold (i.e., the number of patients waiting in accident and emergency was above 20) had occurred. However, when the technology was introduced, no consideration was given to the change in escalation processes or how reliable the escalation plans were. This lack of change resulted in the product being deemed a failure initially even though it met the requirements as specified.

When I explored this area further in these interviews an additional code was identified that highlighted 'technology isn't the answer in itself'.

<u>Technology isn't the Answer in Itself</u>

This final code was the most interesting to me and for this research project. Just developing and implementing the new technology creates the ‘so what’ question. By this I mean ‘so what’ will you do differently now you have the technology. As the Head of Product Design commented:

> *“They think the tool will solve the problem for them*.”

This final analysis identified a key question for the Main Case Study research to explore further – within a complex organisation like the NHS what is different now that the new technology has been deployed? This area will have significant implications for the NHS as increasingly more technology is delivered through as the 4IR develops new capabilities. By implementing a new technology solution, the organisation and stakeholders will need to be able to answer the ‘so what’ question. What are we going to do differently now than before? What are the implications and how are we going to manage them? In the earlier example of automated escalation, the staff weren’t ready for this process and the changes it initiated. In a different area for example if artificial intelligence can predict when a patient will deteriorate (Fiahult, et al., 2017) what will the doctor do differently and how will this be built into a care pathway. I see this as the ‘so what’ paradigm we need to be able to answer in the design process.

The ‘so what’ paradigm formed a key aspect of the research in the Main Case Study using ADR for a new cyber product for the NHS as an organisation with a poor record of new technology adoption.

4.4.6. Summary from Pilot Case Study

This Pilot Case Study was used to identify through an induction process key themes for the Main Case Study to explore further. The outcome has identified several areas to investigate using ADR to develop the new product for the NHS.

The following themes were used within the Main Case Study as the basis to build the initial interviews and areas to explore with the NHS and C21 team.

Theme one was focused on how the ADR methodology engaged and maintained the relationship with key stakeholders throughout the process. The theme resonates with Institutional Theory emphasis on the power dynamics of senior managers versus users and the wider intuitional political impact.

Theme two explored if the ADR process worked within the governance of the NHS. The experience from TS suggested that having a process or methodology such as ADR in itself isn't sufficient. The execution of the methodology is key. The questions the main research tested was how the ADR method was impacted by the institutional pressures internally and externally.

Theme three built from theme one as a continuous feedback loop of maintaining engagement through the process. How did the ADR method adapt to the institutionally shaped communication patterns of the NHS?

Finally, theme four and the main hypothesis. How can you ensure that new technology developed delivers the difference expected? From this Pilot Case Study there is initial evidence that shows good technology products in themselves don't always deliver the benefits expected. As we move into more advanced technology and consider the capabilities of the 4IR, what factors need to be considered in achieving the expected benefits within the organisational complexity of the NHS. This Pilot Case Study has provided areas to explore including the external pressures from powerful stakeholders. The need for a wide base of stakeholders and ensuring that the 'so what' question has been answered.

The ADR process does include feedback loops in its process however the Main Case Study tested how these were used within the NHS and if there were any gaps.

4.4.7. Next Steps

The outcome from this Pilot Case Study provided a valuable template for the interviews in the main study. The learning has also identified areas that the ADR process was tested against. These include engagement with stakeholders within an institution, external pressures caused by institutional power bases, and how can a design process ensure that the ‘so what’ question on what will change be answered.

4.5. Main Case Study - Developing a Cyber Security Platform for the NHS

The main case study was established to follow the ADR methodology for the creation of a new IS artefact. The methodology is outlined in Figure 15 below. There are 4 main stages within the methodology. The project followed each of these stages which are summarised below. The stages and tasks that the project undertook are described and these stages and steps form the basis for the layout of the next section of the report.

The actual use of each stage and its impact, effectiveness, and the outcomes in terms of IS artefact development and wider generalisations on the use of ADR are discussed in Chapter 5 Solution Evaluation.

4.6. Stage 1: Problem Formulation Stage

Tasks to be performed with the ADR methodology are (my approach to delivering these is in italics after each step):

- Identify and conceptualise the research opportunity.
    - *This was achieved through research with my own team as knowledgeable professionals in this field, wider research at conferences and in-depth interviews with NHS stakeholders.*

- Formulate initial research questions.
  - *The question was formulated from the research and tested with the NHS stakeholders*.
- Cast the problem as an instance of a class of problems.
- Identify contributing theoretical bases and prior technology advances.
  - *Built from the research and the use of the institutional lens on the subject*.
- Secure long-term organisational commitment.
  - *I was able to confirm the company's long-term commitment to the development and for NHS development partners to work with*.
- Set up roles and responsibilities.
  - *The teams' roles and responsibilities were defined*.

4.7. Stage 2: Building, Intervention, and Evaluation

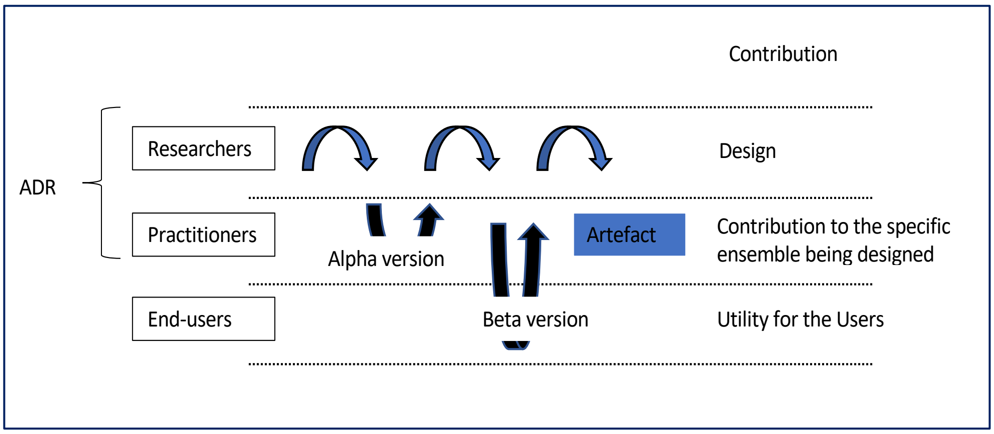


Figure 15 The Generic Schema for IT-dominate BIE (Sein, et al., 2011, p. 42).

Tasks for Stage 2 of the ADR methodology:

- Discover Initial Knowledge-creation target.
  - *Agreed with the NHS development partners.*
- Select or customise BIE form.

    - *Adopted the standard cycle initially*.
- Execute BIE cycles.
    - *Undertook multiple cycles.*
- Assess need for additional cycles, repeat.
    - *There was a need for multiple cycles.*

4.8. Stage 3: Reflection and Learning

Tasks for Stage 3 of the ADR methodology:

- Reflect on the design and redesign during the project.
    - *Significant redesign needed and undertaken throughout the project.*
- Evaluate adherence to principles.
- Analyse intervention results according to stated goals.
    - *Significant movement in goals and how these were delivered.*

4.9. Stage 4: Formulisation of Learning

Tasks for Stage 4 of the ADR methodology:

- Abstract the learning into concepts for a class of field problems.
- Share outcomes and assessment with practitioners.
    - *Feedback received from both the internal company team and the wider NHS stakeholders through system adoption.*
- Articulate outcomes as design principles.
- Articulate learning in light of theories selected.
- Formalise results for dissemination.

The challenge for the project was the generalisability of the outcome and its contribution. Each of these stages and tasks are discussed in detail in Chapter 5.

5. Solution Evaluation

5.1. Introduction

I am presenting the findings from the study using the ADR methodology framework stages as the logical steps. For each stage the data will be analysed against the criteria set in the ADR method emphasising the experiences of the researcher, the C21 team and the stakeholders involved. The findings are based upon this specific case study, generalisations will be made in the subsequent sections and considerations on how to use the ADR framework in similar contexts discussed.

The following Figure 16 shows the stages of the ADR within the project timeline:

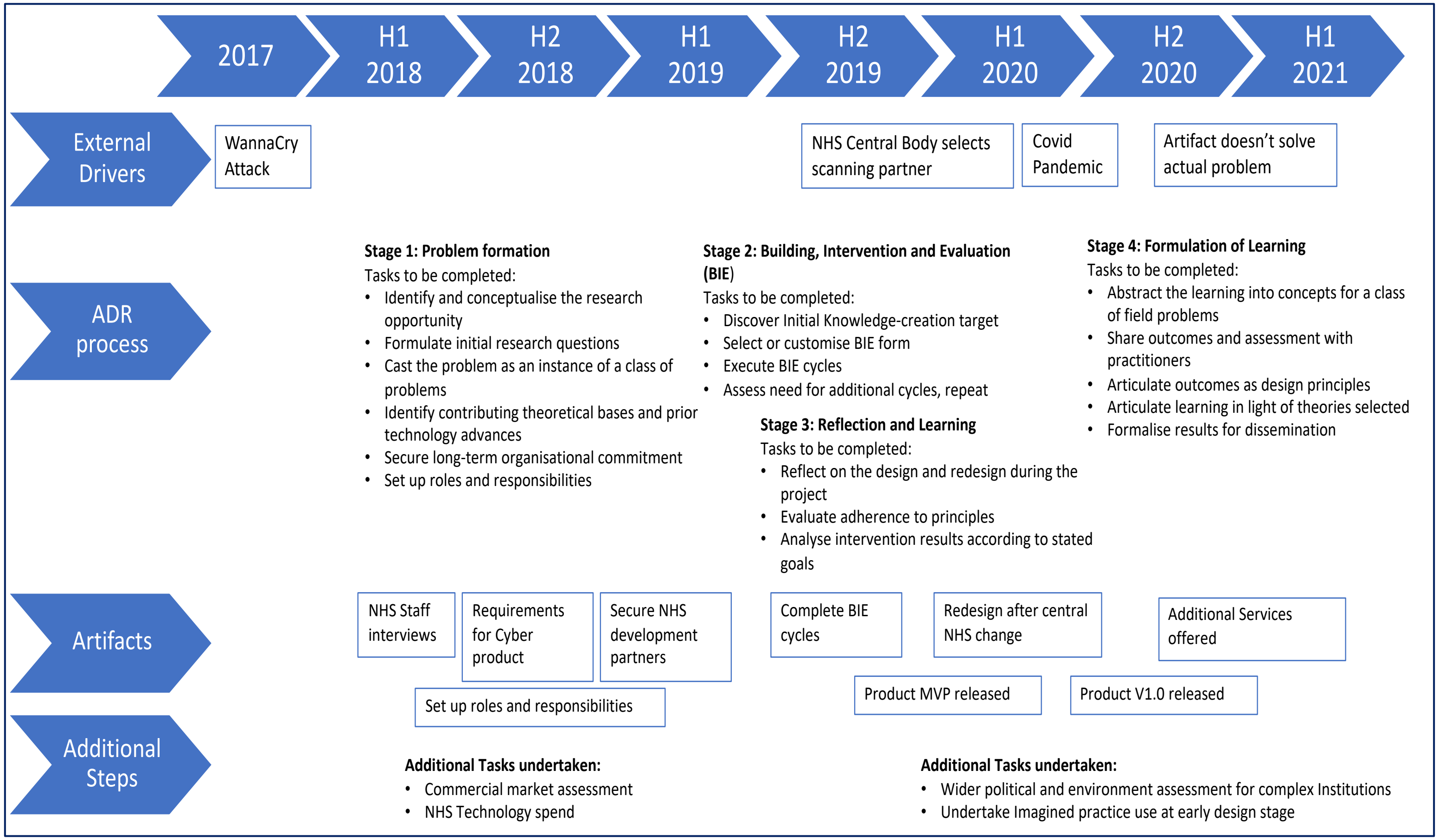


Figure 16 Overview of ADR Approach for the Project.

The findings section of this report is presented using the ADR stages and tasks as a framework. For each Stage and Task, I reviewed how well they worked for this project, the artefacts generated, the impact of external drivers, and finally any new steps I undertook or would recommend are undertaken.

5.2. Stage 1: Problem Formation

5.2.1. Introduction

The Stage 1 of the ADR method proposed by Sein et al (2011) prescribes a set of questions that need to be addressed and tasks completed. I will address each of these in turn and explain how I used the methodology to shape the project following the recommended stages. I will then describe the additional steps I undertook for this stage. The following sections show the questions, principles, and tasks for problem formation that had to be considered initially.

5.2.2. Identify and Conceptualise the Research Opportunity

The first step in the ADR method is initiated by establishing the principal type of problem that is being solved. ADR has identified two principal problem approaches. I needed to determine if this was a field problem, and the creation of the artefact will be driven through a practice-inspired research project at the junction of technological and organisational domains. The alternative option was to create artefacts that were informed by theories and have the power to generalise.

The problem for this project was focused on a very practical challenge to the NHS, how to avoid another cyber-attack through a software vulnerability exposure as demonstrated by the WannaCry attack in 2017. Members of my team had to respond to the WannaCry attack on the NHS and specifically worked in hospitals trying to recover impacted PCs and devices. It was during an internal company discussion after the WannaCry attack that as a team we identified a problem with how NHS organisations, focused initially on the secondary care hospitals, were able to manage their vulnerability risk.

The impact of the WannaCry attack was documented in section 2.6.3, however, these are just statistics. The real impact on the ground was far greater. The NHS has over the last two decades increased its reliance on technology as a core tool used to manage patient care. This was not always successful (Wachter, 2015, National Audit Office, 2006). However, by 2017 electronic systems were in use in every aspect of care delivery and many services could not be delivered without the electronic systems. Examples that we found of the impact from the WannaCry attack are described in Table 16 below:

Service Area	Disruption	Impact
Outpatient Departments	PCs could not be accessed to see patient appointments	Outpatient appointments had to be cancelled but could not initially be rescheduled as the booking system was unavailable. Manual processes had to be initiated
Theatres	PCs would not allow the booking schedule or clinical records to be seen	Operations were cancelled or delayed whilst paper-based records were located
Medical secretaries	PCs were not accessible	Medical reports could not be typed
Medical equipment	The PC attached to a medical device was locked	The medical device could not be used,

Service Area	Disruption	Impact
		and the procedure had to be cancelled

Table 16 Impact from the WannaCry Attack.

The impact of the WannaCry attack meets the requirement for ADR as a field problem to be solved. The problem identified was associated with how an IT leader and team in an NHS hospital can easily access and interpret the multitude of data that is available on cyber risks with the focus on cyber vulnerability risks.

5.2.3. Formulate Initial Research Question

To determine the initial scope of the problem I undertook a set of semi-structured interviews with NHS IT managers and stakeholders as part of scoping the problem task.

5.2.4. Problem Scoping Stage - NHS Staff Interviews

5.2.4.1. Purpose of Interviews

The literature review has demonstrated the challenges of developing new technology and implementing this into the healthcare sector including lack of engagement, underfunding, and multiple stakeholders with different perspectives. To help clarify the scope of the problem I undertook five interviews with NHS staff to establish their views on cybersecurity in the NHS. The outcome of these interviews along with the wider research through conferences and workshops was combined to build the requirements for the initial design for the new cyber vulnerability system – the IT artefact under Stage 2 of the ADR process.

The Pilot Case Study identified four themes from the experience of TS as a company that has delivered systems to the NHS that were then explored further in for the first-round interviews in the Main Case Study. The first theme identified from TS was the need for an engagement methodology when dealing with a complex organisation. Areas specifically noted included the power dynamics of senior managers and end-users of the new technology. This was seen as the impact of decisions made by stakeholders who were not users of the technology and often had negative outcomes. It is clear after the project had completed that we did engage with the correct stakeholders at the hospital level but not the wider stakeholders in central NHS bodies who were removed from the organisation problem we were seeking to resolve. Even with multiple decades of working in the NHS and recognising the constant change I missed the shift of power from local to central.

The second theme from TS identified governance and the issue of adhering to a process. TS staff clearly felt TS as a company had a process, but the evidence suggested this wasn't followed and lead to issues with design and adoption. For this research project there was a clear methodology in ADR and the project explored and demonstrated how well this applied within the NHS.

The third theme from TS centred around the feedback process from a complex organisation. Specifically, how can you maintain a relationship over time with the multiple stakeholders and decision-makers within a complex organisation? The findings identified challenges of consistency, specifically on testing a product version and the feedback loop. The literature surrounding design methodology identifies the user feedback as key to the design process and this is an area that was explored further in the Main Case Study research phase.

The final theme from TS and the most interesting was that just delivering 'good' technology didn't always achieve the difference expected. This area was taken forward into the Main Case Study as a key question. I identified this as the 'so what' question, just having technology doesn't always deliver a change and the need to fully understand what other aspects must be considered within an organisation like the NHS for a successful outcome was key.

The problem scoping interviews are structured through an initial background on the company and my role within it. This is followed by data collection approach and analysis, followed by the results and discussion on key findings.

5.2.4.2. Background

C21 has been working with the NHS since 2010 providing a wide range of professional IT services, including strategy development, IT implementation services, and general IT support. Through this work, C21 has built up a network of partner NHS organisations who were happy to work with C21 on investigating the cyber vulnerability risk problem with a focus on vulnerability management. I identified five NHS staff to interview from these partner NHS organisations to provide the context for the problem under investigation. To articulate the problem and confirm the need for a solution to the problem for the NHS at a local organisation level. The NHS staff interviewed covered the following roles: IT Directors (2), Head of IT, Operations Manager and Cyber Security Manager from four different hospitals. The staff were practitioners in the organisations and would meet the lessons learned from the Pre-liminary Case Study. I ensured that the end-users were included, and data collected from more than one organisation.

5.2.4.3. Data Collection Approach

The data was collected through five semi-structured interviews, with a typical session lasting 45 minutes. These were recorded and then transcribed. The base question asked are shown in the Table 17below:

Question	Purpose
Introduction and Background	
What is your role and background?	Understand role and experience, relax the interviewee
General Cyber Questions	
Could you describe the impact that a cyber-attack has had on your organisation?	Understand what the impact of an attack has had on the organisation – help build the reason why an investment in a new system is needed
Could you describe some of the key challenges you have experienced from managing cyber issues at your organisation?	What aspects do we need to consider the new IT artefact would have to address
In your opinion why are there so many cyber issues or concerns in the NHS?	Background information that we would need to consider
When procuring a new system – IT, clinical or medical device	

Question	Purpose
what process do you follow for understanding the systems and software in use?	Looking at the wider factors involved in procurement of new systems and their interactions with cyber risks
Are you or your team fully involved in every purchase / decision that involves any software or device with a software system?	
What changes would you like to see to how the users outside of IT understand the risks and issues of new devices/equipment / technology they are buying?	
What have the central NHS bodies responded to or implemented to reduce cyber threats?	As the NHS is a large complex organisation what support has been provided from bodies external to the hospital.
What is the process for supporting this?	
Are there any downsides to this?	
WannaCry Specific Responses	
Regarding the WannaCry and DeepBlue threats how would you	Looking for evidence of how the hospital would respond differently and what they

Question	Purpose
manage the response to them today? a. What would be your preferred method / solution?	would need to support this different approach
For a CIO / IT manager to accept a new technology to address this cyber threat what factors do you feel are important: Supplementary based on feedback	Looking for key aspects for the new system
What is your view on the best device for alerting users of concerns / risks – i.e., PC, large TV screen, mobile? (Strengths and limitations and anticipated benefits)? what are the main reasons for this choice?	Looking at specific requirements for the design
Is alerting all that you need to address the concerns you have in managing the response to a potential WannaCry type attack?	
Have any of your previous IT suppliers spent time working on the user interface / experience with you or your team?	

Question	Purpose
Are there any other factors that should be considered for the next generation of cyber security solution?	Wrap up question for anything I had missed.

Table 17 Semi-Structured Questions Asked in Main Case Study.

5.2.4.4. Interviewee Selection

The interviewees were selected from the four development partner hospitals who had agreed to be part of the development. The selection was based upon their experience, knowledge base, and interest. The range of interviewees included a Chief Information Officer, Director of IT, head of IT, Operations Manager, and Cyber Security Manager. This provided a broad range of experience, seniority, and knowledge from four different organisations who would be using the system and potentially purchasers of the system in the future. The use of interviewees from different organisations was a key lesson learnt from the Pilot Study.

5.2.4.5. Analysis of the Interviews

The interviews were analysed following the established approach of open coding (e.g., Strauss, 1987, Strauss & Corbin 1998, Kaplan 2008). Each transcript was analysed, and a code allocated to each key feature. The features were then mapped through axial coding (Strauss & Corbin, 1998) to generate the key themes reflecting the approach to requirements that C21 would need to consider within the NHS setting for a new cyber security product.

The model adopted for this analysis followed the same process I used within the Pilot Case Study at TS. The initial data being coded, and key concepts induced. This was then followed by axial coding leading to the tentative requirements areas being identified. These themes were then explored in greater depth through the design workshops.

5.2.4.6. Findings from the Interviews

The raw coding from the interviews can be found in Appendix E. A total of 37 codes were initially identified. These were then checked for commonalities and reduced to the following tables of summary codes and themes identified.

Theme 1 Impact of Cyber

The first theme I identified was the impact of a cyber-attack on the NHS. This is shown in Figure 16 below.

Quote	Code	Axial Coding	Theme
'The impact is far reaching it doesn't just affect the PCs'	Doesn't just affect PCs as most people think	Impact of cyber-attack isn't just an IT issue	When we design the new system need to consider the wider organisation impact and engagement
'most people think the computers go out of action it also affects the users trying to serve the patients'	Affects users trying to serve the patients		
'I think it needs to come from the top'	Executive support required	Not an IT issue but wider executive team need to own the issue	

Figure 16 Impact of Cyber Theme.

This theme highlighted the need to consider the wider organisation and impact of cyber-security. This may seem obvious, but the NHS does have a legacy of IT systems being seen as 'just for IT' and not involving the wider users (Wachter, 2015). Another aspect that came through was the real effect of a cyber-attack on the NHS and its impact on the patients being cared for and treated. This changes the risk dynamics, as in other industries such as banking or retail, the impact is financial. For the NHS, it literally could be life and death. Examples of this were seen when the WannaCry attack happened on the NHS, and the impact on patient services was reported as tens of thousands of patients affected (Evenstad, 2016).

The solution for the problem and new artefact design would need to consider these aspects in the design process to ensure that the system could support the message of the wider impact a cyber breach would have. There would also be the need for executives to understand the risks their organisation was carrying and support how these threats were managed or mitigated.

<u>Theme 2 Investment in Cyber-security</u>

The second theme developed from the coding was the impact of limited budget for cyber-security. Figure 17 shows the summary coding below.

Quote	Code	Axial Coding	Theme
'Budget – a lot of people don't see cyber security is an issue until after the attack'	Senior people don't see funding cyber security as a key issue	Impact of funding for cyber	The investment in cyber and technology in the NHS doesn't appear to meet service needs
'we have a lot of old kit, trying to get the hardware replaced isn't easy'	Old systems	The NHS has a lot of old systems	
'we don't have the resources it is the balancing between the two of being reactive and proactive'	Resources to react when a problem is identified	There is a need for more than just technology	

Figure 17 NHS IS Investment Theme.

The interview process didn't set out to look at budgets specifically, however the subject was raised fifteen times during the process. There were three key areas discussed.

<u>Funding for Cyber-Security</u>

This code came through as almost a request to help the executive team understand the risks from cyber-security and then fund the investment to protect the organisation. This code was and wasn't surprising. Under the NHS CareCERT programme, Trust Boards are expected to be informed of any major risk identified and the plan to mitigate this. This action should provide the executive team at the hospital with clear visibility and understanding of why the investment is needed. Through personal experience, I have seen the breadth of discussions and financial pressures on Trust Boards and the difficult decisions of prioritising spending decisions between clinical services and support services. The aim is to change the attitude from what one IT manager reported:

'*a lot of people don't see cyber-security as an issue until after an attack'.*

This is 'closing the door after the horse has bolted' and WannaCry showed the impact of this type of approach.

The design process for the new system needed to consider how we can effectively communicate the risk to the executive team. Also bearing in mind how the new system investment costs would need to be positioned against other financial pressures the hospital would be under.

Old Systems

The literature review identified the under-investment in technology in the NHS. The current 'technology debt' that is being carried by the NHS is directly increasing the cyber-risks it is carrying. Through the quantity of old technology in use and therefore old IT operating systems the risk of them being vulnerable to a cyber-attack increases. The context and diversity in types of software and equipment that is embedded with varying lifecycles in NHS organisations is also far wider than would be found in other industries. Almost all medical equipment has an inbuilt IT operating system. Examples include CT scanners, infusion pumps, patient monitoring devices, and laboratory equipment. These systems are not normally under the control of IT and the users will not be aware of the IT system in use or the risks being carried.

The situation is complicated further as many of these medical devices cannot easily or cost-effectively be replaced or updated. In many instances, the clinical teams cannot see or understand the risk. If replacing or upgrading the medical equipment isn't an option, then the new cyber vulnerability design will need to consider how to identify the risks and communicate them.

<u>Resources to React</u>

The final code highlighted an area also identified in the Pilot Case study. There was a concern that have a new technology solution would not in itself resolve the problem for them. There was also the question of 'so what', the system has identified an issue, but do we have the resources to resolve the issue. This code was the most raised with the issue being mentioned eleven times. In the design process we considered how we could mitigate the need for human intervention. There was at this early stage no consideration of going beyond a technology solution. We didn't consider the 'imagined use case' sufficiently to fully understand that the new artefact would solve the problem as shaped but not solve the end-to-end issue i.e., the 'so what' question of how the IT team would manage the output form the new system we designed.

<u>New Area for Research</u>

As the discussion and impact of investment and budget was raised so often, I initiated a separate research workstream into the current budgetary spend of NHS hospitals on IT and cyber-security. This is discussed in section 5.3.7.

<u>Theme 3 Design Aspects Theme</u>

The third theme identified was a wide range of areas that were considered as part of the design process. The data collected helped provide the basis for the design concept and an initial version that was then tested with user groups from the NHS. The codes were grouped as follows in Figure 18 below.

Quote	Code	Axial Coding	Theme
'At the moment we have multiple tools and there is no one window into any of it'	Lots of tools but no one window showing the risk	Currently using multiple systems but no clear picture	Key aspects for the design
'I would like to have something up on the wall a nice big display'	Visual on the wall	Easy to spot the key message / risk and share	
' Mobile would be great we all have work phones we get emails on them all the time'	Mobile alerts		
'should be far more proactive and should alerting them it is detecting malicious or anomalous activity that needs investigation'	Alerting to the key issues		
'ideally an automated process that would pop up as an app on the phone or something like that'	Automated processes in vulnerability management	Currently a lot of the process is manual work checking spreadsheets and cross reviewing different reports	
'it takes a lot of manual effort '	A lot of manual processes in current response		
'I think when we look at advancements in AI for instance there is a real example of actually how can advanced analytics / AI ML actually identify'	Use of AI		
'It is usually off the shelf product a lot of companies will say it is NHS specific or it is trying to solve an NHS problem but it is off the shelf and that is just a sales pitch '	Software normally off the shelf and not designed for NHS	Building into the design process the challenges of working with the NHS	
'I would want it to be flexible in the NHS there is a bit of culture '	Flexible to meet NHS culture		
'sometime the board I think don't understand what cyber security is but something visual that showed them that what there threat score or risk score would be very powerful'	Easy to understand reports for trust boards	Easy to use and report risks from the system	
'what is attractive to me I want it to be seamless I don't want the users to have any adverse effect'	Seamless process		
'challenge is to how do we actually communicate '	Communicate the risk easily		
'a way of being able to actively detect and protect those better MDM solutions aren't always great at deploying patches across every kind of platform and threats are becoming more and more '	Mobile device management	The system itself cannot be seen as a risk and how would it work on mobiles	
'I would want the solution to be secure in itself because if it is a security product you want it to be secure the foundations '	Secure in itself		

Figure 18 Design Aspects to Consider.

<u>Hospitals Currently Have Multiple Monitoring Systems</u>

A consistent code identified was the multiple different systems and processes the IT staff were using. The challenge or issue was that these systems only covered part of the need the technology staff required. An example would be there was a system for monitoring anti-virus, a system for monitoring windows applications, an excel spreadsheet from NHS Digital for cyber-risks, and a system for monitoring network traffic. All these operated differently, required different actions and did not provide a single lens on the whole cyber-risk picture and some areas were left unmonitored. This was summarised by an interviewee:

> *'So, one challenge is not knowing what you have got entirely and there isn't anything giving you the full picture'*

The new cyber vulnerability system being designed needed to consider how to reduce the quantity of processes and systems being viewed to deliver an improvement in services.

<u>Easy to Spot the Key Alerts</u>

This code identified the need to ensure that the system user could easily identify the key alerts. There is evidence that the growing number of prompts may be counterproductive as healthcare professionals are increasingly suffering from "reminder fatigue" meaning many reminders are ignored (Backman, et al., 2017, p. 2). The new cyber vulnerability system needed to consider in its design how to message a risk but not overload the users with multiple alerts. The balance between the two was a critical design aspect.

<u>Removing Manual Processes</u>

This code augments the resource pressure identified in the budget theme. The current situation is heavily dependent on manual intervention and processes.

> *"Because if a CareCERT comes out we need to check if we have a particular system or bit of hardware that is affected by the vulnerability and now it is in the CareCERT. We have spreadsheets which tell us what assets we have we have some*

tools that tell us what PCs we have out there and what software we are running but in order to go back and confirm affected or not affected we must check all of that manually, so it is quite an overhead on the team". NHS IT Manager

A key requirement for the new system was to automate as much of the process as possible and even discuss the future role AI will have and how this could be used. At this stage the plan was to see what technology could be developed to remove the manual checking currently used.

The Challenge of Working with the NHS

This code flagged up some of the issues the interviewees had encountered with systems not designed for the NHS. The interviewees raised issues around the NHS culture and how some 'off the shelf' systems weren't suitable for the NHS. An example included a globally well-known cyber security product that was designed for cyber specialists but not for general IT users. As such when the system was purchased it couldn't be used as the requisite skills were not in the IT department. The issue of skilled resources was raised as another factor for consideration. The interviewees identified that the NHS operate a national pay scale and the role of cyber specialists pay does not match that paid in other industries. This makes recruitment of the correct skills for managing cyber issues challenging.

These factors were considered during the design phase, but the full implication not understood at the early design stages. The product was being designed for the NHS, but we were also seeking a product that was more generic and could be used in other sectors. The issue of appropriate skill capability in the NHS was another factor that had to be consider in the design process.

Ease of Use

The key codes that have driven this co-axial outcome were the frequent references to reporting and communicating the risk easily for the wider organisation stakeholders. The data collected indicated concerns around how the complexity of reporting cyber security and vulnerability risks were made to the stakeholders outside of the IT department. The process needed, through the design stages, to ensure that the outputs from the system disseminated the information in an easy to interpret and understood way for the appropriate audience. Specifically, the report for the executive team must display what is important to them – what is the risk, its impact and what is being done to mitigate this risk. The data presented for general staff must be aligned to what they need to know – general level of threat or specific impact for their department and themselves.

Secure in Itself

The last code was obvious but the implication in the design was significant. The new system itself had to be secure and not pose a risk by providing an attack vector for cyber criminals. The system needed to be built with this in mind from the concept through to final delivery.

Summary

This section has highlighted the main factors that the interviewees felt initiated the problem and what a new cyber vulnerability platform had to consider. The outcomes of these codes influenced the design at a macro level but also highlighted areas that were not identified through internal assessment only. Examples of these new areas included the need to not just add another system to the list the IT team at an NHS Trust already had but seek to provide a single view of relevant data. The code on automation was one that needed further investigation through the design process to understand what could and what should be automated.

Theme 4 External Factors Theme

The final theme to be identified was the most interesting from a personal perspective and research concept. The interviewees identified several external factors that could impact on the design process and eventual artefact developed. The coding and thematic development was built from the areas as shown in the Figure 19 below.

Quote	Code	Axial Coding	Theme
'the one hand be told to do things from central government '	NHS Central support for the hospitals	External influences to be considered	These are external factors that need to be considered in the design process
'at the moment because there is no national direction'	No national direction		
'and we have to manually review those'	Current process needs a lot of manual checking	Resource implications need to be considered outside of the IT artifact	
'at the moment we are try run that through an excel spreadsheet but the reality is that we don't have enough resource'	Current alerts from central NHS are excel sheets		
'I have seen all sorts there has been complete lack of knowledge or understanding from the cyber security side of it, they are purely looking at it from a clinical level '	Systems purchased without cyber assessment	The impact of 3rd party actions on cyber security	
'A lot of systems are legacy shall we say suppliers are very slow at times and adopt best practices'	Suppliers need to take more responsibility		

Figure 19 External Factors Theme.

The final set of codes identified provided insight into factors outside of the core system design and operating model. At the time of the data being collected and analysed the true significance of these was not appreciated. The implication of not considering two of these codes (external influences and resource implications) impacted the design, investment cost and eventually the new service being offered. This subject is explored further in section 5.5.3.2.

<u>External Influences</u>

These codes first indicated the effect of external influences and factors on NHS hospitals as one interviewee shared:

> *"so we are on the one hand be told to do things from central government, locally we need to understand where we are and there are local initiatives plus we have got cyber essentials plus which is an accreditation we have all these different things should we be doing it what should we be doing what is the priority so you have these conflicting drivers which are out there*

> *and you have other internal drives on how our estate is affected and we need to get them working'.*

As described in section 3.5 the NHS isn't s single organisation but a complex and multi-tiered organisation. The result of the structural model is that unlike a single organisation, NHS hospitals have multiple internal NHS influences that come from outside of their own organisation. Examples from the interviews included the establishment and management of CareCERTs. This provided clear notification of potential cyber risk but also added a significant amount of work to the hospital. The work was associated with reporting and monitoring rather than the actual work needed to resolve an issue. There was also a mention of limited national direction provided from NHS Digital. This specific code was only noted once and so couldn't be validated with data from other interviewees but is an area that was considered further in the design phase.

Resource Implications

The issue of resources needed to manage and respond to NHS Digital CareCERTs was raised by four of the interviewees. The implication was the workload needed to manage the excel spreadsheet-based system used by NHS Digital was creating significant pressure on the IT teams. If the new system reduced the resource overhead required to meet external requirements that would be a significant improvement in workflow. As one IT director stated:

> *'..there is an array of alerts that come through on a weekly basis. We just can't manage with the resources we have within the organisation'.*

The same issue was raised even when you are alerted to an issue, by two of the interviewees:

> *"The next thing is around what do we have to do to address that, what is the effort to address that and understanding that*

> *because there is no point having an alert without doing nothing with it is trying to explore what that would look like"*

> *"But then there's the other element of it is how do you then deal with that? It's not just about knowing about is how do we do it? Who deals with that? And that's probably where we're where we are at the moment"*

This issue currently fell outside of the scope of the IT artefact but was considered in the project as part of the larger solution. The failure to fully recognise that at the design stage we needed to consider the imagined use of the product and how would the IT artefact in itself solve the real problem was a mistake. This is a key lesson learnt and whilst not explicit in the ADR cycle, is an aspect I would highly recommend when designing new IT artefacts to invest the time in fully understanding the imagined use of the new artefact.

3rd Party Impact

The final code identified was associated with the impact of IT operating systems being located on devices outside of the normal control of IT department. As discussed in section 2.6 a wide range of medical devices and equipment contain IT operating systems that are vulnerable to cyber-attacks. This code reflected the desire that these manufacturers and purchasers of these items considered cyber risks when developing, supplying, and supporting them within the NHS.

A good example was provided by an interviewee:

> *"We have a lot of system suppliers for some reason aren't able to update to the latest standards and the NHS has no ability to mandate that"*

This final code and theme identified an area for further research outside of this project around the risks that medical equipment carry from a cyber risk perspective.

5.2.5. Summary from Problem Scope NHS Interview Data Collection

The interviews from the five key stakeholders from four NHS Trusts provided four key themes that had to be considered in the design process. The key considerations were used to support the initial minimal viable product including how we engaged with the wider organisation so that the product isn't just designed for IT technicians.

Budgetary constraints and issues were raised as concerns for how well prepared the NHS was for managing cyber risks and attacks. This theme was explored further with specific analysis on NHS spending on IT and cyber management in section 5.3.7.

There were a range of key requirements identified that had to be considered in the design process including the challenge of working with the NHS itself. This aspect caused considerable discussion internally as a business seeking a wider market than just the NHS, how could the dichotomy of a product being specific to NHS versus generic be resolved. The decision was made in the ADR cycle based on findings from the customer feedback and internal investment decisions to focus on the real-world problem we had first and then consider wider generalisations later.

The final theme and one not considered critical at the initial stages of design was external influences. Colleagues and I working on the project were aware of the influences from external parts of the NHS – i.e., within the NHS but external to the hospitals we were speaking to. The impact of these external influences had a significant impact on the design and outcome of the new product at a later stage. Institutional Theory explores the power base within organisations and affects they have on policy and service delivery. For this project that change came from a central NHS Digital decision to procure a specific network scanning tool. Our adoption of the ADR process hadn't considered the wider stakeholders who were removed from the hospital setting. The impact from this error was realised with the minimal viable product initially including a scanning solution that we would have to remove at a later date. This is explored further in section 5.5.2.

5.2.6. Next Steps

The outcome from this problem scoping data collection provided a good basis for Stage 2 of the ADR method. The process also identified two factors that would require further work including investigations into the NHS IT and cyber management budget and the external competitor influences on the process. The outcome of this work is discussed in section 5.3.5. These areas combined provided a broader picture of the wider institutional field in which the new artefact would operate. The process for wider institutional study wasn’t explicitly called out in the methodology although it could be argued that to determine if this was a field problem, and therefore the creation of the artefact would be driven through practice-inspired research. This would suggest the wider considerations were needed. I would make a recommendation of ensuring that when using ADR in a complex organisational setting i.e., any public sector body that the stakeholder maps all stakeholders and influencers at all levels of the organisation are correctly identified.

5.3. The Problem to be Solved

The first ADR stage identified the problem as being perceived in practice through the WannaCry attack. This was confirmed with the Problem Scoping interviews and competitive market research. The output of this stage was the determination of the initial scope, the roles and scope of the practitioner, and formulating the research question.

5.3.1. Initial Scope

The ADR process adopted and extended with the addition of the competitive market review allowed the initial scope to be identified.

This was easiest presented as a diagram of the problem or rich picture as shown in Figure 20 below.

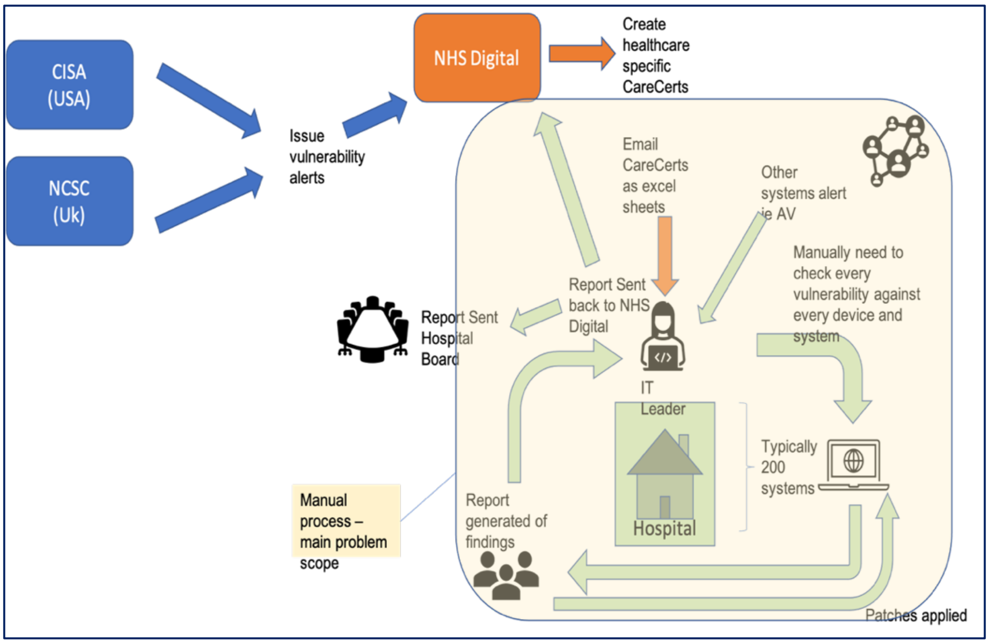


Figure 20 Rich Picture of the Problem Scope.

From this rich picture the product design needed to address the following problems in Table 18 below.

Problem Area	Problem to be solved
CareCERTs are issued as an excel spreadsheet	The CareCERTs are issued as excel spreadsheets via email to the IT department. They contain all the vulnerability alerts which have had their urgency set but NHS Digital. There isn't any filtering for the systems the organisation may or may not have.
Manual check of all potential devices and	The IT team will need to then check all their systems and devices to see if the specific vulnerability exists. This is a manual process of scanning every

Problem Area	Problem to be solved
systems to identify any matching vulnerabilities	device and checking the software compared to the CareCERT.
Alerting the IT team to the vulnerabilities	The outcome of the scan then needs to be checked and then the appropriate teams and people alerted to act. This is again a manual process.
Providing a single lens on cyber vulnerabilities	Alongside the CareCERTs there are several other systems that can identify vulnerabilities including anti-virus (AV) and system licensing tools. These are separate systems with no single view of all the risk surfaces.
Report generation for organisation and NHS Digital	The IT Director then (depending upon risk level) must create a report for the hospital Board to alert them of any risk and a report to NHS Digital. This is another manual process.
Confirming vulnerability has been mitigated	The final step is to remove the vulnerability (often requires a system patch to be made). Before finally checking again manually that the vulnerability has been resolved.

Table 18 Problems to be Solved.

The new product sought to automate and summarise as many of these steps as possible and address the challenges raised from the Problems Scope Interviews.

5.3.2. Cast the Problem as an Instance of a Class of Problems

The research from the Problem Scoping Interviews and the broader competitive landscape identified the main problem as a need for a technology solution that could automate the current process of vulnerability risk identification. The solution sat well within the need for a new IT artefact that addresses this issue. The requirement for automation was mentioned nine times in the interviews with NHS IT staff and generated one of the axial codes. This class of problem also mapped to the market assessment where new systems were being developed to address the cyber risks being generated. It has been reported that this problem area is a race between the perpetrators of the cyber-attack using technology from 4IR and new systems being designed to protect organisations (Pogrebna & Skilton, 2019).

5.3.3. Identify Contributing Theoretical Bases and Prior Technology Advances

I am using the ADR approach and setting this within the Institutional Theory framework as established in Chapter 3. The contribution of using the lens of Institutional Theory helped to understand how the approach to NHS organisations, the stakeholders, and power bases within the organisation worked and where it failed. The project built upon the work by Currie and used the outcome of her work on the National Programme for IT (Currie, 2012). This identified several areas that would have to be addressed including change management and how societal, interorganisational, and individual (agency) factors influence decisions. This project was focused interorganisational as meaning between different hospitals and the power influencers. I failed to consider the wider somewhat removed stakeholders and power influencers from central NHS and government bodies.

The technology advances within this industry have been reviewed within Chapter 2. The 4IR has shown the expectation of what technology advances will deliver for the healthcare sector. This needs to be considered in light of the issues the healthcare sector has had historically with adopting new technology (Wachter, 2015). This project built upon this dichotomy that any new technology advance must be capable of being implemented within the NHS organisation.

5.3.4. Secure Long-term Organisational Commitment

A key aspect of the ADR methodology is the establishment of a researcher-client agreement. This meets the requirement for a problem at the intersection of technology and organisational domains. To deliver this I needed to secure long term organisational commitment. Through the last 20 years of providing services to the NHS I have built up a strong relationship with several hospitals. For this project I approached four NHS Trusts who agreed to become Development Partners for the development of the new IT artefact (product). At this early stage the commitment asked for from the Development Partners was time and effort rather than financial. As Development Partners the four trusts agreed to be involved in multiple cycles of product development, providing feedback at each stage and assisting in the design process. Through the ADR methodology this was an extensive engagement process between the stakeholders and end-users at the NHS sites and my team developing the new product. The Trusts were engaged from the initial concept through multiple versions of the artefact such as wire frames, alpha and beta versions, minimal viable product and eventually the final product release.

5.3.5. Scope and Role of Practitioner

I adopted the role of senior manager for the team that would develop the product. This was in line with the role of practitioner in an action research project and would allow me to interact with all stakeholders and observe the process. There was an acknowledged impact with my involvement as an active practitioner, but it allowed me to observe how the field problem was solved through practice-inspired research at the intersection of technological and the organisational domain of the NHS.

5.3.6. New Tasks Undertaken for this Stage of ADR

The early stages of the ADR process undertaken for this study identified two additional areas of research: NHS technology debt and the wider competitive landscape. The findings from these activities are described below. The ADR process isn't explicit in the need for these additional tasks but for this study they proved very useful, and I would recommend that the need for a wider organisational field review is useful for the ADR method.

5.3.7. NHS Technology Debt

The Problem Scoping interviews identified a consistent theme of under investment in technology for the NHS. This is something I have seen first-hand but wanted to evidence and benchmark this. I contacted all the NHS Trusts in England and asked them to confirm the percentage of annual revenue they have invested in IT over the last 5 years. With a secondary question of the percentage invested in cyber security. This is public information and out of 223 NHS Trusts in England 80 responded with IT spend data and 36 of these were able to identify the amount of cyber security spend.

The following Figure 21 shows this percentage spend over the last 5 years.

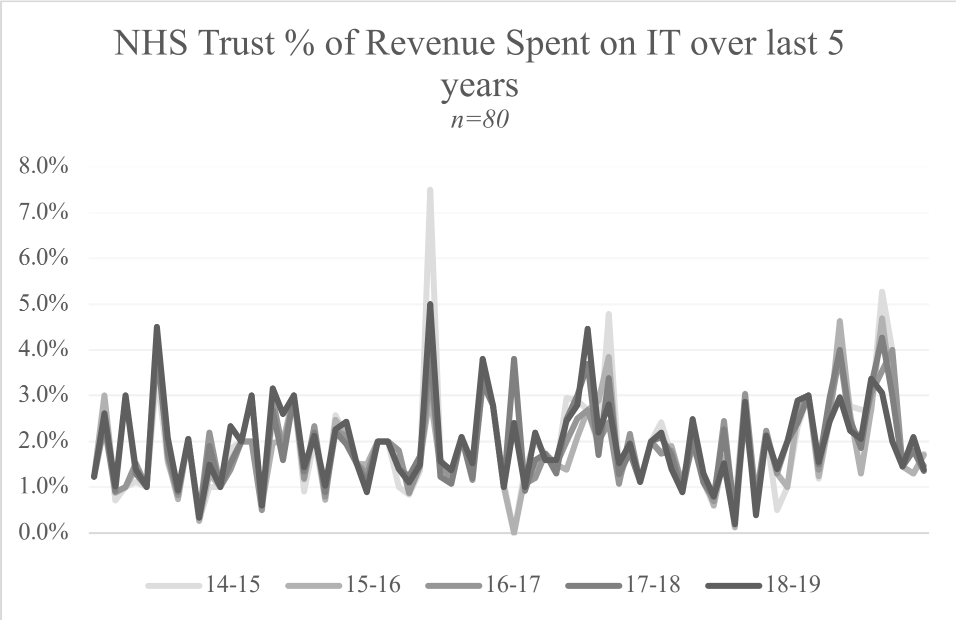


Figure 21 Percentage of Revenue Spend on IT over 5 Years.

The average spend on IT over the last five years was 1.9% of revenue. This does not include any central funding that organisations like NHS Digital have spent. Even though these figures do not include NHS Digital spend which was just over £261 million in 2018/19 (Digital, 2019). The total reported as a percentage of NHS England spend is less than 0.3 percent so minimal impact. When you compare this to what other industries invest there is a clear under investment in IT.

The Flexera Report (Weins, 2020) on ICT spend shown in Figure 22below shows the IT spend by industry.

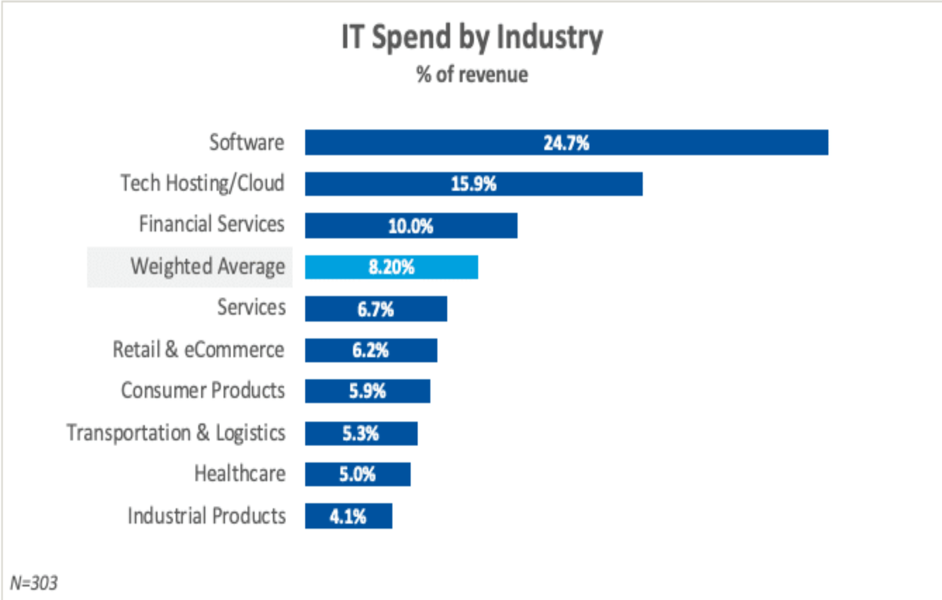


Figure 22 Flexera 2020 State of Tech Spend (Weins, 2020).

The reported spend on health in Figure 23 includes the USA which has a historical higher spend than other nations (Wachter, 2015). The Flexara data is aligned to other research including the Deloitte report in the USA that found the percentage of revenue spend on IT ranged from 7.16% in banking and securities to 1.51% in construction with healthcare reported at 3.49% (Kark, 2018). This trend for underinvestment in the healthcare compared to other industries can be tracked back to the Wanless report ‘Securing our future health: Taking a long-term view’ (Wanless, 2002) where the recommendation was for 4% of revenue to be invested in ICT. By 2007, when Wanless reviewed the NHS funding again, the spend under the National Programme for IT (NPfIT) had reached 3% including central government spending (Wanless, et al., 2007). The original investment target wasn’t met during the NPfIT phase and has fallen back since then (Currie, 2012).

The NHS has a complex IT landscape with multiple layers of management and different systems and networks. Within this environment it is not unusual to find old software still in use (Ghafur, et al., 2019). The term ‘technology debt’ was presented by Professor Mark Skilton in a meeting with me to describe the long-term underinvestment in healthcare technology. This finding aligns with my own experiences and what the NHS IT stakeholders confirmed during the problems scoping interviews as one NHS CIO stated:

> *‘I think a lot if it is based on investment, we have a lot of old kit, trying to get the hardware replaced isn’t easy, the amount of systems we use are archaic they are not simple there complex.’*

The WannaCry attack was focused on old operating systems that hadn’t been updated (Smart, 2018). There is a clear dichotomy between the capabilities coming from the 4IR into healthcare and the current investment levels to support the technology already in the NHS. From the problems scoping interviews an NHS CIO described the challenge of this hybrid landscape:

> *‘[the cyber security challenge]…plus you get new technology we have now got a hybrid of different technologies actually they will be working with, so a hybrid of different vulnerabilities and patches so managing that on a small scale is bad enough, manging that with medical devices across a huge estate is very difficult, where does the priority lie.’*

The investment into cyber security reported by the NHS Trusts as shown in Figure 23 equated to an average of only 5% of total IT spend. However, this simple spend survey could not answer the question: ‘was the investment was being made in the right areas and reducing vulnerability or was it being spent on new systems they aren’t effectively reducing the risk’. An NHS IT manager interviewed as part of the problems scoping research shared their perspective:

> *‘At the moment we have multiple tools and there is no one window into any of it. If you check one thing and another thing the next day you don’t check the same system you would have missed a vital machine in the middle.’*

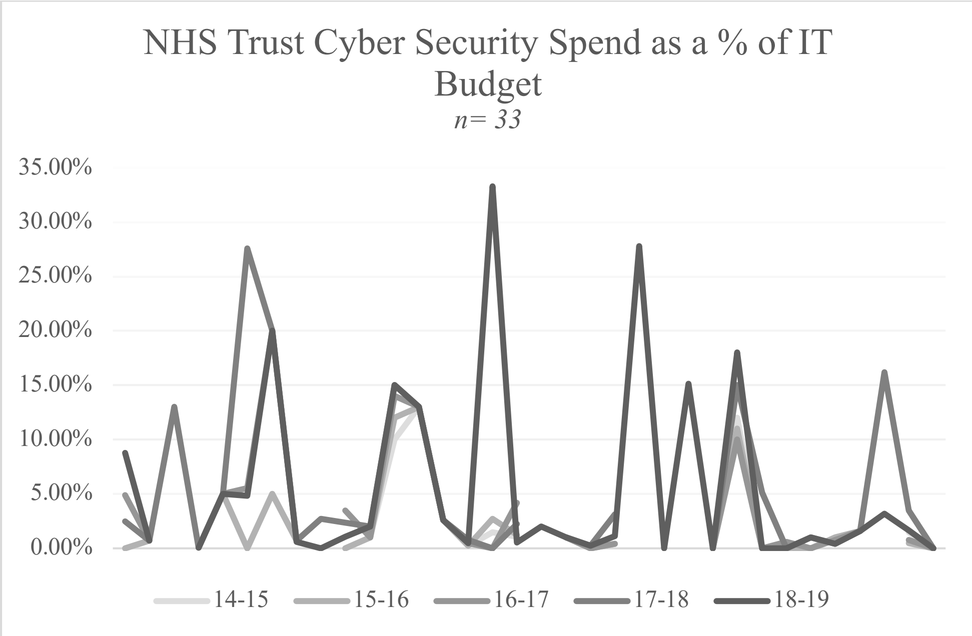


Figure 23 NHS Cyber Security Spend as a % of IT Spend.

From my experience as a senior manager in the NHS the spikes in spend will reflect a one-off purchase of a new system from capital funding and the overall average remains relatively low. From the HIMSS 2021 Annual European Digital Health Survey (HIMSS, 2021), IT Security and data privacy was identified by 87% (n=384) as their top priority for 2021. On the surface this conflict between priority and spend would appear to have a simple solution – invest more in cyber security. The reality within a complex organisation like the NHS is far more complicated. Areas that need to be considered include the risk appetite for the organisation.

The context of organisational requirements including risk tolerance, satisfaction levels and in the NHS patient safety levels need to be considered. The simple presentation of cyber security spending as a percentage of the IT investment on its own isn't a reliable basis for decision making. This approach also does not capture the IT effectiveness and the level of successful IT investments. The literature and context reviews highlighted the poor track record the NHS has in IT Implementation and benefit realisation (National Audit Office, 2006).

The surveys simply provide an indicative view of average investment, without regard to complexity or demand. For example, if an NHS diagnostic machine (CT Scanner) can only operate on an old IT operating system, does the NHS organisation stop using that machine even though clinically safe and needed for patient care. Or does the same organisation feel the risk of a cyber-attack can be managed but the risk to patient care cannot. The same argument would be played out when investment decisions are made, do you invest in a new diagnostic machine and fix that one issue or invest in a cyber security product that reduces the risk to the wider organisation. The debates are occurring all the time and often not in a coordinated way. A good example from the problems scoping interviews highlighted this issue shared by a CIO was:

> *"a new digital camera for ophthalmology they might have got a good deal on it, but it is actually running windows XP still so not windows 10 it is not compatible so they need to understand it might be a really great system they are buying but if the software it is running on doesn't meet the most modern security standards (it doesn't) it is a threat to the whole organisation".*

NHS Technology debt was out of scope for this project but is an under researched area that will have significant impact on the healthcare organisations as they seek to explore and exploit the new tools and technologies of the 4IR. This is even more critical as the COVID pandemic has accelerated the adoption of digital tools and technologies in the NHS.

5.3.8. Competitive Landscape

The ADR process doesn't detail how the problem is scoped out and defined. I have established that the project is a field problem at the intersection of technological and organisational domains. I reflected on the lessons learned from the Pilot Case Study where I had identified that in initiating product development without undertaking the opportunity to understand and research the current commercial and technical landscape was a mistake. To ensure that I didn't immediately start product development but undertook a wider review of the problem scope I attended several large international conferences where both suppliers and stakeholders were in attendance. This research allowed an increase in the problem scoping capability. The outcome of the attendances was mapped to two areas: commercial market and non-NHS stakeholders. The research identified that cyber security is a very broad term and as a research project I would need to work a specific area – vulnerability management. The research also confirmed that the problem was truly international and not specific to the NHS. This generalised problem scope would be useful in how I generalised the outcome of the research and contribution to practice.

5.3.9. Conference Attendances

I attended the following conferences shown in Table 19 to help the initial problem scope and maintain current knowledge through the design process.

Conference	Coverage	Key Takeaways
HIMSS 2018, Las Vegas	Largest global healthcare IT conference Section for cyber security	40,000 visitors Small, dedicated section for cyber security companies. There was a wide range of very specialist companies. What was missing was a solution offering basic vulnerability management and a broad view of cyber risks.

Conference	Coverage	Key Takeaways
NHS cyber security Webinar 2018	Focus presentation for NHS IT leaders	Visibility There are lots of start-ups in the cybersecurity space and the key question now is how to integrate the different tools. Threat Intelligence This needs to be relevant to your organisation Some feeds are paid, some free, some are an exchange where multiple organisations feed data in for mutual benefit. Trends A big problem in cybersecurity is staffing issues – recommend in-house training or consultancy staff with cybersecurity knowledge or a Security Operations Centre. Lots of vendors now focusing on security e.g., Cisco, Symantec, Microsoft, and are looking to integrate the tools they have. Security Orchestration, Automation and Response (SOAR) and Endpoint Detection and Response

Conference	Coverage	Key Takeaways
		(EDR) tools useful in generating alerts and sending tickets to security staff to help resource strapped teams.
CD Howe Health Conference Canada 19	Invitation only healthcare conference with leaders from USA / Canada	I met with Telus (https://www.telus.com/en/) basically BT for Canada but with a wider portfolio and they operate several large IT services in healthcare in Canada – running most of the hospitals systems as an outsourcer Their President of health quickly saw the benefits a vulnerability management system offers and even wanted it for his internal use… another confirmation that we were on the right track. Also discussed cyber security risks with CIO of Kaiser Permanente (a large USA Healthcare system) and they also have lots of dedicated cyber tools for specific risks but no general vulnerability management tool.

Conference	Coverage	Key Takeaways
HIMSS 2019, Orlando	Largest global healthcare IT conference Dedicated section to cyber security Dedicated education section	Significant change in the size of the cyber security area and number of vendors over the last 12 months. However, all the talks and systems were very focused on specific challenges and risks. Again, no obvious vendor for vulnerability management as a complete toolset. This is a growing marketplace and recognition in healthcare sector of the cyber threat and tools available.
Cyber Security Conference London 2019		• Engagement was good with several hundred cyber security and ICT professionals from across the public sector. • • The NCSC's opening talk focused on understanding the current threat landscape. Interesting facts included their finding that 500k routers were compromised across 54 countries last

Conference	Coverage	Key Takeaways
		year, and the recent case where Microsoft released patches for SharePoint vulnerabilities that hackers then rushed to exploit before the updates were applied – the same as WannaCry approach • Presenters say attackers have a 7-day advantage due to time scan frequency, and the scan intensity, authenticating of assets and estate coverage should be priorities when combating exposure to vulnerabilities. This again confirms the need for a tool to solve this problem.

Table 19 Key Takeaways from Conferences Attended.

The attendances at these four conferences supported the development of the problem scope aspect of ADR. The methodology for Stage 1 is seeking to address the problem formulation question.

This project, to develop a new cyber vulnerability IS artefact, was identified as a field-based problem. The methodology doesn't prescribe how this is achieved. The attendance at the conferences provided a strong background in formulating the scope and requirements for the research question. I would advise any future researchers seeking to solve a problem through ADR to spread their research net even wider and include stakeholders within the organisation and the wider eco system. This would, in my opinion, be even more relevant where the research is based within the context of a complex organisation exhibiting institutional behaviours.

The outcomes from the conferences supported the development and scope of the cyber vulnerability problem through the following aspects: market awareness and problem scope, these are summarised in the following sections.

5.3.9.1. Market Awareness

The first conclusion from the conferences was recognition that cyber security was a global industry and there was an on-going threat to healthcare sector. There was a clear market for cyber security products with a growing number of suppliers. This confirmation was a key check and resolved an issue raised from the Pilot Case Study that a product wasn't being developed for a single or small market. The second aspect I observed was the products typically fell into two categories. They were either general cyber products that were not specific to any market, or very healthcare specific products addressing a single risk vector in the healthcare market. The significance of this division is understanding how a generalised product would work within a complex organisation such as the NHS. Balanced against this generalised product approach was the need for multiple systems if they are for a specific risk vector. These findings reflect the issue raised from the Problem Scoping Interviews. The need for a single pane of glass to help the organisation easily understand the picture across their risk vectors. If the hospital has many different systems, there is an increased risk that any alerts will be missed as multiple systems need to be observed. This was a key part of the problem scoping to ensure the design allowed a comprehensive view of the vulnerability risk that was easy to interpret.

5.3.10.Problem Scope

The conferences also confirmed another aspect that needed to be considered within the problem scope, what specific area of cyber security was the project addressing. From the conferences and educational sessions attended the market need was significant. This confirmed the earlier research (see section 2.6.1) that cyber security risks have multiple different vectors that need to be addressed. The routes to address these include both technological and human behavioural changes. In defining the problem scope for this project, I have overlayed a known issue that has clearly impacted the NHS, Ransomware attacks such as WannaCry with the NHS Digital approach for providing the cyber security management model.

A key lesson from the Pilot Case Study was the need for clear analysis and requirements gathered at outset. Taking the work of Pogrebna and Skilton (2019) and their periodic table of cyber threats (see Table 21 below). I have overlaid the operating model that has been identified as the scope of the problem to be addressed.

			Monomers		Polymers		Composites			
Executable File				Basic monomers		Malware polymers		Composites		
Macro				Malicious monomers		Hybrid polymers		Complex composites		
Exploit						Email or messaging polymers				
Web Crawler						Technical stealth polymers				
Adware										(Cyber) Harassment
Backdoor	Virus	Worm	Trojan	Wiper	Brute force	CAPTCHA Bypass	Payload	Hacking	Advanced Persistent threats (APT)	(Cyber) Theft
Rootkit	Bootkit	Malicious Mobile code	Malicious crypto miners	Malicious bot	Denial of Service (DOS) Attack	Man-in-the-Middle	Botnet	Network Attack	Hijacking	(Cyber) Fraud
Logger	Browser Hijacker	Spyware	Point of Sale (POS)	Ransomware	Voice Fabrication	Data dibbling	Unwanted programmes /Apps	Drive-by Download	(Cyber) Extorsion	Cyber Terrorism
Social Engineering	Crimeware	Phishing	Spear-phishing	Whaling	Spam	Water-holing	Malicious Research	E-mail crime	(Cyber) espionage	Cyber Warfare
	Cyber squatting	Stolen Devices	Software piracy	Malicious Insider	Deceptive Callers	Phone Phreaking	Blockchain Majority Attack	Blockchain Price infliction		

Table 21 Periodic Table of Cyber Security Threats (adapted from (Pogrebna & Skilton, 2019, pp. 16-17).

Problem Scope to be addressed

Technical remediation - To fix the issues identified in your on-site assessment, focussing on existing technology and systems – NHS Digital Objective

5.3.11.Outcome of Stage 1

Stage 1 of the ADR process was focused on the problem scoping and identification tasks. The outcome was a clearly defined problem that the design process could address and worked well within the NHS setting. Building from the Pilot Case Study the addition of the competitive landscape research allowed confirmation beyond the hospital setting of a problem need and equally a gap in the market. I would recommend that anyone using the ADR process for a new IT artefact does undertake wider research into the competitive landscape. The competitive research provided supporting information on the problem scope and scale. It also ensured that there wasn't an existing product on the market that specifically addressed the need before significant resources were expended.

Using Institutional Theory as a lens on the problem formation, the initial stages in this project missed the need to consider the interplay between the macro and micro-organisational players. The work undertaken at this stage was focused on the stakeholders at the local organisations level. The design team, researcher and the NHS partners were acting as if the power and decision-making capability was held and maintained at a local level. There was a belief that this was the correct decision-making body with autonomy. The design was therefore focused on the specific needs at this level of the organisation. The power influenced by the eternal stakeholders was missed at this early stage and was not identified to later in the project. If the power shift had been recognised earlier, it would have avoided a timely and costly change being needed at later stages on the project.

5.4. Stage 2 Building, Intervention, and Evaluation

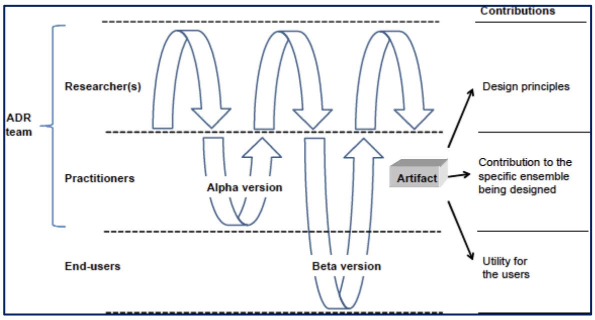
5.4.1. Introduction

Stage 2 of the ADR process builds the initial design of the IT artefact and is then updated with feedback from organisational users and design cycles. The Build, Intervention and Evaluation (BIE) form has two models:

- IT-dominant BIE
- Organisation-dominant BIE

The difference between the two approaches can be seen in the Figure 24 below.

IT-dominant BIE



Organisation-dominant BIE

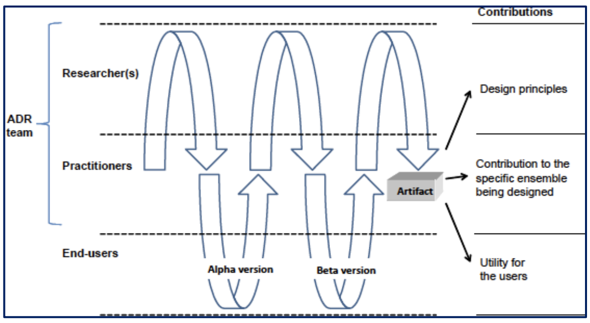


Figure 24 BIE Models.

For this project, we adopted the IT-dominant model utilising our cyber team's in-house practitioners for the initial evaluation of the alpha version. After the alpha stage and the need for redesign due to the external changes in the scanning engine, we reverted to involving end-users in all phases of the development. When dealing with challenging organisations such as the NHS, it is always a difficult decision when to release the product for their input and feedback. Even though we had undertaken Alpha testing on our own systems first before moving to Beta with the Development Partners, we still received some feedback from a Development Partner site:

"No doubt it will be a good product, but it's not doing what I want currently."

In any action design approach, the balance of when to share and show the artefact is going to be crucial. Too soon and you may lose the end-users enthusiasm for being involved, too late, and the product may need a complete redesign to meet the users need. In this project on reflection, we should have engaged earlier but been clear on the design and development cycle stage. This could have flagged that the scanning engine artefact wasn't needed earlier in the process, although our engagement was still only at a hospital level and not a central NHS body level.

Sein et al (2011) proposes three principles that needed to be followed at this stage of ADR as shown in Table 20 below.

Principle	How I included this in the Project
Principle 3: Recognises the two influences of the IT artefact and the organisation cannot be separated. To address these there must be an iterative process involving the two drivers.	The project worked on a weekly cycle internally with the team and a fortnightly / monthly review cycle with our partner NHS organisations.

Principle	How I included this in the Project
Principle 4 Reflects the value that all participants are involved in the mutual learning.	The approach adopted was as a learning organisation, this operated internally and externally with our partners – I adopted a saying of we have two ears and one mouth, and we will use them in that proportion.
Principle 5 The key to the methodology is that evaluation isn't a separate stage following build but are interwoven into the design process.	The approach was based on a constant cycle of evaluations from initial wire frame designs through to the eventual product release.

Table 20 Stage 2 ADR Principles.

These principles were key to the approach adopted for the project and worked well with the local teams. The issue we had was that our engagement with participants was at the local organisation level. As a complex organisation, the NHS had multiple external influencers outside of the local organisations. The model's adoption as we implemented for this project hadn't considered these external influences. This lack of awareness of decisions being made within the wider NHS that would directly influence the local NHS organisations resulted in a significant change in the design after the initial beta release. The outcome would be the recommendation that anyone using ADR within a complex organisational setting considers the need to include, at least at a monitoring level, the other power bases within the organisation.

Sein et al (2011) proposed for IT dominant artefacts the beta version is taken into the wider organisation and further intervention and evaluation ensues. In our interpretation of this we engaged with wider stakeholders in the hospitals and not the wider organisation. Our focus was too narrow and didn't cover the wider power base and decision makers.

The cycle of build, interventive and evaluate as a continuous process worked well and this can be seen in the Figure 25 how the workload was allocated.

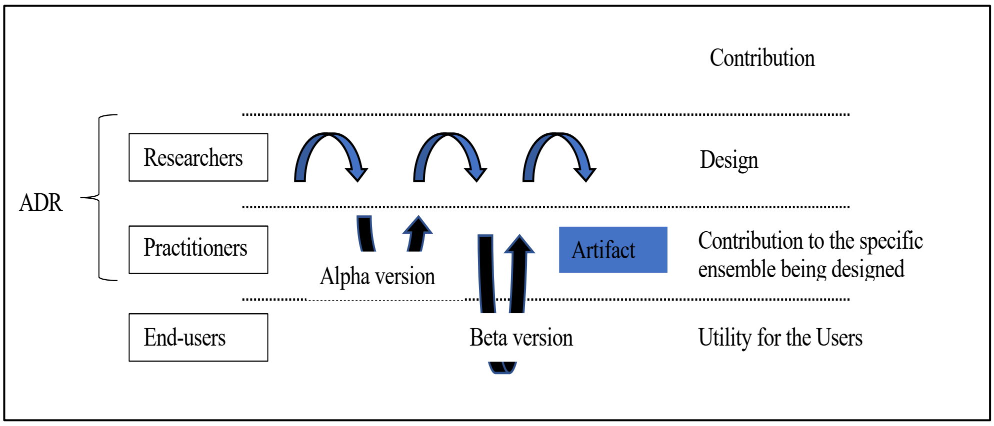


Figure 25 The Generic Schema for IT-dominate BIE (Sein, et al., 2011, p. 42).

The following Figure 26 shows the planned approach adopted for this project.

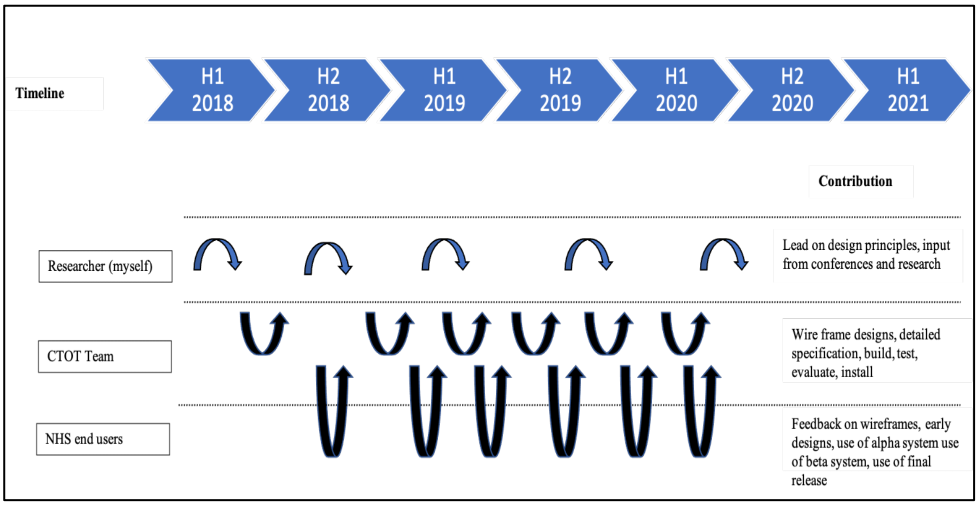


Figure 26 Planned Adoption of IT-Dominate BIE Cycle for this Project.

In the actual project, the planned development of the beta version being taken into the wider organisation and further intervention and evaluation was not against a steady state environment. The wider institutional influences on our pilot sites meant the needs of the end-users changed during the development phase.

The actual approach adopted is shown if Figure 27 below and reflects the need for ongoing changes during the development cycles as the institutional field changed.

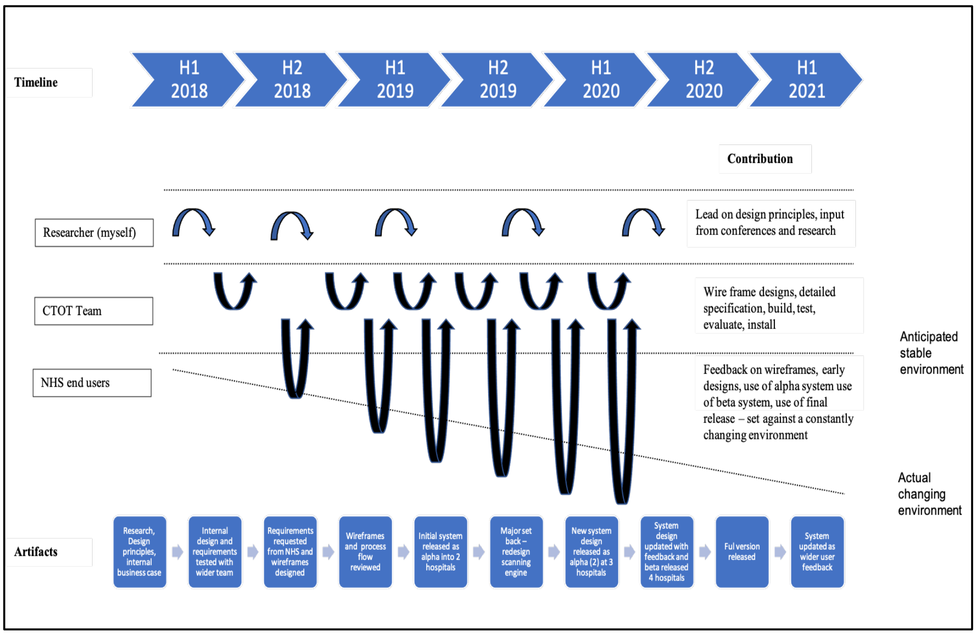


Figure 27 Adoption of IT-Dominate BIE Cycle for this Project and Artefacts Developed.

5.4.2. Discover Initial Knowledge-creation Target

The first phase in Stage 2 of the ADR was the based around discovery of the initial knowledge creation target. This process was focused around resolving the requirements identified within the initial scope (see section 5.3.1). The data sources to define the knowledge-creation target were combined from four main sources as shown in Table 21 below.

Source	Outcome
Infield experience	The C21 team have worked within the NHS organisations providing hands on interactions and working alongside the end-users. From this, the C21 team were able to gather a view of the issues and what a target outcome could be.
Desk based research	Through researching issues reported in journals, webcasts, data breaches, risk reports, and other grey material to help understand the issues and what a resolution would need to address.
Conference / exhibition	The wider market awareness of competitors and papers being presented at conferences. This provided confirmation of the scope and scale of the market. It also allowed views on where and how certain products were targeting cyber risk vectors and not necessarily a general vulnerability tool.

Source	Outcome
Problem scope interviews	This final input was the most valuable as it identified from the key NHS stakeholders what they felt was important and what a new target artefact would have to achieve.

Table 21 Data Sources for Knowledge Creation Target

This step was critical to the design methodology before any actual design and development was commenced. The process ensured that as a design team we moved away from the initial concept of a scanning [2] solution to a more holistic approach. The initial internal design criteria identified the following three objectives as detailed in

Dashboard must be able to be viewed on Windows, Mac, iOS, and Android devices
Compatible with older browsers e.g., IE10 if possible
Allow reports to be downloaded in a specific format maintaining all data

Table 22.

[2] A scanning solution is a software product that will scan an entire IT network and capture the data (asset number, software versions, licenses etc) that is being used on devices connected to the network.

Primary Objectives

Develop a secure, customisable dashboard for NHS IT management staff that displays high-level vulnerability data for their network in easy-to-read graphs. Rapidly highlight issues of non-compliance with the NHS Digital CareCERT so these can be prioritised with the option to drill-down into details to facilitate remediation. Provide reporting and alerting options for this data.

Partner with an NHS organisation to allow us to gain access to a live NHS network and also N3 providing the recourses we need to test and move the development forward when we are ready, making sure all commercial agreements are in place.

Secondary Objectives

User Authentication**:** AD/SQL authentication

Network Monitoring: increase the scope of discovery to all network user devices and include routers/switches as well as live monitoring data i.e. polling via SNMP to firewalls, storage.

Risk Scoring: Utilising information from CVS or other risk score the customers compliance to demonstrate the actual risk to the business

Tertiary Objectives

Management Tools: add the ability to automate remediation work i.e. patches through SCCM

Dashboard Requirements

Show compliance level of discovered assets against CareCERT & CVS information with live data feeds

Dashboard must be able to be viewed on Windows, Mac, iOS, and Android devices
Compatible with older browsers e.g., IE10 if possible
Allow reports to be downloaded in a specific format maintaining all data

Table 22 Extract from V1.0 of Requirements Specification Document.

This approach method worked well and involving the end-users and stakeholders at an early stage also mitigated one of the themes identified in the Pilot Case Study:

> *'Relationships must be with wide base of end-users and stakeholders to drive correct needs and requirements.'* (TS Product Manager)

The issue that this process didn't address within the setting of NHS organisations was the complexity that a large organisation can affect the requirements and target outcome. I failed in this project to engage with and fully understand the wider NHS stakeholders who could influence and impact the local hospitals. Specifically, the initial design spent considerable time and resources developing a network scanning solution. This was subsequently rendered unrequired when a central NHS body announced its intention to use an existing commercially available scanning technology. The influence of the central body over local hospitals altered the needs overnight. I will explore this these further in the Chapter 6 Discussion section but the failure to correctly apply ADR in the wider setting was an expensive lesson learnt. When using ADR in complex organisations, consideration should be given to the widest set of stakeholders and the power they will have to influence and reshape local decisions is a critical aspect of the design process.

The second target outcome that was missed relates to the 'so what question', just designing and delivering new technology in itself isn't always the answer. This issue was identified through the Product Scoping Interviews and the Pilot Case Study Interviews. Both data sources identified that designing and developing a product may not solve the problem identified. The NHS stakeholders interviewed all raised concerns over availability of resources to manage the cyber security alerts. The Pilot Case Study identified a theme.

'What is different now the technology is available'.

The project was focused on designing the artefact and not on the wider discussion on the change management that would be required when it was implemented. The researchers' and designers' assumption that technology in itself solves the problem was a mistake. This aspect from design principles of understanding the impact a new artefact will have and ability to imagine how it will be used is the second lesson from this project. The literature has a strong base for supporting the users in the design process (Sanders & Stappers, 2008, Schnall et al, 2016, Micheli et al 2018). Designing for behavioural change though extends this beyond user involvement in the process to understanding the impact the design will have on the end-users (Niedderer et al 2019). In this project the ADR cycle worked extremely well in the user's involvement in the design, but I didn't consider the wider impact of the imagined use of the product in its setting. This is what I refer to as the 'so what' question. In this instance 'so what' if you can identify every PC with a vulnerability. If I don't have the skills or resources to manage this new problem, then I haven't solved the overall problem. This isn't an explicit step in the ADR cycle, but I would recommend that any new design undertaken considers the impact on the user and how this artefact will change the problem statement it was seeking to address.

5.4.3. Select or Customise BIE Form

The project was initiated under the IT-dominant BIE form. Our internal practitioners along with a small number of the Development Partners evaluated the alpha version. This form was selected based upon the belief that we had within C21 a broad set of NHS experienced practitioners that would be able to provide the feedback and design input at this stage. This model adoption met the criteria for IT-dominant BIE as defined by Sein et al, (2011). However, the BIE approach is on a continuum and not a binary decision. On reflection for this project, we should have moved more to an organisational-dominant BIE before Beta version was released. If we had correctly mapped the wider organisational power stakeholders and engaged earlier, we could have avoided the need for a redesign at Beta stage.

5.4.4. Execute BIE Cycles

Recognising the drawbacks that were self-inflicted on the project, the BIE approach from the ADR methodology was highly successful. Over the course of the design and interventional, feedback and evaluation from the users as a continual cycle, the artefact was developed successfully. The following Table 23 shows the activities in this period and the comments captured from my research diary.

Stage	Activity	Comment
Alpha 0.1	Internal practitioners and team focus on the core requirements of: Local scanner • Network scan available on ad hoc basis as well as scheduled	This internal version met the needs identified in the problem scope interviews and market research.

Stage	Activity	Comment
	- Local scanner to be built to be an appliance type device on Linux Pre-defined Dashboard & Alerts - Will be designed together in the upcoming weeks but that any information in the database will be available so scanning output, CareCERT/CVE - vulnerabilities & queries between them Reports - All reports created via MVP can be exported to PDF and Excel-CSV	My diary notes highlighted that we were unsure exactly how we will map the scan results as we are getting thousands of CVEs / CPEs. This was a risk to the project and was a design challenge we would have to overcome
Alpha 0.2	We have now installed the CareCERT scanner in Development Partner 1 and have started to look at the performance of both the scanner and impact to the local network, this is a big step towards getting the solution onto a hospital network. The data has not been sent to the dashboard (azure cloud) yet as this phase 2.	The involvement of a Development Partner early on to test the scanner was encouraging but highlights the issue that our ‘end-users’ weren’t aware at that stage of wider influences that would be made

Stage	Activity	Comment
		from central NHS bodies.
Alpha 0.3	As the vulnerability dashboard was developed the internal practitioners identified the key requirements (M – must have – R1 next release): • CareCERT matching (M) • Dashboard (M) • CVE matching (M) • Inbuilt scanner (M) • Multi-layer authentication (M) • Dashboard alerting (M) • Drill down data (M) • Audit – basic (M) • Risk score manual (M) • NSCC database matching (M) • Basic reporting (M) • Alerts (email, text etc) (R1) • Audit full (R1) • Agent scanner (R1) • Advanced reporting (R1) • Automate risk-score (R1) • Device management integration (R1) CMDB	The list was matched back to the initial requirements and the internal team believed it met the key criteria. There were several areas still needing solution including CareCERT matching.

Stage	Activity	Comment
	• Port scan / packet sniffer AI alerting • Centralised reporting NSCS accredited (R1)	
LORCA	At this stage we applied to join the London Office for Rapid Cyber Security Assessment (LORCA). This was a government backed organisation aiming to support the leading cyber products developed in the UK.	At the time this felt like a big win, recognising that our product was clearly addressing a cyber need. On reflection it was a distraction as the LORCA team were not part of our user group or institutional setting and distracted the team with meetings and requests that were not key to the project.
External review	The product was given an external review by Deloitte cyber security team. There feedback was: • Make the tool as easy as possible to use, and	Even at this early stage it was becoming clear that the product in itself wouldn't address the overall problem. However, keeping

Stage	Activity	Comment
	cheaper than the all-encompassing scanners • Offer a compliance tool or service • Make sure you have as wider a coverage of CVEs as possible • Offer remediation	the alpha version in-house meant we were still focused on this and not the behavioural impact aspects.
Alpha 0.4	The scanner and dashboard were deployed to second Development Partner site, initial key feedback was: The Trust is keen to get started with the product, they raised several requirements that weren't currently in the roadmap such as medical devices are a significant issue as clinical staff only see the benefit and not the risk and IT are seen as blockers - must use WannaCry as an example of what can happen. This system will identify what our problems are but then what can we do to address the issue – Security Operations Centre / Remediation Operations Centre needed	The feedback from the end-users was key at this stage, we were beginning to see issues with the scanner we had designed and still need to clarify our dashboard and what it would show and how we could automate the CareCERT matching. At Alpha stage the hospital was identifying how they would address the issue the new artefact identified – internally we still

Stage	Activity	Comment
		ignored this and focused on the Alpha output as an IT artefact.
Alpha 1.0	The final Alpha version or minimum viable product was released to the development partners. At one of the evaluation sessions the question was raised: ‘Not sure if I want the system to do this but can it remediate automatically?’	At each stage of the alpha evaluation the feedback helped focus the dashboard for the vulnerability product/ at each stage though we weren’t adjusting to the questions on what to do with the information the new system would identify.

Table 23 Activities and Comments Captured from the Research Diary.

At the end of the first round of evaluation and testing the ADR approach had worked well in the engaging and evaluation as a concurrent process rather than discrete aspects of design. The product had two parts to be designed and developed. A scanning engine to identify what the system component parts on the hospital network were, and a dashboard that then matched these results to NHS CareCERTs and provided the information in an easy-to-use format.

The scanning engine was proving problematic to fully scale and at the same time as we were working through these issues the NHS central team released its cyber security plans. These plans included aspects that we were addressing at a local level including requirements to address poor visibility of vulnerabilities. This would be through improved CareCERT alerting and responses. The plan however also included a commitment to supply a scanning engine from a well-known US supplier, centrally funded. Whilst the scanner wouldn't be used at every local level it would be used for the entire NHS perimeter protection.

This had a significant impact on the project and required a redesign and a review of the initial requirements. As well as the feedback from the Development Partners. The outcome of this internal review was to stop all activity on our own scanning engine and seek a partnership with the appointed national scanning company. The product was also refocused on addressing the second challenge of automating the matching of scanned results to CareCERTs alerts and subsequent reports needed. This necessitated further cycles of BIE building on Alpha version 1.0 with the learnings and feedback from the local and national teams.

5.4.5. Assess Need for Additional Cycles

As an output from the first round of Development Partner evaluations and central NHS body intervention the design addressed three specific challenges.

<u>Partnering with an Existing Scanning Engine</u>

We quickly moved to forming a relationship with the scanning company and designing how our product (now called OTLO) would operate and work with the scanning system. This development whilst commercially challenging did provide an easier route to the data needed for the OTLO dashboard. The additional benefit of this approach was the ability to design OTLO so that it was a module that could be added to the scanning engine platform and so generated a new route to market. This approach could have been considered earlier in the design cycle if we had understood the need for a wider engagement with stakeholders beyond our narrow view of the organisation and the power players with that. This reflection will be explored further in the next section.

<u>The Automation of Matching Scan Engine Results to CareCERT Alerts.</u>

The specific challenge here was to design a new way of matching the operating system identity descriptors from the scan engine to the system descriptors issued with the CareCERT. What we found was that the scan engine would identify for example a Windows operating system on a hospital PC as MS v16.8 but the CareCERT would show Microsoft Windows - Versions 7 SP1, 8.1 and 10 (all variants). There was a need to design a way of automatically matching the scan results to the CareCERT definitions and avoid a need for manual checking. This was resolved using automation tools to design a new look-up and matching artefact. The new tool which was the core of the OTLO product met the definition of a design artefact according to Gregor and Hevner (2013). The artefact not only addressed the specific need within this institution setting but the new technical product would match any Common Vulnerability and Exposure (CVE) alert against any scan and so met the generalisable criteria. We were using tools of the 4IR to address cyber issues and create a new artefact. There was also a vision at this stage of potentially going further and using AI to analyse the data collected and look for Zero Day threats – i.e., a vulnerability that hadn’t yet been identified by the original manufacturer. At this stage of the project there was insufficient data for a training data set, but the vision is still there for this to be developed in a later version.

The following Figure 28 shows the workflow that this process generated from a design perspective.

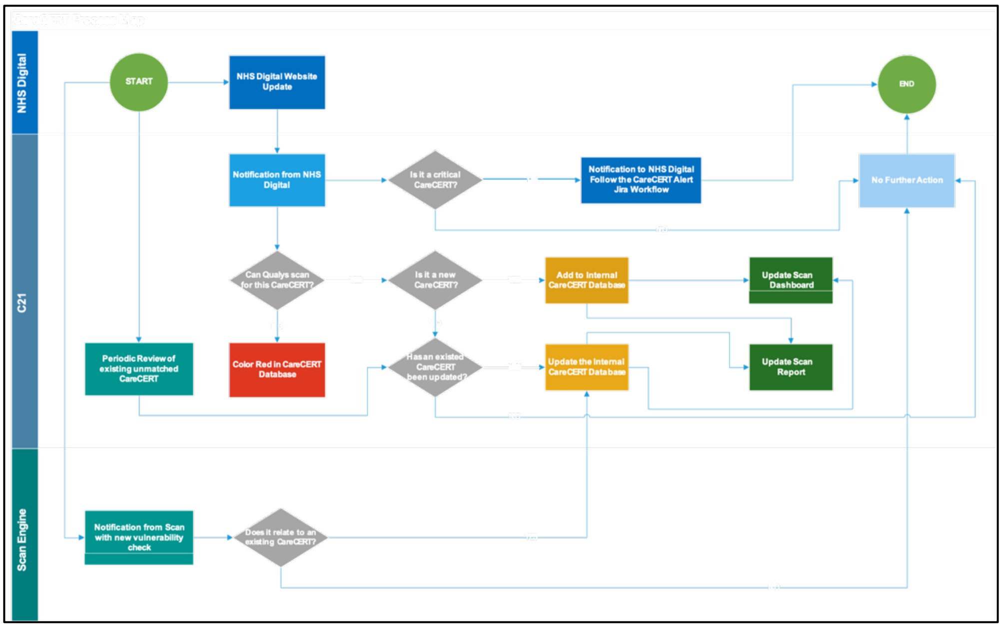


Figure 28 Auto-matching Process of CareCERT / CVE to Scan Results.

The outcome from this new artefact removes a significant amount of manual matching for NHS organisations and now allows the scan results to be matched quickly and easily to CareCERTs. The artefact also supports the report needed for the hospital and wider NHS reporting mechanisms.

<u>The Remediation Need</u>

The final area that was designed at this phase, following the feedback from the users, was the remediation work required once a risk had been identified. The focus of the project team during the initial cycles of BIE had been on developing a new IT-dominant artefact. This was despite clear feedback from end-users that the new system would only solve part of the issue. It could even be argued that by OTLO alerting end-users easily and effectively to cyber vulnerabilities, the new system would apply additional pressure on the remediation concerns for the IT team. Through the feedback from Development Partners, a new remediation service based upon behaviour needs was designed. The new service called Vulnerability Management Service (VMS) was designed with Development Partners to provide the final step in solving the original problem. When the new artefact (OTLO) identified a cyber vulnerability the C21 team of experts would intervene and remediate the patching of the systems. This didn't meet the automatic remediation asked for as the risk was too high that clinical infrastructure would be affected. The new service design is shown in Figure 29 below.

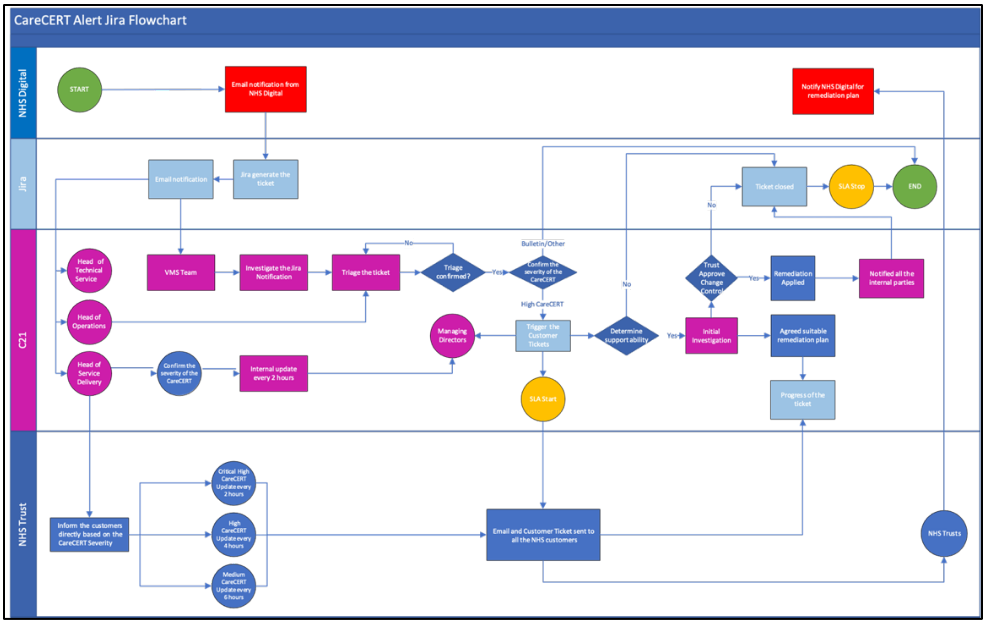


Figure 29 Vulnerability Management Service Workflow Design.

These three areas were addressed through multiple iterative BIE cycles with the Development Partners as Alpha version 2.0 and 3.0 were released until finally Beta version 1.0 was released and the product moved into normal operational support. OTLO as the product artefact is now live and operational in the NHS and a video showing how it operates within the scanning engine platform can be found here https://www.youtube.com/watch?v=z9AGE_djG3k&t=1s. The VMS service is now supporting NHS hospitals across Essex, Kent, Surrey, and Sussex.

The project was initiated to solve a specific field problem caused by the WannaCry attack. Using the ADR methodology and with strong support from four Development Partners constantly involved in the evaluation and feedback OTLO and VMS have been designed and launched as an innovative artefact with a behavioural service change that intervenes in the NHS to solve a problem. As such this meets the criteria for ADR and has contributed to both a real-world problem and added to the knowledge of how to use ADR within a complex organisational setting.

Reviewing Stage 2 through the lens of Institution Theory helped me understand some of the issues encountered. Through the Stage 1 process of problem formation, I missed the impact of external influencers whose power impacted the artefact design. In Stage 2 this lack of understanding the dynamics and shift of control was realised. The artefact had to be redesigned when the need for a dedicated system scanner was removed. Currie (Currie, 2012) described the NHS as a battleground with competing actors seeking control during the NPfIT. This project was initiated 10 years after the NPfIT and at a point when the behaviour and powerbases between central and local control are changing. Through the mistaken belief that the autonomy and power was held locally, as had been the policy since the demise of the NPfIT, this project was blinkered to the wider influences. The NHS as an organisation and NHS staff as stakeholders are used to the constant flux and change. The actors within this environment are used to this behaviour without even realising it. The reality is that the NHS, through one lens, isn't a stable organisation and undergoing change at a micro and macro levels continuously.

For an external entity seeking to design a new artefact the lack of awareness of the multiple influencers can easily lead to mistakes in understanding the actual need or problem being requested to be solved. Also, how a solution should be delivered, as well as who has the authority to define the needs in the first instance.

The NHS isn't unique as a complex organisation and many of the inter-organisational factors experienced in this project would affect other IS projects be that public or industrial settings. The ADR approach does have the flexibility to deal with the dynamic issues experienced, however it would have been preferred if we had taken a wider look at the stakeholder base and influencers and seen that there was a powershift underway. This would have avoided the changes needed at a later date.

5.5. Stage 3: Reflection and Learning

Stage 3 transfers the learning from the instance to the wider class of problems. The third stage is continuous with first two stages and allows a conscious decision to reflect on how the project was framed and approaches taken when using ADR. The principle of guided emergence reflects the combination of the emerging design (Principle 2) and the updates to it from interaction with the organisation, participants, and users (Principles 3 and 4) and the demonstration of continuous evaluation (Principle 5). (Sein, et al., 2011).

To support this process and gain a wider input I completed five semi-structured interviews with members of the project team. The approach taken was to investigate the project from their own perspectives, what had worked well using the ADR process and areas from where lessons could be learnt. The five team members included, the product manager, commercial lead, technical architect and two directors. The objective of this stage of the research wasn't to score or compare the wider teams' perspectives but to understand their observations and apply their lens on the project to augment and develop my reflections.

The initial questions are shown in Table 24 below.

Question	Purpose
Introduction and Background	

Question	Purpose
1. What is your role and background in the cyber project?	Understand role and experience, relax the interviewee.
System Design and Development Approach	
2. Could you describe from your experience of how the cyber product was conceived and designed?	Gather information from individual perspective on the initial design approach and compare to my research notes.
3. Could you describe what worked well in this process.	
4. Could you describe some of the key challenges you have experienced from managing this process in C21?	
5. In your opinion what could we have improved on? a. Supplementary question based upon answer.	
ADR Cycle – digging a bit deeper	
6. We started the cyber design project from a real-life issue - WannaCry, was this appropriate and why? Should we have started from a different perspective – i.e., a more	Was the original starting point correct or had I missed something.

Question	Purpose
theoretical point – if so, what could we have used as a starting point?	
7. If any, in what areas could we have gathered more information / understanding at the outset? a. What problems would this have avoided later in the design?	Did I miss anything at the outset, looking back did the team member feel we should have undertaken a task differently.
8. It was identified early on that NHS budgets were an issue; how well do you believe we considered this and its impact on the design process and why?	Was the NHS budget a factor in the decisions we made?
9. What is your view on how well we considered the wider competitive marketplace before and during the design requirements phase?	Understanding from the team member perspective how well this analysis worked.
10. During the engagement cycles with the development partner sites what worked well and why?	From the team member viewpoint how well did the BIE cycles work and what can we learn from them.

Question	Purpose
11. During the engagement cycles with the development partner sites what didn't work well and why?	
12. What would you do different next time round?	
13. How could we have avoided the impact of the external change in scanning approaches and the change we had to make to our product?	Did I as lead researcher miss anything, what in hindsight could we have done differently?
14. How could we have Improved our awareness of the external influences on the hospital decisions for the scanner?	
15. What other factors should we have considered in the design approach?	General catch all to see what else the team member felt we should have considered.
16. How could we have identified the need for the additional service offering - (VMAS) so that we could solve the initial problem identified and beyond just the technology solution - and have identified this at the	Could / Should we have identified the need for VMS earlier and would it have altered what we did.

Question	Purpose
outset of the project or early on during the process?	
17. Are there any other factors that should be considered for designing the next solution?	Anything else that we can capture from a lesson learnt perspective.

Table 24 Initial Reflection Questions to Research Team.

The responses from the wider team members will be used within this section and the discussion to provide a rounded view of how ADR was used within the complexities of the NHS as an organisation.

5.5.1. Interviewee Selection

The interviewees were selected from the senior leadership, the design team, the technology team and the client engagement and marketing team. This allowed views to be captured from directors with oversight of the company, from the actual team working on the design and technology and from the member of staff working closely with the NHS development partner sites. This approach provided a broad church for input and comments from all areas of the business involved in the artefact development over the lifetime of the project.

5.5.2. Reflecting on the Design and Redesign Approach for the Project

5.5.2.1. The Initial Design

The concept for this design project was initiated by a real-world problem from the field that had a significant impact on the NHS – the WannaCry attack. This wasn't the first and won't be the last time that a new design opportunity arises for the NHS from a problem or challenge inspired from practice rather than a theoretical basis. The selection of ADR as the methodology for the project supported this approach and allowed the initial problem to be scoped against this background. Reflecting on initiating the project from this point confirmed the strength of ADR. The design team were very embedded into the problem and could see the issue and the lack of any comprehensive solution. As the Chief Technology officer for the project shared:

> *'Because everyone we've spoken to is using spreadsheets and, you know, messy data wasn't being captured accurately. And so originally we were looking at how can we piece that together in a more automated fashion.'*

This design problem was instigated from the team's lived experiences from supporting the NHS within hospitals. We found during the research stage that other cyber security systems had been founded from a more theoretical basis. Darktrace, a UK Cyber start up currently valued at £1.9b, (Bloomberg, 2021) is an example that was created between ex-MI5 security officers and researchers at Cambridge University to solve a theoretical proposition of using AI to protect networks (Brewster, 2018). Our research, at events such as HIMSS conferences, also didn't identify any new systems being initiated from the real-world health vulnerability perspective. One of the C21 directors who was advising the NHS at the time of the WannaCry attack described the problem the project set out to solve:

> *'How we could provide some real benefits, not just to improving the of security within an NHS trust, but also to relieve that pressure on the staff. At this point in time, we're trying to try to deal with all of those cyber issues which are coming through.'*

There were however some challenges of this approach which I missed and are only now on reflection are clear.

The first challenge relates to the NHS as a complex organisation. The lived experience we had was with acute hospitals – the front line of healthcare delivery. On paper they are self-governed large entities, many employing over 10,000 staff and with annual budgets in the hundreds of millions. When you work within a hospital in the NHS it often feels like a stand-alone enterprise. It will have its own board of directors, its only norms and unwritten rules and decision-making models.

However, the hospital forms part of the wider NHS which as an institution has a wide range of external factors and stakeholders who can influence the hospital. This subtle but powerful external impact was missed when we initiated the project, our lens on the design question was focused on the end-users of the problem as expected for an ADR design approach. In hindsight we should have broaden our scope or lens on the problem and engaged with the more central bodies such as NHS Digital and NHSx on their plans for cyber. In our context, this was particularly important as these central bodies also shaped the wider policy context, which further influenced our target organisation more subtly.

The second aspect of the design I would do differently was to broaden our research. As we had started from a field inspired problem where the design team were literally on the ground fixing the problem. We felt we knew what the issues were and how to fix them. Even when I interviewed five senior NHS mangers to support identifying the issues many of these aspects that the design had to address were reinforced. This over confidence in our understanding of the problem led us to miss some key aspects of the design as the product manager described:

> *'So, I think actually understanding the complexity of the solution we were intending to design wasn't grasped early on. I think its complexity came about much later in the process about what we wanted to undertake.'*

The initial design was for an all-encompassing product built from the ground up to meet the problem we had encountered in the NHS. The design was trying to solve the comprehensive problem that had been identified. This included the complete scanning and identification of all connected devices (computers, laptops, servers, and network switches) on a hospital network. Identifying all the software components including version and patch updates for these installed systems. Then comparing these system versions to the published list by NHS Digital on its CareCERTs and alerting the identified issues to the appropriate staff. All these activities undertaken within the challenges of an NHS hospital and its technology complexity and diversity.

The commercial lead from C21 concurred:

> *'So, I think where the idea came from, that was the right starting point, it was the next stage, it was the bit from concept through to getting into a point where we decide that we want to build and for me that due diligence part, so the research around what actually is we're asking to do. Who else out there was doing it and realising that the products out there, the scanners that were out there, have been developed over 20 years.'*

Had we undertaken even more in-depth research into the wider market we could have identified that some of the component parts of the total solution had already been developed for other sectors such as the scanning engine. These tools did not need to understand the nuances of the NHS as they were just network scanning engines, and the focus of the design would have been (and this is where the product ended up) on matching the scanning engine outputs to the CareCERTs and automating this process for the NHS.

My interpretation of the ADR process focused on engaging the end-users – in this instance the IT and cyber security managers at the NHS hospitals. What I missed and would recommend anyone undertaking a design process where the organisation has complex institutional behaviours embedded across its environment, is to ensure the widest possible set of stakeholders being involved. In our case, it would have saved the project considerable time and money if we had understood the potential intervention from the central NHS body as well as the wider system on the local hospital wherein, we were working and designing.

5.5.2.2. The Redesign Stage

Where I felt the ADR process worked well was on the redesign stage. Through the cycles of engaging with the customer we were gaining direct and invaluable insight into their needs and how well the design would address them.

> *‘So, I think in that instance, the type of people that we're engaging with, like we had good working relationships with them making it easy to tackle misconceptions about software and then use it and what didn't work well and why and sometimes prioritisation of the trusts’*
>
> Product manager
>
> *‘That worked well in that we were able to show our partners what we were aiming to build, and they had the opportunity to feed into this where their needs were, where the needs were being met at the moment, and where the solution could fill that gap for them. So, I think gathering all of that was really good. I think maybe we could have done more than what we did and that would have helped a lot and had more touch points with those partners.’*
>
> Commercial manager

The last point raised by my commercial manager highlights one of the challenges of this approach. The questions of how much time and input can you ask of an external stakeholder even if they had committed to being a Development Partner. For NHS staff this is always a challenge, and I believe C21 benefited better than most would have done due to our long-term relationship. Even so, we still had meetings cancelled or delayed and the engagement fluctuated throughout the design stages.

The engagement of the NHS teams did really support the project at two key stages. Initially, when we redesigned the product following the withdrawal from the scanning engine aspect to focus on the CareCERT automation. The feedback and direction on the automation development minimised the impact of the change. The second stage was the realisation that the product as designed would not deliver the real benefits we sought. The product delivered the automation and alerts as required. However, the expected benefits weren't delivered. Through the engagement model it became clear that automating the alert was only part of the solution. As a design team we hadn't imagined how the product would be used and the need for a service wrapper. The design of the service wrapper (Vulnerability Management as a Service VMS) was achieved quickly and with minimal changes to product design.

I have questioned myself on if we should have identified the need for a service wrapper sooner in the design process. We had recognised early in the problem scoping stages the lack of cyber expertise in the NHS. Naively I had assumed the automation of the alerting would have addressed this skills gap. The wider team concurred that it wasn't clear if we could have identified the need to redesign earlier in the process:

> *'I think we probably would have changed the angle a little bit because it's [the product] not focussed on what end-users want'*

Product Manager

> *'I would say it would be difficult just because it's that process has helped us learn about the needs of the wider needs of the right teams'*

Technical Architect

The need when designing a product to imagine its end use case and how it would be used is well understood in areas such as furniture design or building design. For software design I have found little evidence of this as part of the design process. This could be a lack of my understanding or interpretation of the tools. It wasn't an explicit aspect of ADR and the engagement we followed identified the key signals that a service wrapper would be needed, but our focus was on the product, rather than its use. The imagined use of a software artefact, including the skills required, and its wider impact on work practices, is an area that I would consider for wider research as important components to augment the current ADR process.

In summary for the design and redesign stages, the ADR process provided a strong basis for engaging with the end-users and stakeholders. It should not be underestimated the time and effort required from the stakeholders to make this successful. However, to augment and build on the current ADR process, I would also encourage three additional considerations or steps to be undertaken. At the problem initiation stage undertake a wider stakeholder and competitor engagement where the process is used in a complex organisation or situation. During the design stage ensure that you can answer the 'so what' question on how the artefact will be used in the real world setting and does the artefact in itself solve the problem or deliver the benefit. If not do you need to consider additional elements or services to ensure the expected benefits are delivered.

5.5.3. Evaluate Adherence to Principles

Th ADR method has seven core principles, I have shown my interpretation of our adherence in the Table 25 below.

Principle	Adherence comments
Principle 1: To ensure that field problems are seen as	The project met this principle and adhered to the core

Principle	Adherence comments
knowledge creation opportunities through practice-inspired research at the intersection of technological and organisational domains.	requirements. The project was initiated through a real-world problem and conceived using practice inspired research at the juncture of technology and organisational domains.
Principle 2: This principle seeks to ensure that the artefacts created and evaluated are informed by theories and have the power to generalise.	The project created a new artefact, and this was evaluated within the organisation it was conceived for. The artefact could be generalised, but this was not tested within this project. The ability to use the artefact in wider fields was desired and would be an interesting next step.
Principle 3: Recognises the two influences of the IT artefact and the organisation cannot be separated. To address these there must be an iterative process involving the two drivers.	The project lent heavily on this principle of the iterative process between the development of the artefact and the organisation. The challenge arose when the organisation and stakeholders engaged were not necessarily the totality of who should have been involved. This is an area in which I would ensure in future when dealing with complex organisations I had covered all the stakeholders and better

Principle	Adherence comments
	understood the interplay and politics involved.
Principle 4: Reflects the value that all participants are involved in the mutual learning.	On reflection and from my interviews all the project team learnt from the process. What I did not evaluate was the stakeholder involvement. The artefact was accepted and in use in the NHS, but I didn't specifically investigate if the stakeholders felt their contribution provided value to the design process which is seen as a key part of ADR.
Principle 5: The key to the methodology is that evaluation isn't a separate stage following build but are interwoven into the design process.	This was a key theme in our approach and the artefact was constantly evaluated both internally and externally with the stakeholders at the development partner hospitals. The success of this approach allowed us to constantly update and reflect what we have learned. Although we did have to make a few major changes in the design these were picked up much earlier than if we had left

Principle	Adherence comments
	evaluation until the final product was released.
Principle 6: The principle of guided emergence reflects the combination of the emerging design (principle 2) and the updates to it from interaction with the organisation, participants, and users (Principles 3 and 4) and the demonstration of continuous evaluation (principle 5).	This principle was the outcome of our project as first the artefact had to change and then secondly the need for a service wrapper to be designed to ensure benefit delivery. The question on reflection is could or even should we have seen the need to change early in the design stage (Principle 2) or on the right intervention with stakeholders (Principles 3 and 4).
Principle 7: The final principle is to move from a specific problem and solution to a generalised solution for a generalised problem and any derivation of design principles from the research outcome	The outcome of the project is an artefact that is now available through a world leading scanning engine as a bolt on application and has been installed in the NHS on long term contracts. The artefact is still targeting the NHS and healthcare sector so not truly generalised yet. The project has highlighted areas where the design principles could be enhanced when dealing with complex organisations such as

Principle	Adherence comments
	the NHS. The enhancements include wider stakeholder engagement, more in-depth competitor analysis and the investigation into how the artefact will be used in the real world. I refer to this as imagining the artefact's use in the real world and if it does deliver the expected benefits in the environment in which it is being used. These areas are explored further in section 6.2.3.

Table 25 Adherence to ADR Principles.

5.5.4. Analyse Intervention Results According to Stated Goals

The final part of this phase of the ADR method was to analyse the intervention results against the goals. The need for evaluation is a central part of any rigorous research process but within design research, there are limited frameworks for evaluating project outcomes (Venable, et al., 2012). Examples of how evaluation is undertaken include 'does it work' (March & Smith, 1995) or its utility (Gregor & Jones, 2007) and potential side effects (Venable, 2006). Hevner et al (2004), proposed a more comprehensive list of utility, quality, and efficacy as the key attributes. These should be evaluated through the artefact functionality, completeness, consistency, accuracy, performance, reliability, usability, and fit for the organisation.

Many of these build from the earlier work of Checkland and Scholes 5 'e's of efficiency, effectiveness, efficacy, ethicality, and elegance (Checkland & Scholes, 1990). To support the design of the evaluation approach Venable et al (2012) built on the earlier work of Pries-Heje et al (2008) to develop an evaluation strategy shown in Table 26 below.

DSR Evaluation Method Selection Framework	Ex Ante	Ex Post
Naturalistic	Action research Focus Group	Action Research Case Study Focus Group Participant Observation Ethnography Phenomenology Survey (qualitative or quantitative)
Artificial	Mathematical or Logical proof Criteria-based evaluation Computer simulation	Mathematical or Logical proof Lab experiment Role playing simulation Computer simulation Field experiment

Table 26 A DSR Evaluation Method Selection Framework (Venable, et al., 2012).

ADR aligns to the naturalistic evaluation approach where the environment is real, in this instance a real problem with real end-users in a hospital. The artefact was evaluated both ex Ante – i.e., before instantiation and ex Post. Venables et al (2012, p. 429) do caution that *'naturalistic evaluation is affected by confounding variables or misinterpretation, evaluation results may not be precise or even truthful about an artefacts utility or efficacy in real use.'* The challenge we uncovered in this project was the difference in the effectiveness of the artefact and the efficacy. Using the definition provided by (Checkland & Scholes, 1990) where efficacy is the degree to which the artefact produces the desired effect without considering the situation concerns. Effectiveness is the degree to which the artefact has met it higher level purpose and delivers it benefits.

The artefact initially met its efficacy evaluation of identifying and alerting on vulnerabilities. It didn't however achieve at the later stage its effectiveness as the benefits originally signposted were not delivered.

The following Table 27 provides a comparison of the stated goals and objectives against what was delivered. The stated goals of the project were to address these specific problems.

Problem Area	Problem to be solved
1: CareCERTs are issued as an excel spreadsheet.	The CareCERTs are issued as excel spreadsheets via email to the IT department. They contain all the vulnerability alerts which have had their urgency set by NHS Digital. There isn't

Problem Area	Problem to be solved
	any filtering for the systems the organisation may or may not have.
2: Manual check of all potential devices and systems to identify any matching vulnerabilities.	The IT team will need to then check all their systems and devices to see if the specific vulnerability exists. This is a manual process of scanning every device and checking the software compared to the CareCERT.
3: Alerting the IT team to the vulnerabilities.	The outcome of the scan then needs to be checked and then the appropriate teams and people alerted to take action to resolve the vulnerability. This is again a manual process.
4: Providing a single lens on cyber vulnerabilities.	Alongside the CareCERTs there are several other systems that can identify vulnerabilities including anti-virus (AV) and system licensing tools. These are separate systems with no single view of all the risk surfaces.
5: Report generation for organisation and NHS Digital.	The IT Director then (depending upon risk level) must create a report for the hospital Board to alert them of any risk and a report to NHS Digital. This is another manual process.
6: Confirming vulnerability has been mitigated.	The final step is to remove the vulnerability (often requires a system patch to be made). Before finally

Problem Area	Problem to be solved
	checking again manually that the vulnerability has been resolved.

Table 27 Goals and Objectives Delivered.

These problems were then, through the initial engagement phase, developed into three objectives as shown in Table 28 below.

Primary Objectives Develop a secure, customisable dashboard for NHS IT management staff that displays high-level vulnerability data for their network in easy-to-read graphs. Rapidly highlight issues of non-compliance with the NHS Digital CareCERT so these can be prioritised with the option to drill-down into details to facilitate remediation. Provide reporting and alerting options for this data. Partner with an NHS organisation to allow us to gain access to a live NHS network providing the recourses we need to test and move the development forward when we are ready, making sure all commercial agreements are in place. Secondary Objectives User Authentication: AD/SQL authentication Network Monitoring: increase the scope of discovery to all network user devices and include routers/switches as well as live monitoring data i.e., polling via SNMP to firewalls, storage. Risk Scoring: Utilising information from CVS or other risk score the customers compliance to demonstrate the actual risk to the business Tertiary Objectives Management Tools: add the ability to automate remediation work i.e., patches through SCCM Dashboard Requirements Show compliance level of discovered assets against CareCERT & CVS information with live data feeds. The Dashboard must be able to be viewed on Windows, Mac, iOS, and Android devices Compatible with older browsers e.g., IE10 if possible. Allow reports to be downloaded in a specific format maintaining all data Automatically prioritise alerts and refresh data

Table 28 Initial Objectives for the Project.

In analysing the intervention results I will look initially at how we addressed each of the problems before considering the wider objectives. The results for each problem area are detailed below.

<u>Problem 1: CareCERTs are issued as an excel spreadsheet:</u>

This problem was addressed in the artefact through the ability to automatically import the alerts from NHS digital into the OTLO product and the create a look up system that ensured all CareCERTs were available to find and retrieve within the new artefact. The result is that the system user can now easily look up any previous CareCERT, its references and urgency level, easily and effectively, without needing to find the email alert and excel spreadsheet.

<u>Problem 2: Manual check of all potential devices and systems to identify any matching vulnerabilities</u>

Problem 2 was one of the major challenges for the project. There were two aspects to this problem; the scanning tool to check each device; and then the ability to match the result to the CareCERT library and create the output. The scanning engine was initiated at the start of the project within the overall aim of creating a comprehensive end to end solution. This was an error driven through lack of research of the wider competitor market and compounded by a limited stakeholder engagement. The key lesson from this stage of the design was we should have involved a wider stakeholder base for a complex organisation like the NHS and undertaken broader competitor analysis. This problem was resolved through the ADR cycles and a partnership with a global scanning engine supplier has proved successful.

The second aspect to address the matching criteria took a major part of the project to resolve. The concept was straight forward matching a CareCERT alert to scan result from the hospital network. This was envisaged to look as follows:

Step 1 CareCERT alert issued for Windows 7 v1.xx needs to be patched

Step 2 Scan all devices on the network and identify any with Windows 7 v1.xx software package

Step 3 Patch the devices

Step 4 Re-run scan and check all patched OK

The CareCERT alerts and the scan engine results however were not using the same naming convention and so the ability to easily match the alert to the result needed to be designed and built. The process involved multiple cycles of design, build, evaluate, and feedback. During this time the team engaged multiple universities specialising in cyber products as well as the LORCA team. None of these routes provided a solution. We then designed an automation process that involved multiple stage operations:

Step 1 CareCERT alert issued for Windows 7 v1.xx needs to be patched

Step 2 Scan all devices on the network and identify any with Windows 7 v1.xx software package

Step 3 First time only for any scanned software package – using robotic automation match the scan result to the Original Electronic Manufacturer (OEM) published details on their technical website

Step 4 Store these matched details into our database

Step 5 Using our algorithm, compare the scan results to our OEM database and to the CareCERT reference to identify any matches – these are then issued as devices to be patched

Step 6 Patch the devices

Step 7 Re-run scan and check all patched OK

The two-stage process of use robotic automation to initially identify an OEM code to the scan code and then to run the algorithm matching the CareCERT to the database to identify the at-risk devices that need attention and patching was our unique design solution. This process used tools from the 4IR to resolve cyber risks and vulnerabilities generated by 4IR tools used for the committing cyber-crime. The artefact is still the only one addressing the NHS CareCERT process today through an automated process.

Problem 3: Alerting the IT team to the vulnerabilities

Once Problem 2 had been solved the alerting question opened the door to who within the NHS should receive the alerts and therefore act on them. It was at this stage that the need for a service wrapper (VMS) was first identified as part of the solution. The earlier research had shown that lack of cyber skills and knowledge combined with resource pressures from staff shortage were mounting in the NHS. The original plan was that the automation of the vulnerability alerting would assist with the NHS cyber staff pressures. The artefact would save the time spent manually trying to match the scan results to the CareCERT. However, through the iterative cycles with the development partners it became clear that the new artefact would illustrate to the wider organisation the lack of skills, knowledge, and ability of the cyber staff and to resolve the cyber issues. This inability to act on the information or the ‘so what’ question required subsequent changes to the design.

On reflection, I was keen to understand if we should have or could have identified this need earlier in the process. Should we have ‘imagined’ the use of the product and recognised that the design needed to change as the artefact in itself wouldn’t deliver a clear benefit. Through this project, I do not believe that we would have been confident at the outset in making that decision. I do however believe that through the iterative cycles with the stakeholders we should have been asking that questions of how the artefact will be used and the implications of its use. As the product manager stated:

> *‘…early on, we were only looking at it as a product and a product that will - resolve the need and provide the visibility. We kind of looked at how our competitor in this specific field and decided that we wanted to do something similar better and try and quickly get ahead. The fact that the service was required, could we've have identified that earlier. I would say it would be difficult just because it's that process has helped us learn about the needs of the wider needs of the right teams.’*
>
> Product Manager

The outcome is that the artefact does provide alerts on a web-based dashboard that either, our own teams providing the VMS service use, or if the hospital does have sufficient resources for their own teams to manage the vulnerability.

From the experience of this project, I would recommend that when undertaking the ADR cycle the researchers should consider the imagined use of the artefact at each stage and keep testing if the artefact will deliver the expected benefit or will it need another element. The aim being can you answer the so what question of what the artefact will mean to the stakeholder.

Problem 4: Providing a single lens on cyber vulnerabilities

Problem 4 was easier to solve through the engagement cycles and once we had identified with the stakeholders the key cyber elements they were seeking. The dashboard working with the scanning engine extracts the necessary data such as vulnerability alerts, and anti-virus status for every application. Through the ADR process the design was able to be shaped to meet the requirements of the local stakeholders and reduced the level of design complexity when the actual use was better understood. Again, the ADR model worked and avoided us fully building what we had planned, when this was not required by the stakeholders.

Problem 5: Report generation for organisation and NHS Digital

The next step in the process for an NHS hospital is to report back to NHS Digital their compliance with the CareCERT once issued. The original concept was for the artefact to produce this report based upon the outcome of the scan and allow an email to be generated. Through the process of the design and testing NHS Digital moved to an online system which required a change in the artefacts design. This was relatively straight forward, and the artefact was able to produce the information needed. As with problem statement 4, the constant ADR cycles allow for inflight changes without the need for a significant change in the design or development process that may have occurred through a different design approach.

Problem 6: Confirming the vulnerability has been mitigated

In the original problem statement, there was two component parts. Firstly, the step was to remove the vulnerability (often requires a system patch to be made). Before finally checking again manually that the vulnerability has been resolved.

The assumption was made at the time that removal of the vulnerability – the remediation step would be undertaken by the hospital. The artefact would then only have to check that the affected component part of the software had been patched and vulnerability was removed. The original artefact was designed to meet the second part of the problem. The first part of the problem was the area that we had missed in our original scoping. The assumption we made was that the NHS staff would undertake the remediation work and patch the component part. Through the ADR cycles it became clear that this assumption was wrong and a redesign of the artefact with a service component was needed. As discussed, the timing of this need being identified by the design team was a lesson learned from the process and will form part of the formulation of learning.

<u>Objectives Met</u>

The final part of the stated goals was the delivery of the objectives. The following Table 29 shows the outcomes.

Objectives	Outcomes
Primary Objectives	Achieved
• Develop a secure, customisable dashboard for NHS IT management staff that displays high-level vulnerability data for their network in easy-to-read graphs. Rapidly highlight issues of non-compliance with the NHS Digital CareCERT so these can be prioritised with the option to drill-down into details to	• The artefact achieves this objective in full. The ADR process supported the output and ensured it was successfully deployed.

Objectives	Outcomes
facilitate remediation. Provide reporting and alerting options for this data. • Partner with an NHS organisation to allow us to gain access to a live NHS network and N3 providing the recourses we need to test and move the development forward when we are ready, making sure all commercial agreements are in place.	• The development partner model we adopted with four NHS Trusts was key to delivering the ADR process. Although we worked with the four trusts the input was not consistent across all development partners. Another lesson learned was being clear at the outset what is being asked in terms of time and effort of the development partner in the ADR cycle.
Secondary Objectives • User Authentication: AD/SQL authentication. • Network Monitoring: increase the scope of discovery to all network user devices and include routers/switches as well as live monitoring data i.e., polling via SNMP to firewalls, storage.	Part achieved • The system uses Azure AD authentication. • Failed – through the external stakeholder changes we moved from our own network scanner to a third-party scanning system. The ADR approach supported this change; however, I feel we should identify the

Objectives	Outcomes
• Risk Scoring: Utilising information from CVEs or other sources risk score the customers compliance to demonstrate the actual risk to the business.	eternal stakeholder input earlier in the process. • This requirement wasn't required when we worked through the ADR cycles with the development partners and was dropped. This saved significant cost in developing a feature that wasn't required.
Tertiary Objectives • Management Tools: add the ability to automate remediation work i.e., patches through SCCM. • Dashboard Requirements • Show compliance level of discovered assets against CareCERT & CVEs information with live data feeds • Dashboard must be able to be viewed on Windows, Mac, iOS, and Android devices	Part achieved • Following feedback from the development partners we moved to a service model rather than an automated model that wasn't acceptable to the client. • Dashboard was delivered • Achieved and this was the new tools we designed and developed using new tools. • Achieved through working with the new third-party scanning engine

Objectives	Outcomes
• Compatible with older browsers e.g., IE10 if possible	• Achieved the system meets NHS backward compatibility.

Table 29 Objectives and Outcomes.

Through this stage of reflection, the ADR method, was seeking to analyse intervention results according to stated goals. The initial review shows that the project achieved its efficacy evaluation – the artefact alerted to potential vulnerabilities through the newly designed automated technology. It wasn't however, until the service wrapper design was added that the effectiveness evaluation met within the newly agreed scope of the project.

Overall, the project only achieved partial goal delivery against the original targets and objectives. This, however, doesn't reflect the changes that occurred outside of the original stakeholder lead engagement. These external influences affected the basis on which the project was built. The use of Institutional Theory helped frame the need to consider how baseline factors will change when dealing with complex organisations such as the NHS. The norms of changing behaviour that we experienced and the impact of external stakeholders on decision making are features of the NHS as a complex organisation and how to manage them when utilising the ADR method. Factors identified included the need for wider stakeholder engagement and consideration of the imagined use of the product within that organisational setting. Another aspect that influenced the results against the goals, but not directly related to Institutional Theory, was the wider assessment of the competitor market. These areas are explored further in the following sections.

5.6. Stage 4: Formulisation of Learning

This stage transfers the problem from a specific problem into a general solution. The outcome from the artefact and the learnings are transferred to design principles and refinements to the theory. Within the ADR method the final principle is:

Principle 7: The final principle is to move from a specific problem and solution to a generalised solution for a generalised problem and any derivation of design principles from the research outcome.

This case study looking at a new cyber security artefact confirmed the original paper on ADR by Sein et al *'Generalization is challenging because of the highly situated nature of ADR outcomes that include organizational change along with the implementation of an IT artefact.'* (Sein, et al., 2011). The case study did generate an IT artefact, but the artefact only truly delivered the expected benefits when the service wrapper was applied to support the organisational change needed. Sein et al identified three levels for this conceptual move: (1) generalisation of the problem instance, (2) generalisation of the solution instance, and (3) derivation of design principles from the design research outcomes (Sein, et al., 2011). The following sections explore how this cyber security case study could lead to a wider generalisation.

5.6.1. Abstract the Learning into Concepts for a Class of Field Problems

This cyber security case study was initiated as a practice inspired research project. The approach was justified, based on a clear problem identified, in a live environment within the NHS. The project was established along similar lines to an Action Research model with a mutual approach from the design team, the end-users, and the researcher. The use of the ADR method within the complexities of an organisation like the NHS provided a strong framework in which to operate. Whilst the project in this case study was a well-defined and situated problem – a cyber vulnerability problem, I would propose that the same approach would work for almost all new information technologies that the NHS and other complex organisations will need in the future. The 4IR is going to substantially increase the need, proliferation, and use of new information technologies as was shown in Chapter 2. These technologies will include AI, machine learning, and robotic automation, all requiring significant rethinking of how they are used. It is this last part that is the generalisation of the problem. If designers build new system based just on the technology itself but don't imagine or consider the changes required in the whole service provision, then the design will either not meet its true benefits or fail. This case study has shown this to be true within the specific situation and I propose that this is a generalised problem – when designing new technology within complex organisations the designers must consider the 'so what' question within the wider environment. Section 2.4.3 showed examples of where the technology did what it was asked to do but still failed to deliver the outcome needed. To achieve the outcome desired the imagined use of the technology in situ needs to be understood and the overall design considered.

I have argued that the problem is generalised and the solution that we eventually built can also be generalised. The initial phases of the ADR built a solution against the specification identified by the end-users, but it was only when we constantly tested this artefact with the end-users that we identified the real need and answered the 'so what' question. The artefact could, and using tools from the 4IR, did rapidly detect and alert end-users to vulnerabilities in the systems. However, the NHS couldn't respond to these alerts and so an additional service wrapper was required in this instance. The need to consider how the artefact will be used and what the other changes will be made needs to be part of any solution being developed. This will certainly be true when new developments such as AI predicting a deteriorating patient (Fiahult, et al., 2017) are delivered to the end-users. The question that will need to be addressed is how the doctors and nurses are going to use this new information (prediction of a patient deterioration in advance of the deterioration). Also, has the delivery of that information been designed with the changes required in care been considered. If all new artefacts developed also consider the wider use case and changes needed, then the solution design approach we have taken can be generalised.

From this study I have identified three areas where on reflection I could have applied ADR more effectively: greater awareness of the competitive landscape, greater awareness of the decision makers and influential stakeholders within the NHS and the imagined use of the artefact in its real-world setting. The strength of the ADR process allowed this project to overcome these shortfalls and deliver an artefact that is in use and delivering real world benefits.

The first two areas were poor implementation of my understanding of the ADR process. On reflection I would encourage anyone undertaking a new design to spend more time on what, where, and how the competitors within the market are responding to similar problems. On the stakeholder aspects I didn’t fully recognise the unmentioned rules or normal behaviour found in the NHS that may not found in other sectors. This project demonstrated that we engaged and worked with the key stakeholders and end-users at a hospital level. However, within the institutional setting there was a wider range of other stakeholders and influencers we had not considered.

Stakeholders changing the rules is normal in the NHS which may not be seen in other sectors as often. The need though, to deal with scope creep and unfolding external influences, isn’t unique to the NHS, Nandhakumar et al (2005) found similar challenges when implementing Enterprise Resource Planning systems (ERPs). I would recommend that any user of ADR considers the wider stakeholder environment when undertaking Stage 1 of ADR and reviews these stakeholders for the evaluation at Stage 2.

The final area of considering the imagined use or answering the ‘so what’ question wasn’t explicitly called out in the ADR process. Nandhakumar et al (2005) research into ERP implementations showed that the challenge of technology interaction with humans and unintended outcomes has been studied for many years. The need to understand how an artefact will be used in its real-world setting isn’t new. Jones (1998) presented this as human plans and goals and the fact that these are not always known at the outset or that human actors can even recognise their own motivations to realise the outcomes. Other researchers including Orlikowski (1992, 2000) recognised this challenge and proposed using structural / agency theory to embed the rules and resources into the design process. Monteiro and Hanseth (1995) proposed the Actor-Network theory seeking the equal treatment of human and technological actors.

Nandhakumar et al (2005) research used these three concepts: intentionality, affordance, and social structure to study ERP implementation. Their findings show a similar outcome to this project:

> *‘…at the organizational level, the national companies and subdivisions always had freedom in running the local operations and purchasing software. Such strong cultural norms had a profound influence in constraining managers’ intention of creating a unified model of processes for all local operations in different countries (Corporate ERP). By drawing on such norms and their relative power position many national divisions resisted to give up legacy systems. Senior company executives drew on their recourse of authority to promote the project as a major initiative for the company’s success.’*

(Nandhakumar, et al., 2005, p. 235)

The paper on ERP although focused on implementing a new system rather than designing a new artefact highlighted similar challenges and proposed that through the concept of affordance to provide a conceptualisation of technology use in a social situation. The implication in the ERP programme was technology drift. They found that '*the planning stage may not be able to predefine all changes to be installed and foresees their organizational implications'* (Nandhakumar, et al., 2005, p. 239). The researchers identified the need for further research in empirical settings to understand the concepts of intentionality, affordance, and social structure.

This current research project focused on the design of a new artefact but encountered similar challenges to the ERP implementation when the technology was introduced into real world settings. I would propose that undertaking the imagined use at the early stages of design could reduce the need for redesign later in the process, saving time and effort and delivering a better outcome.

5.6.2. Share Outcomes and Assessment with Practitioners

The outcomes from this project have been widely disseminated within the company and will form a basis for any new product developments. The feedback from the team indicated the benefits of the early engagement with the end-users as a key factor. There was also recognition of the need for wider market surveillance before starting at the design stage. The team have been open to the constant cycles and on reflection of the process we will adopt the ADR methodology again, strengthened by the learnings from this project.

5.6.3. Articulate Outcomes as Design Principles

Three areas were identified through this project that I would undertake differently next time. The first, greater awareness of the competitive landscape is not a specific to ADR but is a general principle for any design methodology. I would recommend this for any new design project.

The second, greater awareness of the decision makers and influential stakeholders within the NHS reflects that when using ADR or any other methodology in a complex organisation or institution there must be an awareness of the wider stakeholders and influencers than may initially be considered. This finding builds on Nandhakumar et al (2005) and should be considered whatever methodology is being used.

The final area, the imagined use of the artefact in its real-world setting is a design principle that could be called out in the early stages of ADR. Stage 1 of ADR focuses on the problem formulation, and I would add an addition task to this stage:

- Stage 1 Problem Formulation
- Tasks to be performed:
    - Identify and conceptualise the research opportunity
    - Formulate initial research questions
    - NEW – Understand the impact of the artefact on the organisation through the imagined use of the artefact in context
    - Cast the problem as an instance of a class of problems
    - Identify contributing theoretical bases and prior technology advances
    - Secure long-term organisational commitment
    - Set up roles and responsibilities

The addition of this new task is to ensure that the problem isn't only formulated but this is then set within the context of the organisation and consideration is given to the imagined use of the artefact in that context. This should identify at an early-stage other factors that need to be considered.

To then build and reinforce this focus on imagined use in stage 2:

- Stage 2: Building, Intervention, and Evaluation
- Tasks to be performed:
    - Discover Initial Knowledge-creation target
    - NEW – ensure interpretive flexibility is built into the BIE cycles
    - Select or customise BIE form
    - Execute BIE cycles
    - Assess need for additional cycles, repeat

As the project enters the design, build, and evaluation stages the additional task is to consider the interpretive flexibility not only to the artefact, and its role in the organisation, but also how the organisation redefines the problem in relation to its changing context. This approach works well with the BIE cycles and allows the practitioners to build on the imagined use case with the end-users through the cycles. This additional step should allow the ‘so what question’ to be answered.

These two additional tasks will support the ADR approach to artefact design and reduce the risk that the artefact doesn’t deliver the expected outcomes in the real-world setting.

5.6.4. Articulate Learning in Light of Theories Selected

There are many different theories and methodologies that could have been used for the project including, agency theory, actor-network theory, social cognitive theory, action research, expectation - confirmation theory, unified theory of use and acceptance of technology, soft systems methodology etc. I selected ADR based on the principles or the engagement with the practitioners, researchers, and end-users. Reflecting on the project, the ADR methodology proved powerful in dealing with the changing norms of the NHS and through the early and on-going engagement with the end-users the ability to make significant changes to the design inflight. When dealing with complex organisations and institutions where their behaviour can be difficult to predict having a methodology that ensures you are able to keep check with the end-users throughout the process minimises the risk that the artefact won't achieve its desired outcome. This project demonstrated this through the impact of eternal stakeholders influencing the fundamental design of the system. Also, the identification of the need for a service wrapper to deliver the desired outcomes. The learning gained through this process was the need for wider and deeper understanding of the complex organisation, in this case, the NHS. Also, the need to fully understand how the artefact would be used and what this would mean for the design and outcomes. The ADR method is well suited to being used in complex organisations especially where the artefact being designed will require the end-user to change their processes or behaviour.

5.6.5. Formalise Results for Dissemination

The outcome from this project can be seen through two lenses, academic, and the impact in practice. The project has identified three areas where ADR could be either better implemented or improved. As a practitioner and researcher using ADR in a complex organisation, I would now extend my early-stage work to include a wider competitive analysis and a greater understanding of the stakeholders and external influencers. The need for this additional focus was shown in the Pilot Case Study at TS and the main Case Study at C21. In both examples time and effort was spent on designing and building products that were either dropped completely in the case of TS or needed to be redesigned for the cyber vulnerability product. The main drivers for these changes were lack of competitor analysis and understanding, along with the narrow focus on stakeholders and end-users at a hospital level rather than the wider NHS as an organisation. The need for designers to grasp early on that complex organisations change and 'move the goalposts' as normal behaviour is key to be able to interpret the flexibility needed for a successful outcome. Institutional Theory helps to shape this challenge and understand the need to recognise the behaviour norms and power influencers. The challenge is to then build this flexibility into the design stages.

The project also identified an addition set of tasks that could help answer the 'so what' question when a new artefact is introduced into an organisation and social setting. There is a need to be able at the outset of the ADR process to imagine how the artefact will be used and include the consequences of this use in it design. This requires the designers to understand what changes may result from the use of the artefact and how to support those changes or design them into the process. In the cyber vulnerability project, the design had to be extended to include the services needed to react to the alerts identified. This project has identified two areas where greater understanding of how ADR would be used and an additional task to be considered at Stage 1 and Stage 2 will improve the outcome of the process.

The project also had a significant impact in practice through the development of the artefact. This can be seen in two areas. From a design perspective the artefact has developed and built a novel tool that automates the identification of cyber vulnerabilities from NHS Digital CareCERTs and the scan results from hospital networks into a simple dashboard report. This process removes many hours of manual work and ensures that high risk threats can be identified and acted on quickly. Had this capability been available when the WannaCry attack happened the impact of the cyber-attack could have been significantly reduced or eliminated altogether.

The second impact is its use in the NHS, the artefact is in use across several NHS organisations covering 27,000 staff or 4% of the NHS within its first full year of availability. The system has recently stopped the Windows Print Spooler Remote Code Execution Vulnerability which made headline news (Independent, 2021). The artefact rapidly matched the vulnerability to the systems and tools affected and allowed the patch to be applied through the service wrapper. The outcome of the project has achieved additional academic understanding of design research and developed a new artefact that is having a real-world impact in the NHS.

6. Discussion

6.1. Introduction

The background and context for this project was developed to address the dichotomy between the new IS capability that the 4IR was delivering and the need for new technologies to support the burdening health need. This scope was too broad for a thesis case study grounded in practice. The macro problem need however, was made and I set out to identify a specific opportunity to develop a solution using ADR as a model for testing and learning. Cyber vulnerability met this need, the subject matter is a key factor for the NHS and its impact is significant (WannaCry showed this in 2017). The tools used to develop the threats and provide the solutions rely on outputs from the 4IR. The overlap of the three areas, new technology, healthcare (specifically NHS) and cyber vulnerability, provided a very specific focus for this case study.

This project was therefore established to solve a real-world problem within the NHS, a complex organisation through the lens of Institution Theory. I wanted to explore how new IS artefacts could be designed when an institutional field reshapes the organisation, influencing the problem, the scope, the roles, and the priorities through a shifting resource environment. The problem was organisationally defined (the need at hospital level for a vulnerability management tool) but contextualised in wider field. In designing the IS artefact, this meant the interpretive flexibility extended not only to the artefact, and its role in the organisation, but also to how the organisation redefines the problem in relation to its changing context. This proved to be pertinent and particularly important in public sector contexts where government and other central stakeholders who, although somewhat removed from the organisational problem and context, in relation to the design of an IS artefact can through reshaping the organisation impact the design challenge.

I selected the ADR method for designing a new IS artefact and investigated how effective the ADR process was in the NHS as a complex organisation characterised by two features: public sector organisational characteristics and external environmental conditions.

The discussion is broken down into the following key areas; the impact of using ADR within the NHS as a complex organisation; ADR as a methodology in designing a new IS artefact and the impact of the artefact on the NHS; how does the artefact compare to other industrial tools from 4IR; and can the findings from this project be used more generally.

6.2. Using ADR Within the NHS

This paper is set within the crossroads of two global dynamic forces, the rapidly changing technology environment defined by the 4IR and the increasing pressure on healthcare costs and resources. I have argued that healthcare urgently needs new technology to deliver care effectively and efficiently. There is however a legacy of poor technology adoption within healthcare compared to other market sectors. The reasons behind the poor adoption are complex and multidimensional. There are a wide range of studies into these areas that have indicated both poor design and poor implementation. Within the scope of this project the objective was to investigate if ADR would be a suitable methodology for use when designing new IS artefacts for the NHS. I had the opportunity to work with four NHS organisations on the development of a new cyber vulnerability product from concept through to real-world use. My role was both researcher and practitioner within the wider development and company delivering the new artefact. This allowed a unique insight as the ‘Action’ aspect of ADR supported my researcher involvement in the subject.

This project has shown that ADR is suitable for use within complex organisations, such as the NHS, where institutional challenges arise.

Using ADR in the project I have identified three areas where I believe improvement could be made. Two of them are more enhanced guidelines on areas that need to be considered when deploying ADR and the third was a new task to be completed.

6.2.1. ADR Improvement Area One

The first area, a need for wider study and research of competitor landscape was clearly needed in hindsight and was a failure on my part to consider this adequality before starting the design tasks. This is a simple recommendation for all future design researchers to spend time on the market analysis and competitive approach, irrespective of what methodology or tools are being used. This outcome aligns to the work of Mullarkey and Hevner (2019). Through their own use of ADR to develop a new artefact they also recognised that the early stages require

> *'a thorough investigation and diagnosis of the problem domain and an evaluation of IT solution classes'* (Mullarkey & Hevner, 2019, p. 9).

6.2.2. Improvement Area Two

The second area is more interesting in understanding how well ADR works when applied to a complex organisation. The NHS operates within an institutional setting and its behaviour reflects ideas, values, and beliefs driven through the organisation and the convergence of the organisation to ideation templates created outside of the organisation. In this project the institutional affect was seen through the local organisations being unaware of the external factors and decisions being undertaken by another central organisation within the NHS. The shift that is now underway in the NHS from a decentralised belief system, that has been in place since the failure of the National

Programme for IT (NPfIT), to a more centralised command and control approach.

The literature review identified several themes that researchers should consider when working in complex organisations using Institutional Theory as a lens. The following Table 30 compares the themes to this case study and the experience the project went through.

Theme	Findings from This Project
Any IT change must be understood in the wider socio-political and inter-organisational environment. As opposed to just being an IT project delivered to the end-users. IT dominated change must meet clinical acceptance and benefits realisation. Where there is a lack of alignment creates further barrier to adoption.	This project was initiated at the organisation level of a hospital. It did engage with the key end-users, accepting that many of them were IT as the focus was on technology and not clinical in this instance. Where we failed to fully see the institutional affect was the wider social-political and inter-organisational changes underway. With hindsight the shifting power base was clear and the impact on the project could have or even should have been seen earlier. This would have saved time and effort on developing a scanning engine that wasn't required. The ADR process did allow us to address this issue and the repeated BIE cycles allowed for the adaptions to the design.

Theme	Findings from This Project
The solutions shouldn't be focused on the narrow window of IT and technology but to win the wider hearts and minds of the users who will be expected to adopt the technology. The product must match to the users' settings and practices.	The project initially reflected what the end-users had asked for – a cyber vulnerability IS artefact. This was built and worked. However, the output didn't meet the needs of the end-users. We had initially failed to win the hearts and minds of the users as the product didn't meet their needs in practice. We hadn't answered the 'so what' question of how the product would be used. This was a key lesson leaned and an area I feel we can improve on. The ADR process has the flexibility to keep repeating the BIE cycles, but I would recommend discovering as much of the expected use in practice earlier on in the process – the imagined use of the product.
Communication is key between those leading the implementation and the intended users of the systems. The need and adoption of user engagement in all aspects of	Working with the four development partners was a powerful tool in this setting and ensured that even when there was a shift in control and power base this could be addressed. The development partners were

Theme	Findings from This Project
the process for implementation is advocated	also key in helping to shape the additional service elements. This is a strength of the ADR tools with researcher, practitioners and end-users involved from the outset and through the entire design journey.
Any IT programme must be understood in the competing institutional logics of the history of NHS and its public ethos and professionalism versus the private sector supplier behaviour of efficiency and performance management.	This is a key dynamic that any supplier looking to design and develop new artefacts in complex organisations needs to fully understand. In this project as a supplier, we believed we had the design agreed with the end-users. We had not fully understood the competing institutional logics as the external stakeholders affected a shift in power base.
Explaining to the wider stakeholder why the investment in IT is a priority over the direct investment in staff and treatments. This conflict may be driven by the historical behaviour of professionalism and clinical decision and the prioritisation in short term spending at local level by	The challenge from a cyber security perspective is to gain stakeholder support from the hospital board when they are under pressure for funds and resources from many competing factors. The small investigation undertaken in this case study on NHS IT and cyber security spend shows a significant

Theme	Findings from This Project
executives. If all stakeholders cannot see the benefit of the investment, then resistance will be found.	underinvestment compared to other industries.
That one size does not fit all, and IT adoption and diffusion occurs at a local level you cannot legitimise the innovation through coercive pressures alone from central government.	This theme reflects why the National Programme for IT failed as it tried to impose a central solution. For this project the institutional logics are changing from a local to a more central powerbase. What isn't yet clear is how this will impact adoption of new technology at the local level.
Finally, that policy changes outside of IT often lead to wider institutional forces which can either fuel or prevent the change.	The NHS is a 'political football'. Attempting to work in the NHS without recognising this will not generate the outcomes desired. The new Health and Care Act will move the institutional forces again. Even a small IS artefact on vulnerability is impacted by this change and any supplier working in complex organisations needs to ensure they take a broad view on the stakeholders and influence they have.

Table 30 Institutional Themes as Seen in This Project.

Institutional Theory provided a powerful lens and framework to set this project against. Even with this foresight and learning from previous large IT programmes I still made mistakes and didn't spot the shifting norms and rules within the wider NHS. For this project the work started when local organisations believed they were in control and could act as they saw fit. By the end of the project a significant shift has been undertaken and power pulled back into the central NHS and government bodies. This can be seen in the latest Health and Care Bill or the statement that all centrally funded projects must meet a new requirement on business case and procurement route. The establishment of NHSx as a new arm's length body working between the DHSC and NHS England / Improvement and NHS Digital. These changes are normal in the NHS and NHS staff are used to the shifting dynamics. The challenge for any designer and developer of new IS artefact is to navigate and use tools that can cope with these shifting baselines that operates within the NHS.

For a design methodology to work in this context it needs to be able to identify the environmental and organisational variables within the entity (institutional affects) and the process (institutionalisation). This project has shown that the BIE cycles within the ADR approach can deal with both changes in the entity and the process. On reflection, for this project the changes to the entity through the institutional effects were not identified sufficiently early in the design process to avoid a significant redesign. The BIE cycles allowed for the redesign but at a cost to the project and business.

This is a key learning from the project that when working with complex organisations where change and power shifts are common, additional time should be spent understanding the wider stakeholders and power basis at the outset. This isn't an explicit task in ADR but a clear recommendation when working with complex organisations. As Currie's (2012) work on the NPfIT demonstrated when a centrally driven IS programme failed without local support. Scarbrough and Kyratsis (2021) cited work by Dixon-Woods et al (2013) on a similar failure in a top-down driven project for improvement in an ICU. The Keystone project had proved highly successful in the USA where it was implemented through normative isomorphic pressures of the clinicians sharing the work through social networks. In the UK the project was a top-down mandated change that was resisted. The current cyber vulnerability project highlighted how a local project was impacted by a central change.

The lesson learnt from this aspect is to take more time at the outset and fully understand the environment, stakeholders, competitors, and influential power holders inside and outside of the target end-user setting.

The two areas that I have identified for improvement in the ADR early stages have been combined by Mullarkey and Hevners (2019) and labelled as the 'Diagnosis' stage and the requirements from their findings match the issues that I have identified:

> *'The researcher must understand the application domain of the project to include specific knowledge of the practitioner's organisation with its strengths, weaknesses, opportunities, and constraints. At the same time, the practitioner must become aware of the existing knowledge base of research and practice in the fields of study that will inform the design and evolution of the intervention artefact'* (Mullarkey & Hevner, 2019, p. 9)

The two projects, this cyber vulnerability case study and Mullarkey and Hevners new online enterprise environment were both undertaken within similar time windows and for projects where there was no initial solution to build on. In reviewing the findings from Mullarkey and Hevners work Sein and Rossi, two of the original authors of the ADR method supported this additional element (Sein & Rossi, 2019).

6.2.3. Improvement Area Three

The third area that I identified was to address the ‘so what’ question that once an artefact has been built and deployed was the impact on the user experience and the capability of the artefact to meet that need considered. This is often different to the original specification and requirement. This concept of imagining the use and impact at the early stages of the design process are challenging as the researcher, designer and practitioners are seeking an answer to an often-theoretical question. How will the artefact change the behaviour of the users? If the change imagined doesn’t solve the original problem, then a redesign at the early stage would save time cost and the effort of finding this outcome through the BIE cycles. In suggesting this new step, I am not advocating the removal of the diagnosis stage or the removal of any BIE cycles but an additional element of the diagnosis stage and a regular reflection and evaluation of the BIE cycles. Being able to ensure that the new artefact can answer the ‘so what’ question through imagined use will enhance the practical impact of the artefact. I would propose that as we move further into the technical capabilities of the 4IR the need to ensure that the imagined use of the outcome in its fullest sense has been considered to cover areas such as ethics and governance.

6.3. ADR as a Methodology in Designing a New IS Artefact and the impact on the NHS

The Department of Health and Social Care and the Academic Health Science Networks identified several barriers that would need to be overcome for tools from the 4IR to transform healthcare. These were set at a general level to cover all aspects but do provide a good checklist for the outcome of the design. The first challenge was to ensure that the AI (new technology) solution was grounded in a real-world problem as expressed by healthcare users. This problem and the ADR process fully support this. My read on this barrier is to not develop new technology just because you can but really ensure there is a need and a benefit. Scarbrough and Kyratsis coming from an implementation perspective identified the same need for connectivity between clinicians (system users) and developers to focus on real-world healthcare problems (2021). From this project, the outcome must be able to answer the ‘so what’ question – just because technology can do something does it make a real difference.

The second barrier was to engage healthcare professionals to develop an ethical and trusted approach. This focuses on how you can provide confidence that the data and tools from the 4IR are being used ethically and the outcome can be trusted. The ‘Blackbox’ challenge needs to be overcome in that a clinician or end-user will need to understand how a new artefact has developed the outcome. If the designers cannot clearly articulate how the new tool has created its output, there may be doubt or limited trust in these outcomes. For this project, the basis of the data was a trusted global database of known vulnerabilities and exposures, and we could demonstrate easily how the robotic automation process was matching one output with another. This challenge will be harder where different types of machine learning are involved and needs to be considered at the initial design stage.

The next barrier identified was to build capacity and capability. The challenge the NHS has, is its ability to attract and retain staff with the right skill, knowledge, and experience. Other industries invest more in new technology. This is then compounded as the pressure on executives to balance the staff pay across multiple different professional bodies with different power basis creates other barriers. In this project it was identified that the NHS didn’t have the staff capable of dealing with cyber vulnerabilities and so a service wrapper had to be added. For other areas delivering new technologies the designers will need to consider how the tools and outputs can be supported and used by the NHS if the capacity and capability isn't available within the NHS.

The fourth theme was to ensure there was regulatory framework fit for purpose. In healthcare all medical devices including IS artefacts must be registered and approved with the regulatory body if they are a medical device. This process can often take several years and require full medical / clinical trials to be undertaken. The issue will be as new tools, systems, and devices using AI and machine learning are developed their rate of development may be too fast for the current regulation process to operate at. This isn't an issue for this project as the domain isn't yet a regulated area but is a factor that designers will need to consider for artefacts that fall under a regulator.

The penultimate theme was to explore new funding and commercial models. This is a broad area covering aspects such as who owns the data being used to train and develop new algorithms. How does the NHS see a return on its involvement in new systems development? Through to ensuring that the new systems deliver on benefits which could be seen as a shared risk / return model. This area deserves a research project in its own right and would need to consider ethical and data privacy as well as commercial areas and is beyond the scope of this case study. The cyber vulnerability data used for this case study was made available through NHS Digital as open source and available to the wider community. One area that has not been fully addressed to date is the value that is being developed through the new artefacts matching capability between a CVE code and a network scan result. Over time this matched data set will be of value beyond just the NHS and so will need to be addressed by C21.

The final area was the need to ensure a sound data infrastructure was built with quality data sets and interoperability. This project has fully addressed this area. The data quality is delivered through the NHS

Digital qualified alerts issued on known vulnerabilities and exposures. These alerts are also prioritised which added the impact dimension to their risk level. The network scan engine results operate to a six-sigma accuracy providing assurance on the detection level. The final aspect of interoperability is the key to the design of the new IS artefact. Using robotic automation to match the CVE codes to the scan engine result and show in a human readable format the outcomes, risks and actions needed.

The project addressed many of the barriers the Department of Health and Social Care had identified. The outcome of the project was a success in that a new IS artefact is in use across multiple NHS hospitals providing real benefits. The ADR Stages, Principles and Tasks followed in this project worked from taking an initial problem through to a delivered solution. However, in the process I have identified an additional area for consideration – the imagined use of the artefact in its context. The BIE processes deployed through ADR allow for an interpretive flexibility in the artefacts design and build. This constant cycle through build, intervention and evaluation provides for a very flexible approach to the artefact. In this project I have identified another need for interpretive flexibility – how the organisation redefines the problem in relation to its changing context once the artefact has been implemented.

When the cyber vulnerability product was articulated as a problem the end-users were clear on what was needed – an easy to see alerting tool that prioritised intervention. Through the early stages of the build, the feedback and evaluation, were focused on the artefacts capability to interpret data and provide suitable and timely alerts. The flexibility of the ADR process allowed the design to change – i.e., what widgets were shown on the dashboard, what reports would be needed. The process even coped with the change driven from external influences that resulted in the need to use a third-party scanning engine.

It was only on the final cycles of BIE that we identified a new dimension to the problem statement. Even though the artefact was creating the correct alerts in a timely manner the NHS couldn't fix the vulnerabilities due to staff limitations in terms of resources and capabilities. In fact, the artefact focused a light on these issues and had failed to answer the 'so what' question. So, what are we going to do now we know we have a cyber vulnerability problem?

In considering the problem statement from this aspect the design needed to change. This issue reflects that found by Heifetz and Laurie (1997) of two types of problems: technical and adaptive. We had addressed the technical aspect and delivered a new artefact that met the specifications agreed with the end-user. What we hadn't addressed at this stage was an approach to solve the adaptive problem. The end-users need an adaptive solution to their problem even if they hadn't realised that at the outset.

The flexibility was needed to work with the end-users on the additional service elements that would allow the systems patches (these remove the vulnerability) to be deployed, had to be built into the design. From these findings I would recommend that two additional tasks are undertaken when using ADR. Firstly, during the problem formulation stage, seek to understand the impact the artefact will have on the organisation through the imagined use of the artefact in context. This will require the design team to interpret the artefacts use and how the organisation will react to the artefact being present. This will require the interpretive flexibility of organisation itself.

In practical terms, I am not expecting the initial design to fully articulate the impact the artefact will have, and how the organisation will react. It has been shown that predicating how humans will react to change is never predictable or rational. The strength of the ADR cycles does however provide a framework in which to initially imagine the impact and then test the impact and the end-user's response through the BIE cycles. This requires the new task of identifying the imagined use at the problem formulation stage. Then during the BIE cycles to adapt and interpret the impact as each version is released and flex the design to ensure the original goal is achieved.

If we have undertaken this analysis and activity for this project, we would have identified that the NHS cyber teams were often poorly funded and lacked resources and skills to deal with cyber threats. This would then have been considered when the problem was defined to not only set out the technical needs of the artefact. To also define the impact within the NHS IT departments and what else would be needed to deliver the end-to-end solution. In this instance it was a service wrapper and remote monitoring. In other areas it may be a different way of presenting the findings or how the information is shared. For example, if the artefact instead of alerting on cyber risks was alerting on a deteriorating patient with Acute Kidney Injury (AKI) (there are several AI projects working on this). The capability to alert a medical team meets the initial problem formulation. It doesn't however answer the 'so what' question. In this example it could be that the alert needs to go to certain people based on location or rota. It could be that the alert also needs to be linked to the agreed response to that condition – i.e., what is the locally agreed protocol for dealing with an AKI. You would also need to consider how a trained doctor would react to being told by a machine what to do for their patients. All these impact factors would need to be considered and addressed in the design of the alerting system for a deteriorating patient with an AKI.

As more technology solutions and systems are developed with the tools of the 4IR the need for the design process to address the 'so what' question will only increase. With further automation, machine learning and AI the designers must understand the impact the artefact has when deployed into its end-user context. The design process should ensure that it has the flexibility to deal with the interpreted use when humans and complex systems are involved. The ability to identify this impact early on and adjust the design to ensure the outcome meets the real problem will help reduce technology failures and improve the healthcare outcomes for citizens and patients.

There is a lot of research on how technology is implemented and there are clearly cross overs between the change management, transformation and benefits realisation work and this project. What I hope I have shown is that by considering the impact of the artefact in its intended context at a design and build stage the ability to achieve the desired benefits and adoption of the technology will become easier.

This project has shown that ADR can deliver a new IS artefact that has real impact on the service provision for the NHS. Through the triparty arrangement of researcher, practitioner, and end-user the artefact was designed, built, evaluated, and successfully deployed. It has delivered real benefits to the NHS and made an impact. With the recommendations for areas in the ADR method that we would improve, we could have achieved the outcome sooner and at a lower cost and I hope other designers will learn from these findings.

6.4. How Does the Artefact Compare to Other Industrial Tools from 4IR?

The project was set within the macro environment of a new industrial revolution with a step change in technology capability. Other industries have led the way in adopting new technologies and ways of working (Manu, 2015). However, healthcare has often been seen as a laggard in accepting these new models of service delivery and technology (Parker, et al., 2017). This section of the discussion will compare the new cyber vulnerability artefact developed through this project with concepts and examples used by other industries.

Schwab proposed four main effects of 4IR for business:

- Customer expectations are shifting.
- Products are being enhanced by data, which improves asset productivity.
- New partnerships are being formed as companies learn the importance of new forms of collaboration; and
- Operating models are being transformed into new digital models (Schwab, 2017).

In reflecting on the outcome of this project against these four criteria, I believe the project met two of them strongly and two are still work in progress. Our customers were the IT security teams working in the NHS. From the initial interviews our customer expectations are shifting slowly, but they do see the NHS as being behind the curve of new technology adoption and use. This will change as further investment flows and the benefits of the new technology are seen. The project and the artefact from the case study delivered on the enhancement of data and productivity requested. The artefact collected and collated data from multiple sources. The new design then used robotic automation to match the data and alert on the issues. This data would previously have been manually collected and matched before the new design. The saving in time and costs are significant in themselves, however the bigger outcome is the avoidance of harm to the NHS and patient care.

The new artefact scanned and alerted on issues before the vulnerability could be exploited. In the WannaCry attack the time between identification of the vulnerability and the Ransomware attack was 2 months. The new artefact would have notified the IT teams within 24 hours of the alert and patch being released by Microsoft. If the patch had then been implemented, many of the issues and lost productivity that the attack caused, would have been avoided. The project has formed new partnerships across the solution. These include, the NHS issuing the key Common Vulnerabilities and

Exposures (CVEs), the collation of data from the third-party scanning system and the alerting to the human team to intervene. At the outset of the project the vision was to build a complete platform solution. However, the partner working model proved far more effective allowing each element to build and share with the other components in an open and standardised way. The final criteria for moving to a new digital model was achieved in terms of the artefact creating an alert. The project hadn't yet completed the journey to automated fixing of the problem. This final stage still requires human intervention which lead to the addition service wrapper being required.

Skilton & Hovsepian expected a shift from analytical to predictive and prescription powers through the new technologies of the 4IR (Skilton & Hovsepian, 2018). This project has delivered on the analytical to prescription using the new technologies. The next step in the product roadmap will be to use the data collected from the network scans over an extended period of time. This data can then be analysed for pattern recognition and used to predict issues or concerns that will increase the predictive capabilities of the artefact. This would be achieved by using machine learning to train an algorithm on what data responses would look abnormal. This will lead to a new design issue however of how the design process operates when the outcome of that process can alter the process itself. This is another example of the 'so what' question, if a new artefact can predict or generate an alert, it is the next activity that is key as that will influence the process and could alter the outcome of the process. This subject is discussed further in section 6.5.1.

From the literature review two areas stood out from how other industries were using the new tools and technologies within the IS domain that should be considered within the healthcare domain; the platform approach and the concept of 'hiring' a product or service to get a job done. These two areas are considered for how the new cyber vulnerability artefact was developed.

6.4.1. The Platform Operating Model

The context background and literature review has shown that almost all new IS systems developed with tools from the 4IR are adopting the platform operating model. This approach separates out the data, from the infrastructure, and the network or community marketplace. The value is created through how each user interacts with the network. The differentiator from a supplier or designers perceptive is how much of each element to utilise. At the initial design stage for the cyber vulnerability product there was a vision to adopt a wider platform model as shown in Figure 30 below:

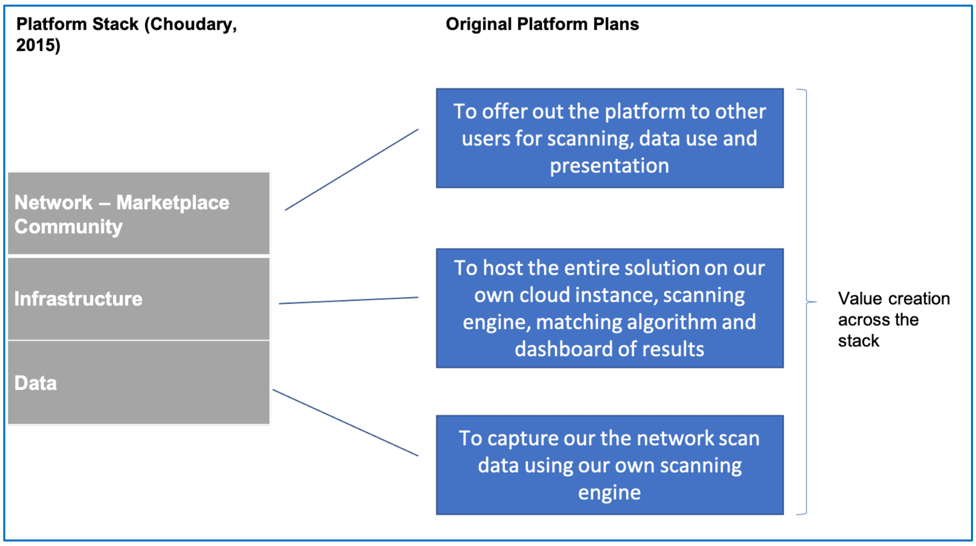


Figure 30 Original Platform Stack Plans.

The original plan would have seen the new IS artefact become a platform for NHS cyber security and potentially other organisations as well. The model would have seen value added across the stack. The scanning engine would have created data that would be of value, we would have leveraged another providers infrastructure (such as AWS or Microsoft Azure) and then provided the service to the NHS. Finally, the dashboard and platform would have been opened to other suppliers for their cyber applications to operate within and use the data from the scanning engine. Ideas that we considered included anti-virus, asset management and license management tools.

When the external actors and power shift within the NHS impacted the design of the artefact there was a need to reposition the concept but maintain it within the platform architecture. The following Figure 31 shows the new model.

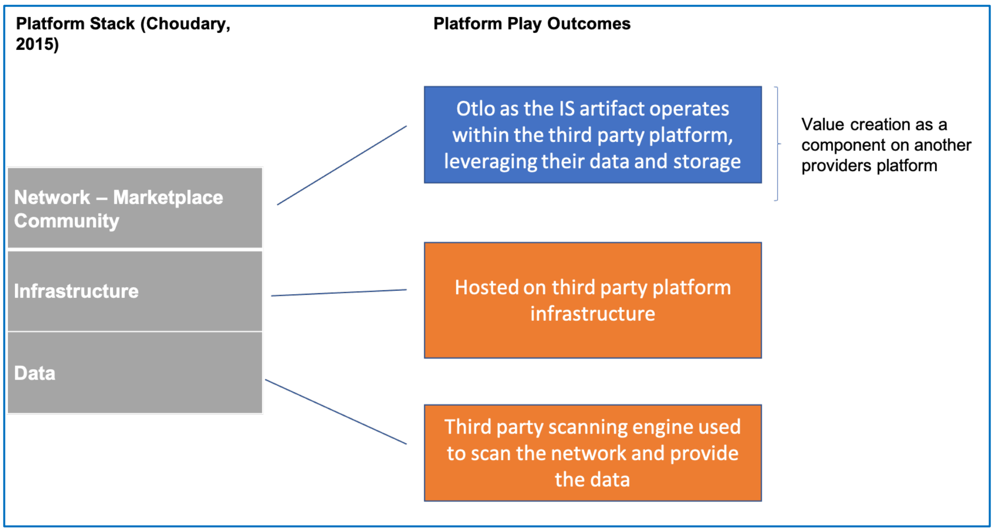


Figure 31 Actual Platform Stack.

Although the outcome wasn't an entire platform owned by us as the designers, the benefits of the platform still hold true. For the IS artefact developed for this project we were able to focus on the true value add and innovation of the OTLO module. The innovation was the automation of matching the outcome from the third-party scanning solution to the cyber vulnerabilities and exposures issued by NHS digital in real-time. The additional benefit from this approach was through the commercial routes to market. As OTLO the cyber vulnerability dashboard we had developed was now available to all the third-party scanning supplier's customer on their platform. This is a significant change in market access.

The value proposition changed but still followed Choudary's (2015) model shown in Figure 32.

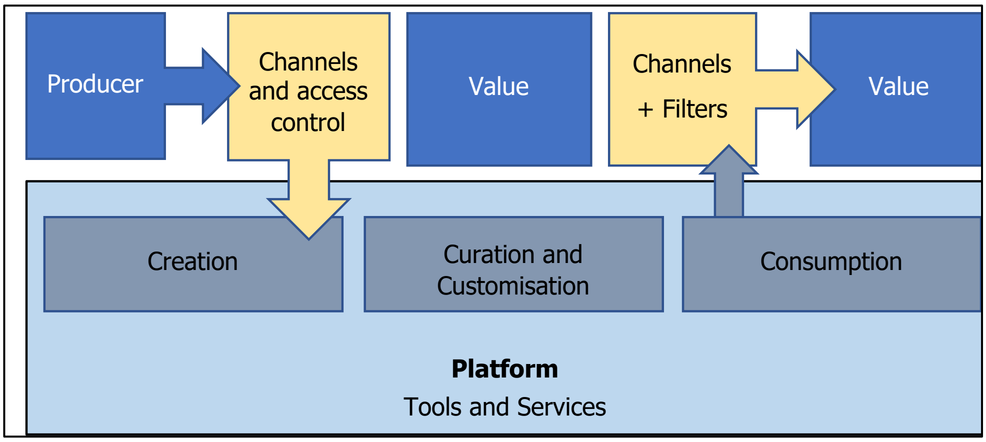


Figure 32 Platform Canvas (Choudary, 2015).

The third-party scanning provider was initially producing the channel and controlling access, thus creating value. OTLO as the cyber vulnerability dashboard then created new information that was made back available through the dashboard channel for additional value.

Jeremy Wyatt (Professor of Digital Healthcare, Wessex Institute of Health Research) provided this model as an example of the components required for a successful platform play in healthcare, this can be seen in Figure 6. I have reflected the OTLO current cyber vulnerability project onto Wyatt's model to show how the project delivered on this platform model in Figure 33.

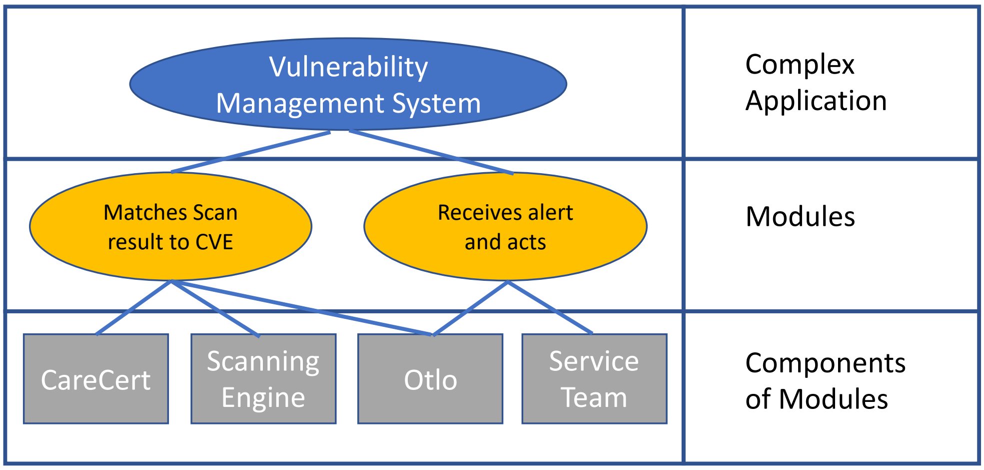


Figure 33 Platform Model for Vulnerability Management.

The platform model is often associated with technology artefacts. There is however another value that can be created, services. In this project the platform outcome created a value but not the entire value required by the service user. The NHS IT teams needed a service to not only identify the vulnerability but to also address the issue and deliver a resolution. The service wrapper for specialist staff was also required. This final aspect demonstrates that even with the use of the latest technology design architecture, there is a need to ensure the 'so what' question has been answered. This final point is best considered through the concept that Christensen et al proposed of hiring a product to get a job done (Christensen, et al., 2016).

6.4.2. What Is the Job You Are Trying to Do?

The proposition that Christensen et al (2016) made was that instead of focusing on knowing the customer, the question should be on finding out what job the customer is trying to do. The argument was that users are looking to hire the product or service to do a job and not buy a solution for them. This subtle variation requires a different lens to be set when considering the problem statement. We set out to build a new IS artefact for this project to identify and alert for cyber vulnerabilities and exposures. The questions with the end-users gathered information and needs to resolve this problem. This was based on getting to know the customer and not what job they were trying to do. The customer wanted an alerting tool – the job they were trying to resolve was to stop potential cyber risks by having vulnerable devices patched effectively.

The ADR approach resolved this issue in the end and that is ability of the BIE cycles to keep intervening and evaluating. This question of what the actual job is you are trying to do supports the earlier concept of 'so what'. When building the problem statement, the designers need to go beyond the initial end-user requirements and consider the wider environment use and outcome. Through resolving the 'so what' question and the imagined use of the product the designer will also address the actual job required.

6.5. Designing IS Artefacts for the Healthcare Environment

This research project set out to design and build a new artefact for a specific healthcare technology need. The case study has shown the effectiveness of ADR as a methodology and some of the additional actions that could be used to enhance the process. In this section I am looking to extend this discussion to the broader aspects of IS design for healthcare using the technologies from the 4IR.

6.5.1. Intelligent System Design

The core component parts of an intelligent system with feedback as presented by Skilton and Hovsepian (2018) is shown in Figure 34 below.

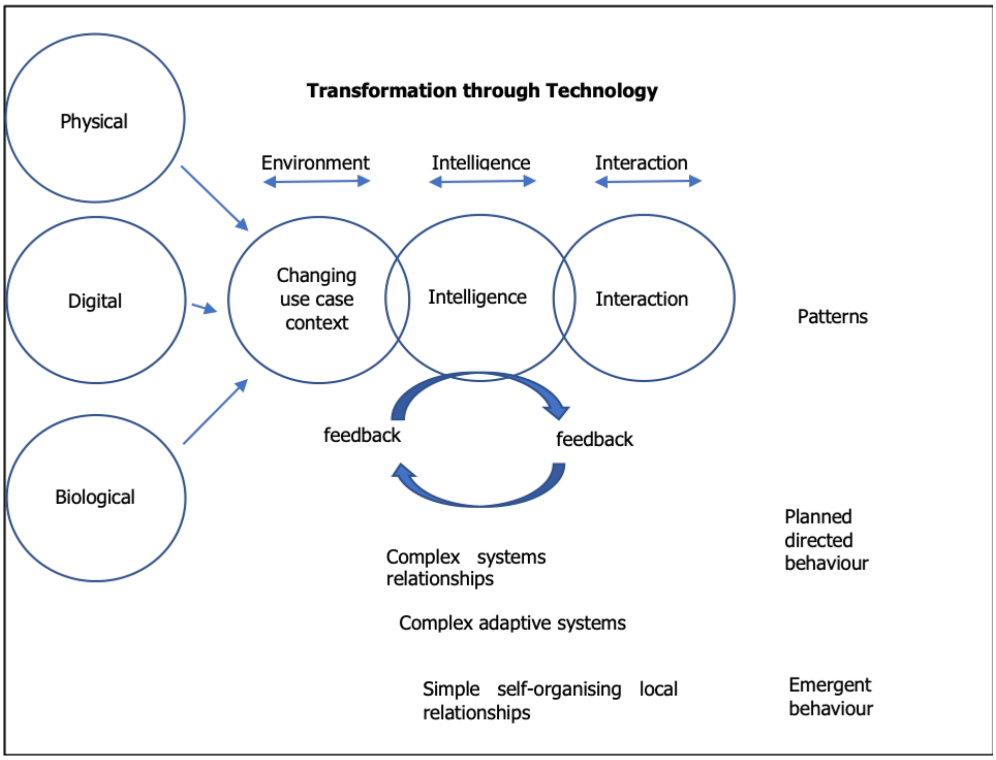


Figure 34 Fusion Feedback and Control the Rise of Intelligent Systems (Skilton & Hovsepian, 2018).

The model looks at transformation through technology and the component parts of physical, digital, and biological merging within a set environment with the interplay between intelligence and action. These factors match the operating model of healthcare.

In an example of this model, we could consider the following healthcare problem for which an artefact would be designed. The problem statement is to design a clinical decision support artefact for a patient with a deteriorating set of vital signs. The input to the system would come from physical observations by the nurse of the patient, digital information from the patient records, monitoring devices, and biological data from the patient. In a non-artefact model, a typical scenario would be a nurse was worried about a patient and contacted a clinician. The clinician would look at the patient, the medical results and data from electronic systems and look for patterns that they had seen before or been taught to look for in their training. Then act on the learning to decide on an intervention. As the clinician learns over time and gains experiences his decision will change based upon this learned behaviour and new emergent behaviour is arrived at.

From a design perspective, the new artefact would need to gather the same data from the nurse which could be via an electronic vital signs, observational data, feedback from the results of biological tests, and from data within the electronic patient record. The artefact would be taught to combine this data in an environment and look for patterns. During the training phase the artefact would use real-life past data and outcomes to learn pattern recognition of certain signals and what was the correct intervention for that signal. On each learning cycle, activity get closer to the correct result.

Figure 35 below shows this process where the artefact is taking actions and observing the outcomes to get closer to the goal. This is an example of reinforcement learning in AI. The artefact will therefore accept data from a wide range of sources within the set environment, look for patterns that it has been taught to find and produce an intervention based on what it has been taught. This can then be tested on training data to prove it is safe and valid. If the artefact is stopped at that point, it has a finite knowledge and has stopped learning and the artefact has passed a certain test or threshold. The design has worked, and it could be argued that this process would have worked in the Third Industrial Revolution. For the 4IR the artefact won't stop there, it will continue through the cycles constantly learning and adapting as it finds new patterns and tries new interventions. This can be seen in a different sector such as entertainment where Netflix algorithms are constantly learning about what shows and films you like and making new recommendations for your viewing and the wider Netflix members viewing behaviours.

The challenge for the designer and wider society is how do you govern and regulate an artefact that is constantly learning and adapting itself in real-time. This conundrum hasn't been solved yet and was highlighted as a challenge for AI, governments, and clinical bodies (Harwick & Laycock, 2018). For the current operating model, the artefacts in use in healthcare stop learning in real-time once an approved version has been released. Any subsequent changes would need to go through the full clinical approvals process to show the new learning is still safe, ethical, and effective.

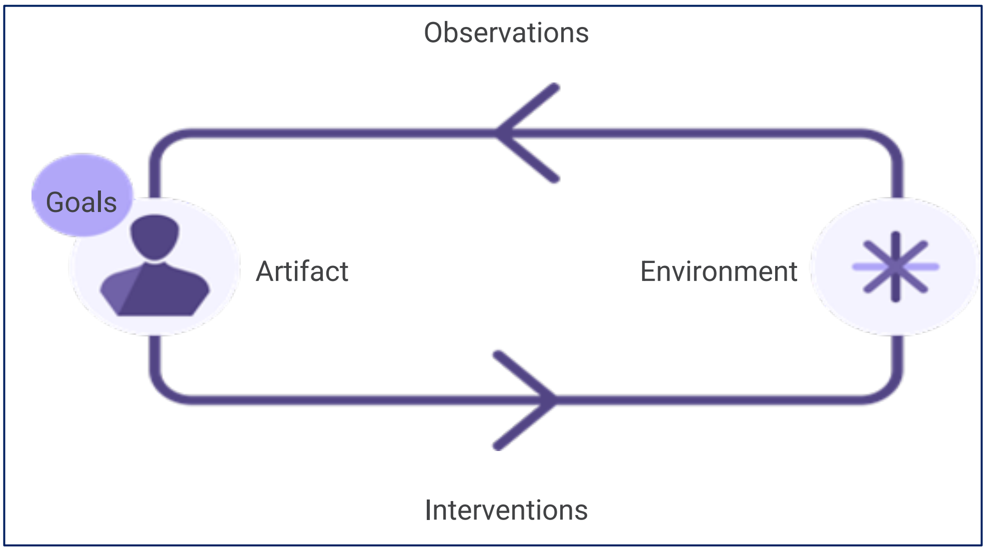


Figure 35 Reinforcement Model for AI.

There is a second challenge that designers for new technology in healthcare face from artefacts providing alerts or advice on interventions, the 'so what' question. By this I mean so what if an alert is generated or an intervention recommended from the artefact. This is only half of the requirement to solve the problem. The end goal is for the alert to be acted on or the intervention made. The designers will need to consider how the alert or intervention is delivered and has the receiving actor got the tools, skills, capability, or capacity to act.

In this example, the artefact may alert that a patient needs a certain intervention, but if this isn't delivered to the right clinician in the right way (i.e., on a mobile device as they are always moving around the hospital). If the data isn't presented with the correct patient information and the intervention easy for the doctor to follow and capable of showing the doctor why this intervention is recommended (this could be links to the academic journals or the clinical pathways that hospital is following) the intervention may not take place and the original requirement won't be met.

Lastly, what if the doctor doesn't agree with the intervention or the alert and ignores the final step the artefact is recommending. This action, or lack of it, can be explained through the lens of Institutional Theory. Clinicians are trained to think independently, their belief system and value system is about them having the ultimate decision and this powerful behaviour may be at odds with the artefact generated outcome. This last point I believe opens the opportunity for further research in the 'nudge' behaviour concept originated by Thaler and Sunstein (Thaler & Sunstein, 2009). In answering the 'so what' questions could we use nudge techniques to guide the user to adopt the right next steps without affecting their beliefs and value systems. This is an area that I believe could be further research and identify this in section 7.3.4.

Although, for the current version of the cyber vulnerability artefact designed in this project the level of new technology was at a robotic automation level there was still the question of so what and the need for further action when the artefact alerted to an issue. In this case study the problem was solved with a service wrapper, for other problems the solution may lie in additional technology design requirements.

6.6. Can The Findings from This Project Be Used More Generally?

The scope of the challenge for delivering healthcare in the 21st century combined with the capabilities coming from the 4IR are significant. The scale and scope exceed the realistic achievability for any specific research project using a case study approach. I therefore narrowed the focus to a specific problem inside a manageable environment. This project was focused on the specific challenge of mitigating cyber vulnerability risks for the NHS. Using the ADR methodology, a new IS artefact was developed and deployed. Academically, advice and a new area for consideration was identified when using ADR. This worked well within the constraints of the project, but can the findings be generalised beyond this specific case study?

I would argue yes. The paper has shown that healthcare globally needs new technology to meet the increasing demand for services. With the capabilities being identified through the 4IR to address the needs of healthcare with technologies including machine learning, AI, robotic automation, and biotechnology. The challenge will be in designing the new systems, products, and artefacts so that they are accepted and adopted by the healthcare professionals and institutions. Given the legacy of failed acceptance of previous large scale technology investments I am proposing the need to develop new systems through a collaborative process which includes end-users from the outset and considers the wider institutional factors. The collaborative approach has a proven track record in design in other sectors. Within healthcare, other factors will also need to be considered including the wider power influences found in complex organisations and ensuring that the new artefact is designed with the context of its impact on the end-users considered.

This project has shown that with the adaptions to the ADR methodology new IS artefacts can be developed and accepted. Whilst this project was focused on cyber security the same approach would work for a wide range of problem situations where new technical solutions are proposed. This paper has included some examples such as AKI alerts or radiology image interpretation. In each of these the initial technical problem was solved when a machine could achieve an outcome to the set specification (i.e., ability to generate a correct AKI alert or spot a pathology on an x-ray). The question that I am proposing needs to be answered is ensuring that the design considers the use of the new artefact in its context through interpretive flexibility This is extending the consideration to not only the artefact, and its role in the organisation, but also how the organisation redefines the problem in relation to its changing context.

The second dimensional question is the generalisation of the approach applicability in a different complex organisation. In this scenario, I again believe that the use of an ADR methodology would work. This paper has shown the NHS to have institutional actors that need to be considered, understood, and factored into the design process. The same holds true for other complex organisation be that public sector bodies such as local councils or even large corporations as seen by Nandhakumar et al (2005) and ERP implementations.

The scope of this project was focused but the approach and outcomes I believe are applicable to both other technologies in healthcare and other complex organisations.

7. Conclusion

The context for this research project was built from the broad fields of IS at the dawn of the 4IR, the increasing need for solutions to meet healthcare demand and the poor legacy of healthcare to adopt new IS systems successfully. The scope of these overlapping areas was too broad a remit for a specific research project to address. As such the project set out to investigate the use of the ADR methodology in a complex organisation for a specific problem – cyber vulnerability in the NHS.

The paper started out with the broad themes of how technology is rapidly advancing and the tools of the 4IR offer a significant step change in capability to address healthcare needs. Recognising that these same tools can also be a potential threat from their misuse. These new developments were set against the backdrop of failed IT and technology implementations by healthcare organisations. The dichotomy of new solutions needing to be implemented into a complex organisation with the challenges of successful adoption to be addressed.

I set the project within the theoretical framework of Institutional Theory to help frame and understand the behaviours, values, and influences that are found within a complex organisation. These factors shape and define the organisation and those operating within the organisation. External investigators (i.e., designers, researchers) often struggle to understand and adapt to the unwritten rules and shifting baseline that is witnessed. For this project even with this insight and having worked with the NHS for over twenty years I still didn’t spot the shifting central focus that external influencers would have on this local IS project.

The Pilot Case Study helped to test my approach and questions, but also identified similar outcomes to the Main Case Study. This reinformed the validity of the outcomes. The Main Case Study research used the ADR method to design, build, and evaluate a new cyber vulnerability platform working with four NHS organisations. The outcome was successful with a new artefact built using tools from the 4IR deployed and in use in the NHS. The ADR methodology worked although I have identified three areas where I believe additional focus and improvements could be made.

The case study was on a focused subject area, but I believe I have shown that the fundamentals of the research can be generalised into other technology and organisational areas and recommend further research into these areas.

7.1. Theoretical Contribution

The research project followed the ADR methodology, itself a relatively new approach to design research. The combination of an action orientated model with researcher, practitioner and end-user working together worked well and achieved a successful outcome. The case study identified three areas where I believe a greater understanding of the ADR process or additional tasks would support the development of new IS artefacts in complex originations.

The first two of these recommendations are not additional steps or tasks but general awareness of areas to focus on at the problem formulation stage. Firstly, spend time on the competitor analysis and the wider landscape. This isn’t a specific task but a general approach that for this project wasn’t fully achieved. Through my research diary I captured developments from conferences, exhibitions, and white papers on what other competitors were undertaking. However, I failed to fully encompass this in the ADR cycle. There is a Task 4 for the first stage that requires the need to identify theoretical bases and prior technology advances. I would certainly place more emphasis on this task for the next design project. I would also ensure that all teams (practitioners) were actively observing the competitive landscape.

Even as we entered the Stage 2 BIE cycles to seek the views of end-users on the competitor developments proved useful.

Secondly when working with complex organisation that are showing institutional behaviours there is a need to ensure that the assessment of the stakeholders and influencers is broad enough to adapt to any shift in the baseline assessment. The BIE cycles can cope when the environment in which the work is being undertaken is moving. However, for this project it took several more cycles before the impact were noticed. I would recommend that during the problem formulation stage when role and responsibilities are established that roles for external influencers and stakeholders are considered and monitored. For this project, if we had identified the impact that central NHS influencers and stakeholders would have had, we could either have asked them to join the team or asked our NHS partners on the team to investigate what they were planning.

The final theoretical contribution was the additional tasks that would support answering the ‘so what’ questions. The recommendation is two new tasks are added to Stage 1 and Stage 2. The objective of these tasks is to support the research team in imagining at the outset how the artefact would be used in context. Then during the BIE cycles ensure interpretive flexibility is used to adjust the artefact to meet the original specification and the actual use in its context that solves the original problem.

The following

Figure 36 and Table 31 show these changes in the overall ADR Methodology that I am recommending.

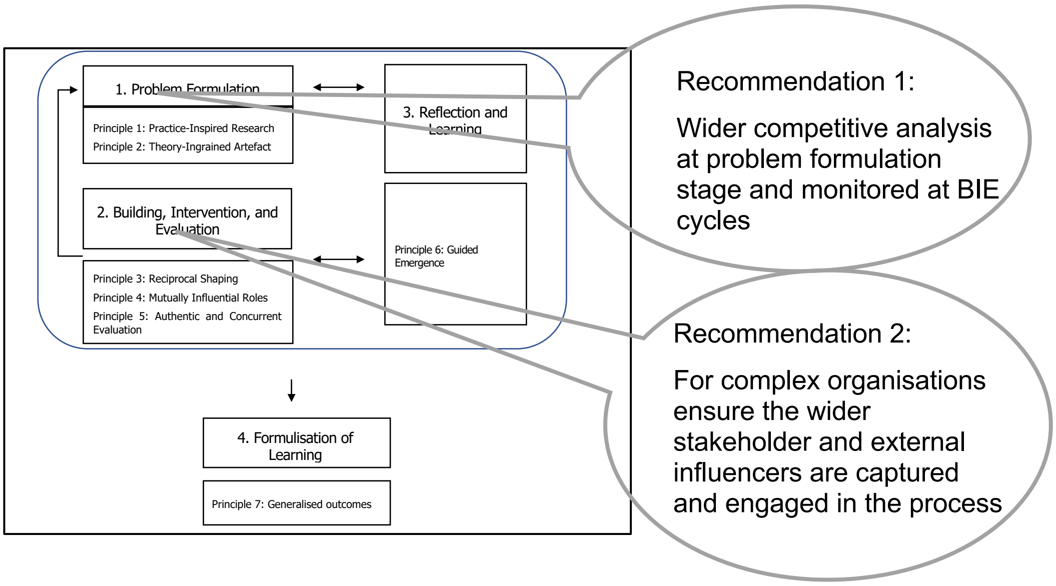


Figure 36 ADR Method: Stage and Principles with Recommendations (Sein, et al., 2011, p. 41).

Recommendation 3:

Additional tasks are added to Stage 1 and Stage 2:

Tasks for Stage 1:	Tasks for Stage 2
• Identify and conceptualise the research opportunity • Formulate initial research questions • NEW – Understand the impact of the artefact on the organisation through the imagined use of the artefact in context • Cast the problem as an instance of a class of problems • Identify contributing theoretical bases and prior technology advances • Secure long-term organisational commitment • Set up roles and responsibilities	• Discover Initial Knowledge-creation target • NEW – Ensure interpretive flexibility is built into the BIE cycles • Select or customise BIE form • Execute BIE cycles • Assess need for additional cycles, repeat

Table 31 Recommended Additions to Stages 1 and 2 of the ADR Cycles.

These changes would enhance the ADR methodology for its use in complex organisations.

7.2. Practical Contribution

This project wasn't based purely on academic contribution, but on making a real-world practical impact. The practical contribution made by this project can be seen through the development of a new tool that uses robotic automation to match cyber alerts issued by NHS Digital to global Cyber Vulnerabilities and Exposures (CVEs) and manufacturers data from the network scanning engine. This tool then presents the outcome in an easy-to-use dashboard that supports the remote monitoring and fixing of the issues identified.

The success of the system can be seen in the sales of the artefact and effective deployment of the new cyber vulnerability system into the NHS. It is currently in use by 6 NHS organisations supporting 27,000 staff.

The following Figure 37 shows the system and the complex data collected and displayed.

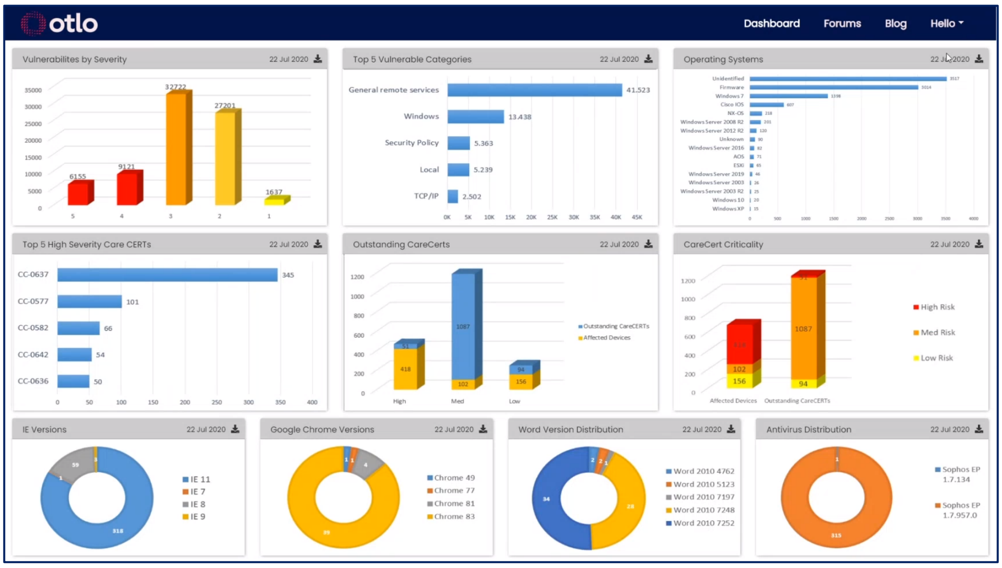


Figure 37 OTLO Dashboard.

At Stage 1 of problem formation, the requirements and needs for the artefact were developed from interviews with NHS IT managers and wider research. The initial scope was captured in Figure 37 showing the following rich picture.

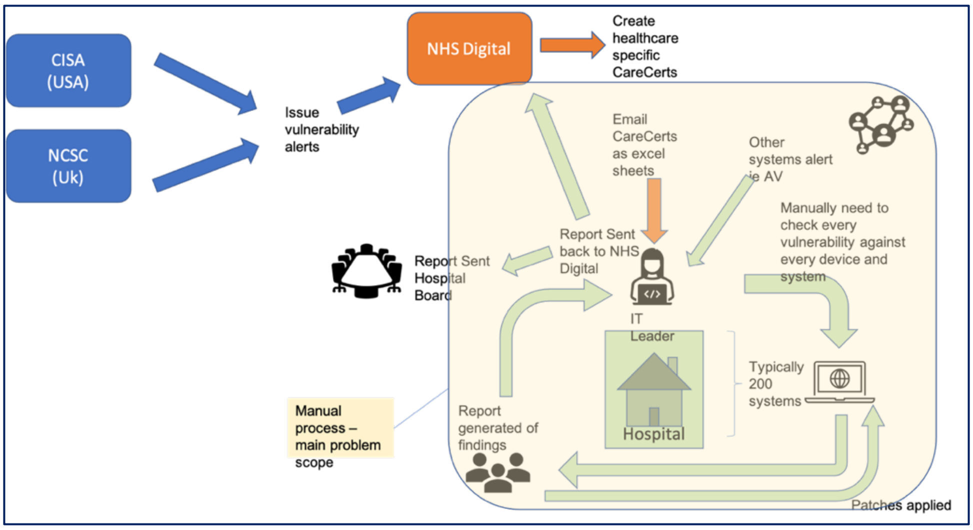


Figure 38 Rich Picture of the Problem Scope.

The new artefact resolves each of the requirements originally identified except for the patch applied which needed a service wrapper. These benefits and impacts can be seen in the following Table 32.

Requirement / Process	Real World Impact
Email CareCERTs as excel sheets.	The new system automatically receives the alerts with no need for human intervention. This removes delays and errors.
Manually check every vulnerability against every device and system on the network.	This stage was the most laborious for the end-user. There was a need to undertake a network scan and then compare the outcomes with the excel spreadsheets. If you have, as most hospitals do, thousands of devices to scan then the results will take a long time to match. The process is made more challenging because the CVE alerts codes don't match the scan result codes

Requirement / Process	Real World Impact
	and there is a need to look up the data on the manufacturers website. The new artefact solves this problem through using robotic automation to match the CVE code to the scan result and to the external data needed to match them together. This saves significant time and effort as well as error reduction.
Other system information.	The hospitals currently have multiple systems showing them key cyber information such as anti-virus (AV). With data held on different systems the key information can be missed or additional steps needed to locate and find the data. The new artefact provides all the data from the other systems in a single pane view.
Reports generated.	There was a requirement that after a network scan and comparison to CVE was completed a report had to be created for the Hospital Boards and NHS Digital. This was a manual process pulling data from the excel spreadsheets and the scan result. The new artefact automates the process by generating the report as soon as the data analysis has been completed.
Patches applied.	The final stage of the process was to patch the affected machines with the new

Requirement / Process	Real World Impact
	manufacturer's software. The original vision was for this to be automated as soon as the alert was identified. This couldn't be delivered and was discounted at the design stage as some of the machines couldn't automatically have been patched or the systems may not work on the newer version. This needs to balance the risk between stopping machines working and protecting them from a possible Ransomware attack – this assessment has high risk clinical implications in healthcare. An example would be a CT scanner, this may be running on old software but automatically patching it could have implications for patient care and safety. As such this functionality wasn't developed. The need was therefore to create an easy-to-use alert that a human could then interpret and manage the patching considering the location and wider clinical risk. The service was initially expected to be performed by the NHS but as we worked through the BIE cycles it became clear the NHS may not have the capacity or capability and so this was added as a service wrapper. This also solved the so what question in that

Requirement / Process	Real World Impact
	just alerting in itself didn't solve the original problem.

Table 32 Impact of New Artefact on Original Problem.

The new artefact has also been adopted by one of the leading global scanning providers as a module for their system. This is a significant recognition of the artefact's capabilities and impact on the healthcare service. The artefact has also been recognised by Health Technology News as a Finalist in the Health Tech Awards 2021. The artefact is continuing to be improved and additions to the artefact for monitoring and managing CVEs in the NHS.

7.3. Suggestions for Further Research

The focus of this project meant not all subjects of interest could be fully explored. There are several potential areas for follow on research.

7.3.1. Additional Empirical Studies

This case study using ADR in the NHS was for a specific user case. It would benefit from additional research where IS artefacts are being developed to test and assess the findings from this study and the benefits of the additional steps recommended. This could be undertaken in a public organisational setting where similar institutional pressures could be observed – such as local governments. It would also be interesting to compare the public sector to a large-scale private organisation and compare and contrast the findings.

7.3.2. Technology Debt

Throughout the research project investment or lack of investment in NHS technology was a consistent theme. This was identified firstly in terms of skills and resources. The ability to recruit and retain the qualified staff necessary to work and support the new technologies compared to other industries. Secondly, the investment in new technology that is fit for purpose for today. The limited research in this study identified a lower investment in technology in healthcare than other industries. This area would benefit from dedicated research as to the impact over time of the underinvestment and actions needed. The Covid pandemic has seen considerable investment in new devices (laptops for example) over the last 12-18 months, but this won't fix all the issues when some clinical departments are still operating on 15-year-old technology that cannot run on the new laptops.

7.3.3. Designing IS With Broader IR4 Capabilities

This project was established to design a new artefact with tools from the 4IR to address a specific need. The outcome was successful in the design and build of a new artefact for the cyber vulnerability need. It included robotic automation but didn't include an outcome that would directly affect the process itself. In section 6.5.1 I discussed the implications of the artefact detecting an outcome that would alter the behaviour or input into the process. A study that investigated how IS design would work where the output from an artefact had a feedback loop that altered the artefact itself or the output from the artefact would help designers better understand the phenomena that will arise as more AI/ML artefacts are developed. This is going to be a critical process where the artefact is operated in a regulated area such as a medical device.

7.3.4. Technology Nudge

This project has shown that just by creating an artefact that generates an outcome, this may not solve the problem itself. There needs to be a clear follow-on action and the ability to 'nudge' the end-user to do something would be an interesting concept to build on. Nudging as a tool for change is well-documented (Halpern, 2015). The use of technology in a healthcare setting to nudge a behavioural change could prove very powerful and help overcome the 'so what' question.

7.3.5. ADR Use in Other Complex Organisations

The case study only focused on the NHS as a complex organisation. I have proposed that the same approach would work well in other complex organisations and a study in areas such as education or local government would be useful to test this hypothesis. It would also be interesting to explore this in large corporations and understand the influence any organisational norms would have on the outcomes.

7.3.6. Who is the Real User or Stakeholder?

The research has shown that when dealing with complex organisations there is a risk that the researcher, investigator, or designer may not engage with the right stakeholder. In this project the Pilot Case Study and the Main Case Study engaged with what they believed was the correct stakeholders. However, this wasn't the case and problems arose impacting the product development. Initially the job titles, influence, and powerbase suggested they should provide the input from the stakeholder or user groups. However, this wasn't always the case. Through the lens of Institutional Theory, it was possible to in hindsight to see that the power base and shifting dynamics caused us to have missed some key stakeholders. Additional research into how to ensure that when designing new artefacts, the correct users and influential stakeholders of the system are considered would be another area for further exploration.

7.3.7. Imagined Use and Interpreted Flexibility

The research identified the need for the designers to consider the imagined use of the artefact in its environment during the early stages of design. Then to review this through interpreted flexibility when engaging with the end-users. This case study didn't however fully explore this area. It would be interesting to consider these areas further. I would be interested to better understand how you could achieve a satisfactory outcome at initial problem identification through the imagined use. Should this be with the end-users or just the internal team? Would the inclusion of the end-users too early alter their views and introduce bias, or would this be the better route and start them to consider the changes the new technology will provide? I would also like to know what the scale and scope of the imagined use at this early stage would need to be to be useful to the design process. Could designers accurately map the full impact of the technology, or would the outcome be a wide range of possibilities to be further analysed at each subsequent cycle?

I also recommended that as the researcher works through the BIE cycles, they include interpreted flexibility. This would look to see how the organisation will react to the new technology and what changes this would cause. The organisations flexibility could determine how much additional change is needed. This case study showed this happening in the specific case. Areas I would like to investigate would be; could this be applied to different artefact development and different research settings? Does the need exist in all technology development areas for such an approach or is it limited to only those using machine learning for example?

7.3.8. Adapting to Change in Realtime

An area that this research project discussed was how systems using tools from the 4IR will be able to update themselves in real-time. The implication of such capability is significant. For example, a medical system used to interpret chest x-rays has to be approved by health regulators as being safe. The approval is based on the version of that systems on which the tests have been completed. If this system in question was using AI/ML to learn as it went and could change in real-time, how would such a system be regulated? For the users, the system could be giving out different answers each time it learnt a new interpretation. How would the users know why the answer was changing and how is trust for the answer built in. These areas were not covered within this research but pose many questions that further research should consider.

7.3.9. Data Value Share

The background research and literature context review provided examples of where organisations, including healthcare providers, have supplied large quantities of data to support the development of new artefacts. When considering the design and build of tools for the 4IR they often require large quantities of data to train and test the new artefacts. The access and use of the data itself raises questions that this research project did not explore but would need to be considered for new artefacts where tools such as AI and ML are used. These questions would include who owns the data - the organisation or the citizens the data is about? If the artefact will generate future value through product sales how is the data provider compensated? If the organisation or data owner is compensated how is the value of the data agreed? These areas are already creating public interest as Google DeepMind discovered when it worked with the Royal Free Hospital (The Guardian, 2017).

7.3.10.Medical Devices and Cyber Vulnerability

The final area I have identified for further research relates to cyber security. This research project was focused on computer devices connected to hospital networks. New medical devices now include wearables and Internet of Medical Things (IoMT). These devices all include computer systems, but they may not be connected or recognised by the hospital network when the network can is run. The challenge for any cyber security system is monitoring and managing these devices and the software that is running on them. This area would benefit from a research project looking at how you could monitor and protect these devises from cyber-attack.

7.4. To Conclude

Schwab described the 4IR as the culmination of emerging technologies fusion (artificial intelligence, robotics, the internet of things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, energy storage, quantum computing, and others) into the physical and biological worlds that will fundamentally change the way we live, work, and relate to one another (2017). To ensure that we can benefit from this revolution we must design the new systems and technologies considering that humans don’t always react to change in a predictable way. When that change is also happening within a complex organisation with its own behaviours, dynamics, belief systems, and power basis the importance of designing the artefact in the context of which it will be used is even more important. I hope this project represents a small steppingstone in that direction.

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9. Appendices

9.1. Appendix A: Artificial Intelligence the Driver for More Technology

This section provides a review of the background and development of Artificial Intelligence from the early work during and after the Second World War through to the latest claims of its capabilities. AI though is just one of many terms used to describe computers that learn another being machine learning, the meanings are expanded on below but for the purpose of this report it will use the terms AI and machine learning interchangeably.

9.1.1. The History of Artificial Intelligence and Machine Learning

Most of the big ideas behind AI are not new and some of the underlying mathematical principles are in some cases centuries old (Polson & Scott, 2018). One of the first leaders in AI was Alan Turing who in the 1950's posed the question 'can machines think' (Turing, 1950) which led to the establishment of the Turing Test – can a person distinguish between answers given by a machine or human.

As this shows machine learning has been researched for over 50 years but it is only in the last few years that the correct combination of three key factors has allowed the progress to be made that is now driving the 4IR. These factors are.

- the increased data volumes now available on which machines can learn and IBM reported that 90% of the worlds data has been produced in the last 2 years (Jacobson, 2013);
- the development of new technologies in computer power; and
- researcher's advances in algorithm development through revisiting the concepts of the neuro networks proposed in the 1940s and 1950s (The Royal Society, 2017).

The following Table 33 provides a brief summary of the stages in development of machine learning and AI (The Royal Society, 2017).

Approximate date	Activity
18th Century	• Machine learning can be traced back to the original work on probability theory and statistics including Bayes Theorem from 1763 that is still in use today (Polson & Scott, 2018).
1940s	• Warren McCulloch and Walter Pitts proposed an artificial neuron, a computational model of the 'nerve net' in the brain (Chui, et al., 2018). • Alan Turing working at Bletchley during the Second World War started to consider the ideas of machine intelligence (Polson & Scott, 2018). • Wald developed an algorithm that accurately predicted the survival rating of a WW2 bomber based on conditional probability and was able to recommend where additional armour was placed to improve survivability, the same principles drive Netflix today (Polson & Scott, 2018).
1950s	• Turing raised the question 'can machines think' and suggested a test for machine intelligence that was subsequently known as the Turing Test – a machine may be considered intelligent if its responses to

Approximate date	Activity
	questions could convince a person it was human. • Princeton students develop artificial neural network using 300 vacuum tubes and gyroscope (Bernstein, 1981). • In 1952 Arthur Samuel created an early machine that could play checkers. • The 1956 Dartmouth Workshop was the meeting where the term Artificial Intelligence was generally accepted to be used for the first time by John McCarthy (McCarthy , et al., 1955). • Researchers at Carnegie Institute of Technology produced the first AI programme, Logic Theorist (Gugerty, 2006). • Marvin Lee Minsky founded the Artificial Intelligence Laboratory at MIT (Bughin, et al., 2017). • In 1957 Frank Rosenblatt's perceptron was an early attempt at neural network and could interpret pixel images and create a label.
1960s & 70s	• This period was generally known as the AI winter where progress was a lot slower than expected and the Lighthill report for the UK Science Research Council noted that 'in no part of the fields have the

Approximate date	Activity
	discoveries made so far produced the major impact promised'.
1980s	• *Parallel Distributed Processing* was published in 1986 and provides the foundation for advances in neural network models for machine learning (Chui, et al., 2018).
1990s	• In 1992 researcher Gerald Tesauro created an AI machine capable of playing backgammon to match top human players. • By 1997 IBM had created Deep Blue and was the first computer playing machine that beat the reigning world chess champion. This advancement was based upon the increased computer power available by then and Deep Blue was running all possible move configurations and selecting the best one. • Yann LeCun pioneered the use of neural networks on image recognition (Chui, et al., 2018)
2000's	• The pentagon stages the Darpa Grand Challenge, race for robot cars in the Mojave Desert that catalyses the autonomous car industry (Simonite, 2018).

Approximate date	Activity
2010s	• In 2011 IBM's Watson AI beat two champion Jeopardy players. • 2012 saw the Alex Krizhesky, Ilya Sutskever and Geoffrey Hinton published their paper on how their model won the ImageNet Classification competition, and annual image recognition competition where no machine had been human to date. • In 2015 DeepMind released a paper in Nature describing how its reinforcement model had learnt to play and win over 80 Atari games with no initial training (Mnih, et al., 2015). • The same team went on to release AlphaGo in 2016 which learnt to play the ancient Chinese game 'Go' and won 4 out of the 5 matches against Lee Sedol the world's top player (Simonite, 2018). • Twice as many articles have been published on AI in 2016 compared to 2015 and four times as many as 2014 – expectations are growing again on the capability of AI (Bughin, et al., 2017). • In 2012 Google had 2 deep learning projects, by 2017 this had grown to over 1000 (Makridakis, 2017).

Table 33 History of AI Development.

Table 33 shows the development of AI over the last 70 years which seen highs and lows. For some sectors where adoption of technology has historically been slow such as health and education, they are out of synch with industries who are leading the charge of AI deployment (Bughin, et al., 2017). Makridakis (2017) argues that the AI revolution is on target and will come into full force within the next twenty years following the same model as digital revolution and will probably have an even greater impact than both the industrial and digital revolution combined. The paper also acknowledges that there is substantial uncertainty over the full impact AI will have. How we navigate the choices between and utopian or dystopian outcome and manage the choices to maximise benefits and minimise negative consequences is yet to be seen.

AI research areas of focus through this period has include reasoning, knowledge representation, planning, learning, natural language processing, perception, and the ability to move and manipulate objects (Russell & Norvig, 2009). The longer-term challenge being taken up by companies such as DeepMind (DeepMind, 2018) is to solve General intelligence.

9.1.2. Branches of Machine Learning / AI

There are three main branches of machine learning:

- Supervised learning – this approach uses labelled data (for example drawing around an image outline and labelling that as an apple or an orange) that the system is trained on. This is training data and is well structured and uses the learning to predict or identify unknown objects from test data.
- Unsupervised learning – in this approach the machine learns without the labels, it is looking for data points to detect characteristics that make identify them as core or less similar to

each other creating clusters and assigning the data points to them.

- Reinforcement learning – this approach focuses on learning from experience, the 'agent' or algorithm is given a task to achieve and is rewarded for getting closer to it – i.e., win a game, as it interacts with its environment it tries to optimise to achieve its goal and learns the consequences of its decisions.

(The Royal Society, 2017)

The following Table 34 provides examples of where these techniques have been developed to products in use today (The Royal Society, 2017).

System	Description
Recommender systems – suggesting products or services	Recommender systems are used in multiple different vertical markets to recommend or suggest items to for example purchase (Amazon) watch (Netflix) or media to consume (Facebook). They use patterns of consumption to build the predictions that they recommend. (Bates, et al., 2014).
Organising information – search engines and spam filtering	Google uses machine learning for example to predict the correct pages to show as a response to a search entry. Spam filters are trained on data showing what is and is not spam and learns from this as it scans emails to place them in the correct folder. As the system is then

System	Description
	deployed into the live usage it refines its training based upon users' corrections for misclassifications.
Voice recognition and response: virtual personal assistants	Natural Language Processing (NLP) and speech recognition systems match the patterns of sounds in human speech to words or phrases they have been trained on and then convert the sound to text. Again, ongoing training improves the accuracy of the systems. The recent step change in technology and accuracy has driven the development of 'smart assistants' such as Alexa from Amazon and Siri from Apple. In 2017 Google announced its speech recognition system reached parity with humans at speech recognition (Polson & Scott, 2018).
Computer vision: tagging photos and recognising handwriting	In this case machine learning has been trained on images so that it can then recognise and label new images it encounters. This is used in markets such as photo identification on social media to tag faces or objects, gaming systems also use

System	Description
	this approach to detect movement of players.
Machine translation: translating text into different languages	Machines are used to translate languages (text and speech) into another. This isn't new but recent advances have made this now possible in real time on mobile devices. Googles translation system released in 2016 generates respectable translations in over 100 languages (Polson & Scott, 2018).
Detecting patterns: unusual financial activity	Through the ability to analyse large datasets machines have been trained to identify patterns on large volumes of normal behaviour. Algorithms are then used to identify potentially fraudulent activity outside of the normal behaviour (such as location of spend patterns) to predict fraud.
Sports management	In Formula 1 race cars generate several gigabytes of data per lap. This data is then analysed by the pit crews in real time to suggest changes in tactics and predict component failures before they happen, allowing early intervention

System	Description
	and avoiding unexpected part failure (Polson & Scott, 2018).

Table 34 Examples of Machine Learning in Use Today.

AI therefore isn't some sci-fi droid from the future; its right here, right now and changing the world one smartphone at a time (Polson & Scott, 2018). The complexity of AI can also be viewed by its areas of use, Jeremy Wyatt (Professor of Digital Healthcare, Wessex Institute of Health Research) devised the following Table 35 as a model for differentiating AI usage.

High Complexity AI applications	Middle Complexity AI modules or components	Low Complexity AI reasoning methods
• Autonomous vehicle • Machine translation tool • Care companion robot • Chat bot • Surgical or pharmacy robot • Mammogram interpretation system • ECG interpreter • Diagnostic decision • support system	• Natural language to SNOMED code processing module • Image processing module • Text to speech module • Knowledge based or • expert system module • Signal processing & classification module • Recommender module	• Deep learning module • Ensemble methods (e.g., Random Forest Models) • Neural networks • Object segmentation algorithm • Signal processing algorithm / filter • Generative adversarial networks • Time series analysis • Graphical models

High Complexity AI applications	Middle Complexity AI modules or components	Low Complexity AI reasoning methods
• Speech driven radiology report tool with SNOMED coded output		• Decision trees, rule induction e.g., CART • Clustering algorithm • Classification algorithm • Regression – linear, multiple, logistic • Inference engine for rules or frames • Argumentation, temporal, or spatial reasoner e.g., QSIM • Text generator using DCGs • Case-based reasoning algorithm

Table 35 A Model for Differentiating AI Usage (The AHSN Network, 2018).

This clearly shows AI is real and impacting a broad range of areas within healthcare.

9.1.3. Implications of Using Machine Learning / AI

There are several areas that need to be considered when machine learning is applied to healthcare that need to be addressed in order to deliver any benefits safely and securely from the technology including:

- Data governance - For machines to learn they require access to data for training and testing purposes (Polson & Scott, 2018), as has been shown data is being acquired at an exponential rate (Jacobson, 2013) but the questions of how the data was acquired and what its intended use were for as opposed to what it is used for in the realm of AI raises governance issues that need to be addressed (The Royal Society, 2017).

- Data interoperability - In order to maximise the ability to extract and understand data that would be useful for machines to learn and act there are several key requirements including
  - Data scientists need to understand what the data represents, how it was created and how it should be used.
  - The users of a new service may wish to know what data has been used to create / train an algorithm and what data was used for testing.
  - Was the data approved to be used for AI research (The Royal Society, 2017).
- Limitations of AI - Several limitations of AI have been identified, Chui et al, (2018) identified five areas for consideration:
  - Firstly, the need to label training data from which the machine is ‘taught’ through supervised learning, and this is often a manual process and involves a large quantity of manual labour and specialist skills (De Fauw, et al., 2018).
  - The second and connected limitation is access to the dataset in the first place to train that is both sufficient large enough and comprehensive to allow the machine to learn and this isn’t always available with clinical trial data given as an example.
  - Thirdly is the challenge of explaining how the machine has generated an outcome from the large quantity of data that a human can understand, in healthcare if you cannot explain the answer how it can be certified through current regulations (De Fauw, et al., 2018).

    - Fourth from the team was generalisability, or the challenge of taking learnings from one setting to another (Silver, et al., 2016).
    - Finally avoiding bias in the data and algorithms which has caused embarrassing issues for some early systems. For example, the COMPAS (Correctional Offender Management Profiling for Alternative Sanctions) system was used to predict the level of risk of reoffending to a judge. The system was trained explicitly without knowing the race of gender of the input data, however when it was tested in real world setting it clearly has a racial disparity. The bias was clearly there but as the algorithm was kept secret researchers were unable to identify the cause (Polson & Scott, 2018).
- Data security - Arm's (2018) survey found that one of the areas of most concern to the public is security through hacking and loss of data being the key areas with 85% (n=3938) of those surveyed raising this as an issue.

These could be seen as limitations of the current approaches or challenges to overcome which are explored in the next section.

9.1.4. Expected Value From the Use of AI / Machine Learning

AI is still very early in its commercial adoption and there is still a gap between AI investment and commercial application, outside of the tech sector it uses is at the early experimental stage (Bughin, et al., 2017). McKinsey and Company report that this is typical in new technology development curves and the new generation of AI applications is based upon the foundations of digitisation with leaders in digital being the leaders in AI (Bughin, et al., 2017). This will be a consideration for health which hasn't always been seen as a leader in digitisation (Wachter, 2015). Investment is growing very fast in AI with between

$20 billion to $30 billion spent by the leading technology companies in 2016 alone (Bughin, et al., 2017), and a 300% increase in 2017 compared to 2016 (ARM, 2018). Chui et al, (2018), report that AI is expected to deliver value improvements of between 1% and 9% of 2016 turnover, with health at the 2.9% to 3.7% range However to date the investment hasn't progressed to large scale adoption with a recent McKinsey survey identifying only 20% of 3,000 AI aware C-level executives were deploying AI related technology with many reporting uncertainty on the business case return. From a government perspective the great potential of AI has been drawn out in recent reports which expect AI to improve healthcare outcome and ultimately reduce cost (Hall & Pesenti, 2017).

Given the challenges the NHS has had on business case investment in IT and technology (Justinia, 2016) the case for new technology will need to be clearly made and benefits evidenced.

There are however examples of where digitally native companies and industries are leading the way and showing the benefits of AI, the following Table 36 provides a selection of these early adopters (Bughin, et al., 2017).

Industry Sector and Company	Use of AI and impact
Distribution – Amazon	Acquired Kiva a robotics company that automates picking and packing, the picking time dropped from 60-75 minutes for humans to 15 mins with Kiva and inventory capacity dropped by 50%.
Distribution – Ocado	Has embedded AI in its core whereby machine learning algorithms steer thousands of products over conveyor

Industry Sector and Company	Use of AI and impact
	belts for just in time human picking and other robots move the bags to delivery lorries.
E-commerce – Otto	Reduced surplus stock by 20 percent and reduced returns by two million items per year through using deep learning to analyse billions of transactions and predict what customers would buy before they placed an order.
Media – Netflix	Uses an algorithm to personalise recommendations to its 100 million plus subscribers helping customers quickly and easily find the film or TV programme they are looking for Provide.

Table 36 Examples of AI in Use.

9.2. Appendix B: Digital Maturity Models

This appendix provides an overview of three examples of maturity models that have been developed for the healthcare sector. For each model there is a steppingstone or ladder of increasing functionality with associated benefits for the staff and / or patients. Each has its strength and weaknesses as detailed below.

9.2.1. Cleveland Clinic

In a presentation at HIMSS 2018 Cleveland Clinic presented their Digitisation Maturity Model showing the steps healthcare organisations need to progress through in order to achieve digital maturity as shown in Figure 39.

Digital Register	Digital Explorer	Digital Player	Digital Transformer	Digital Disruptor
Ad Hoc	*Opportunistic*	*Repeatable*	*Managed*	*Optimised*
Digital health initiatives are disconnected and poorly aligned with enterprise strategy, and not focused on patient experience.	Enterprise has identified a need to develop a digitally enhanced, patient centric strategy, but execution is on a project basis. Progress is not predictable	Digitisation goals are aligned at enterprise level around the creation of digital products and experiences, but not yet focused on the disruptive potential of digital initiatives.	Enterprise has an integrated, synergistic approach to digitalisation, delivering digitally enabled product and service experiences on a continuous basis. Constantly seeking opportunities to disrupt own value chain.	Enterprise is aggressively disrupting in the use if new digital technologies and business models to affect markets. Ecosystem awareness and feedback is a constant input to enterprise innovation
Business outcomes	*Business outcomes*	*Business outcomes*	*Business outcomes*	*Business outcomes*
Enterprise is laggard providing weak patient experiences and using digital technologies only to counter threats	Enterprise provides digitally enabled patient experiences and products, but they are inconsistently and poorly integrated	Enterprise provides consistent but not truly integrated products, services, and experiences	Enterprise is leader in its market, providing world-class digital products, services and experience	Enterprise remakes existing markets and creates new ones to its own advantage

Figure 39 Digital Maturity Model Adapted from (Marx, 2018).

This model focuses on the impact rather than the actual technology or capability. The model uses language that may be difficult to align with healthcare settings such as ‘disrupting in the use of digital technology’. This model fits the American ecosystem where different institutions do compete for business and innovation is often driven on that basis.

9.2.2. HIMSS Digital Maturity Model

The Healthcare Information and Management Systems Society (HIMSS) is a global advisor, thought leader and member association committed to transforming the health ecosystem (HIMSS, 2021). It has created a digital maturity model for the global healthcare market on electronic records. The Electronic Medical Record Adoption Model (EMRAM), provide prescriptive frameworks to healthcare organizations to build their digital health ecosystems. HIMSS have developed an 8-stage model. The following Table 37 shows the 8 stages.

Stage	Description
STAGE 0: All Three Ancillaries Not Installed	The organization has not installed all key ancillary department systems (laboratory, pharmacy, radiology, and cardiology).
STAGE 1: Ancillaries (Laboratory, Pharmacy and Radiology/Cardiology Information Systems), PACS, Digital Non-DICOM Image Management	All major ancillary clinical systems are installed (laboratory, pharmacy, radiology, and cardiology). A full complement of radiology and cardiology PACS systems provides medical images to physicians via an intranet and displaces all film-based images. Patient-centric storage of non-DICOM images is also available
STAGE 2: CDR, Internal Interoperability, Basic Security	Major ancillary clinical systems are enabled with internal interoperability feeding data to a single clinical data repository (CDR) or fully integrated data stores that provide seamless clinician access from a single user interface for reviewing all

Stage	Description
	orders, results, and radiology and cardiology images. The CDR/data stores contain a controlled medical vocabulary, and order verification is supported by a clinical decision support rules engine for rudimentary conflict checking. Information from document imaging systems may be linked to the CDR at this stage. Basic security policies and capabilities addressing physical access, acceptable use, mobile security, encryption, antivirus/anti-malware, and data destruction are in place.
STAGE 3: Nursing and Allied Health Documentation, eMAR, Role-Based Security	50% of nursing/allied health professional documentation (e.g., vital signs, flowsheets, nursing notes, nursing tasks, care plans) is implemented and integrated with the clinical data repository (hospital defines formula). Capability must be in use in the ED, but the ED is excluded from the 50% rule.

Stage	Description
	The Electronic Medication Administration Record (eMAR) application is implemented. Role-based access control is implemented.
STAGE 4: CPOE With CDS, Nursing and Allied Health Documentation, Basic Business Continuity	50% of all medical orders are placed using computerized practitioner order entry (CPOE) by any clinician licensed to create orders. CPOE is supported by a clinical decision support (CDS) rules engine for rudimentary conflict checking, and orders are added to the nursing and clinical data repository environment. CPOE is in use in the ED but not counted in the 50% rule. Nursing/allied health professional documentation has reached 90% (excluding the ED). Where publicly available, clinicians have access to a national or regional patient database to support decision-making (e.g., medications,

Stage	Description
	images, immunizations, lab results, etc.). During EMR downtimes, clinicians have access to patient allergies, problem/diagnosis list, medications, and lab results. A network intrusion detection system is in place. Nurses are supported by a second level of CDS capabilities related to evidence-based medicine protocols (e.g., risk assessment scores trigger recommended nursing tasks).
STAGE 5: Physician Documentation Using Structured Templates, Intrusion/Device Protection	Full physician documentation (e.g., progress notes, consult notes, discharge summaries, problem/diagnosis list, etc.) with structured templates and discrete data is implemented for at least 50% of the hospital. Capability must be in use in the ED, but the ED is excluded from the 50% rule. The hospital can track and report on the timeliness of nurse order/task completion.

Stage	Description
	An intrusion prevention system is in use to both detect and prevent possible breaches. Hospital-owned portable devices are recognized and properly authorized to operate on the network and can be wiped remotely if lost or stolen.
STAGE 6: Technology-Enabled Medication, Blood Products and Human Milk Administration, Risk Reporting, Full CDS	Technology is used to achieve a closed-loop process for administering medications, blood products and human milk, and for blood specimen collection and tracking. These closed-loop processes are fully implemented in 50% of the hospital. Capability must be in use in the ED, but the ED is excluded from the 50% rule. The eMAR and technology in use are implemented and integrated with computerized practitioner order entry, pharmacy, and laboratory systems to maximize safe point-of-care processes and results. A more advanced level of clinical decision support (CDS)

Stage	Description
	provides for the “five rights” of medication administration and other “rights” for blood product, human milk administrations and blood specimen processing. At least one example of a more advanced level of CDS provides guidance triggered by physician documentation related to protocols and outcomes in the form of variance and compliance alerts (e.g., VTE risk assessment triggers the appropriate VTE protocol recommendation). A mobile/portable device security policy and practices are applied to user-owned devices. The hospital conducts annual security risk assessments, and a report is provided to a governing authority for action.
STAGE 7: Complete EMR, External HIE, Data Analytics, Governance, Disaster Recovery, Privacy and Security	The hospital no longer uses paper charts to deliver and manage patient care and has a mixture of discrete data, document images and medical

Stage	Description
	images within its EMR environment. Data warehousing is used to analyse patterns of clinical data to improve quality of care, patient safety and care delivery efficiency. Clinical information can be readily shared via standardized electronic transactions (i.e., CCD) with all entities that are authorized to treat the patient or with a health information exchange (HIE) (i.e., other non-associated hospitals, outpatient clinics, sub-acute environments, employers, payers, and patients in a data sharing environment). The hospital demonstrates summary data continuity for all hospital services (e.g., inpatient, outpatient, ED, and with any owned or managed outpatient clinics). Physician documentation and computerized practitioner order entry has reached 90% (excluding the ED), and the

Stage	Description
	closed-loop processes have reached 95% (excluding the ED).

Table 37 HIMSS EMRAM Maturity Model (HIMSS, 2021).

The HIMSS model is very prescriptive and provides a clear roadmap for what and how organisations should invest in order to achieve digital maturity. This is easier to follow for many users as it provides the system rather than the necessary benefits and changes the investment will drive. As a side point it is also interesting to note that security isn't mentioned until stage 7 of the model. To date globally 10,100 institutions have been scored using this method. In Europe there are only seven holders of stage 7 accreditation (HIMSS, 2021). HIMSS have also developed other maturity models including analytics, continuity of care, supply chain, digital imaging, infrastructure, and outpatient EMR. Again these are very prescriptive and easy to follow to achieve the targets set by HIMSS.

9.2.3. NHSx What Good Looks Like Framework

NHSx, a Department of Health arm's length body has developed the What Good Looks Like (WGLL) programme. The programme draws on local learning builds, on established good practice to provide clear guidance for health and care leaders to digitise, connect and transform services safely and securely. This will improve the outcomes, experience, and safety of our citizens (NHSx, 2021). The framework has seven measures:

1. Well led
2. Ensure smart foundations
3. Safe practice

4. Support people
5. Empower citizens
6. Improve care
7. Healthy populations

For each level there are assessments that are aimed at Integrated Care Systems (ICS) level and not individual organisations are shown in the following Table 38.

Well Led	Own an ICS-wide digital and data strategy that drives ‘levelling up’ across the ICS and is underpinned by a sustainable financial plan. Establish ICS governance to regularly review and align all organisations’ digital and data strategies, ICS-cyber security plan, programmes, procurements, services, delivery capability and risks. Ensure that your ICS digital and data strategy has had wide input from clinical representatives from across the ICS. Identify ICS-wide digital and data solutions for improving health and care outcomes by regularly engaging with partners, citizen, and front-line groups. Invest in regular board development sessions to develop digital competence.

	Support investment in ICS-wide multidisciplinary CCIO and CNIO functions.
Ensure Smart Foundations	Have a system-wide strategy for building multidisciplinary teams with clinical, operational, informatics, design, and technical expertise to deliver the ICS digital and data ambitions. Ensure progress towards net zero carbon, sustainability, and resilience ambitions by meeting the Sustainable ICT and Digital Services Strategy (2020 to 2025) objectives. Make sure that all projects, programmes, and services meet the Technology Code of Practice and are cyber secure by design. Oversee across organisation investment in modern infrastructure to retire unsupported systems. Drive organisations towards ‘simplification of the infrastructure’ by sharing and considering consolidation of spending, strategies, and contracts. Ensure levelling up of the use and scope of electronic care record systems, including using greater clinical functionality and links to diagnostic systems and EPMA. Lead the delivery and development of an ICS-wide shared care record (ShCR) which adheres to the Professional Records

	Standard Body's Core Information Standard.
Safe Practice	Have a system-wide plan for maintaining robust cyber security, including development of centralised capabilities to provide support across all organisations. Establish a process for managing the cyber risk with mitigation plans, investment and progress regularly reviewed at ICS level. Have an adequately resourced ICS-level cyber security function, including a senior information responsible officer (SIRO) and data protection officer (DPO). Ensure that you fully use national cyber services provided by NHS Digital. Ensure the organisations in your ICS are supported to comply with the requirements in the Data Security and Protection Toolkit which incorporates the Cyber Essentials Framework. Have an adequately resourced clinical safety function, including a named CSO, to oversee ICS-wide digital and data development and deployment. Ensure ICS-wide clinical systems meet clinical safety standards as set out by DTAC and DCB0129 and DCB0160. Establish a clear system-wide process for reviewing and responding to relevant safety

	recommendations and alerts, including those from NHS Digital (cyber), NHS England and NHS Improvement, the MHRA and the Healthcare Service Investigation Branch (HSIB). Ensure compliance with NHS national contract provisions related to technology-enabled delivery, for example, clinical correspondence and electronic discharge summaries.
Support People	Create and encourage a digital first approach across the ICS and share innovative improvement ideas from frontline health and care staff. Promote the use of systems and tools to enable frictionless movement of staff across the ICS - allowing staff from different organisations to work flexibly and remotely where appropriate. Ensure that front-line staff across your ICS have the information they need to do their job safely and efficiently at the point of care, including an ICS shared care record. Create ICS-wide professional development, front-line skills development, peer support mechanisms and training opportunities. Pool resources to provide resilient digital support services across your ICS.

Empower Citizens	Develop a single, coherent ICS-wide strategy for citizen engagement and citizen-facing digital services that is led by and has been co-designed with citizens. Make consistent, ICS-wide use of national tools and services (NHS.uk, NHS login and the NHS App), supplemented by complementary local digital services that provide a consistent and coherent user experience. Ensure and monitor a consistent citizen offer by ICS organisations. Ensure a system-wide approach to the use of digital communication tools to enable self-service pathways such as self-triage, referral, condition management, advice, and guidance. Ensure a system-wide approach for people to access and contribute to their health and care data. Take an ICS-wide approach to access to care plans, test results, medications, history, correspondence, appointment management, screening alerts and tools. Have a clear ICS digital inclusion strategy, incorporating initiatives to ensure digitally disempowered communities are better able to access and take advantage of digital opportunities.

Improve Care	Have an ICS-wide approach to the use of data and digital solutions to redesign care pathways across organisational boundaries to give patients the right care in the most appropriate setting. Ensure that organisations across your ICS make use of digital tools and technologies that support safer care, such as EPMA and bar coding. Ensure that organisations across your ICS employ decision support and other tools to help clinicians follow best practice and eliminate quality variation across the entire care pathway. Ensure that organisations across your ICS provide a consistent and cost-effective approach to remote consultations, monitoring and care services. Lead a system-wide approach to collaborative and multidisciplinary care planning using an array of digital tools and services alongside PRSB standards.
Healthy Populations	Lead the delivery and development of an ICS-wide intelligence platform with a fully linked, longitudinal dataset (including primary, secondary, mental health, social care, and community data) to enable population segmentation, risk stratification and population health management.

	Use data and analytics to redesign care pathways and promote wellbeing, prevention, and independence (for example, identifying patients for whom remote monitoring is appropriate). Create integrated care models for at risk population groups, using data and analytics to optimise the use of local resources and ensure seamless coordination across care settings. Ensure that local ICS and place-based decision-making forums, including PCN multi-disciplinary teams, have access to timely population health insight and analytical support. Make data available to support clinical trials, real-world evidencing, and AI tool development. Drive ICS digital and data innovation through collaborations with academia, industry, and other partners.

Table 38 NHSx What Good Looks Like (NHSx, 2021).

This framework or model is interesting as it takes a different approach from both the Cleveland Clinic ‘s disruptive approach and the HIMSS system prescriptive approach. The NHSx framework is focused on a health system level and not an individual organisation. This is supporting the wider NHS changes seen in the recent White Paper (Department of Health and Social Care, 2021) . The framework also places a clear focus on the citizen involvement as the key beneficiary of the assessment. Finally it does provide guidance on the systems that could support the benefits being delivered. These are however secondary to the change and transformation expected. It is useful to not that cyber security does form a clear part of the assessment. The framework is new and hasn't yet had time to be assessed to see its impact.

These are just three examples of maturity models and frameworks that have been developed to support the digitisation of technology in healthcare. There are clearly different approaches, drivers, and priorities. The NHSx approach will be one to review in several years when the new ICS operating model has been implemented and assess the impact of this approach.

9.3. Appendix C: National Programme for IT (NPfIT)

This appendix is a combination of my own personal experiences as a Programme Director working within the NHS and for the National Programme for IT (NPfIT) and wider literature review.

NPfIT was initiated in 2002 when the then Prime Minister Tony Blair met with American and UK health and technology experts. The outcome of this seminar was an originally planned investment of £6billion (Campion-Awwad, et al., 2014). The move towards technology in healthcare had been initiated many years earlier in a piecemeal way but it wasn't until the Labour government came into power in 1997 that a more national approach was formed. The NHS National Executive released an early vision in 1998 which identified four main groups of beneficiaries; patients who would be able to see their own test results at home. Healthcare professionals to have fast and reliable access to a patient record in a single local, NHS managers and administrators to have access to quality information to help improve planning and resource usage. Finally, the public through the use of the data captured for secondary purposes such as performance management and research (NHS Executive, 1998).

NPfIT wasn't the first attempt to move the NHS from an almost exclusively paper based operating model to a more electronic data centric model. Earlier examples include 1984 Wessex Regional Health Authority (WHRA)'s Regional Information Systems Plan (RISP), abandoned in 1990 due to cost overruns and missed targets. Hospital Information Support System (HISS), which ran in seven NHS Trusts from 1988 until 1995 when again the programme was dogged with failure and lack of benefit delivery (Campion-Awwad, et al., 2014).

It was against this backdrop that the NHS Executive set out some challenging targets for technology adoption which included for the first time an implementation plan (NHS Executive, 1998). NPfIT was launched to address many of these previous failings with a belief that technology was now mature enough and the health service ready and in need of the new technology. Campion-Awwad et al (2014) reported that instead of seeking to address the lessons learned from previous failures – address the need to accept that changing working practices takes time and adjust programme management techniques accordingly. NPfIT would instead drive a radical central driven programme into the NHS.

It was at this early stage that I became involved in NPfIT, I was at the time a Programme Director for a regional health authority working on new technology ideas. My specific area was Picture Archiving and Communications Systems (PACS) introducing new technology to the radiology department. I was initially seconded and then moved to a role as Programme Director for London. I spent many months commuting from London to Leeds to work on NPfIT during its business case and pre-procurement phases. The following section show the key aspects of the timeline the programme went through. What the text doesn't fully show and what I experienced was the complete disconnect from the local organisations. This was a truly top down centrally driven programme with leadership who had never worked in the NHS and the main suppliers who had never delivered large systems to the NHS.

The following phases are not based on any central plan or programme but reflect the journey as I experienced them from the outset of NPfIT through to its eventual demise.

9.3.1. Phase 1: Initiation

A white paper was released in 2002 which set the vision for NPfIT as a centrally driven and managed programme of work (Department of Health, 2002). The programme initially had 4 main workstreams to deliver on:

1. An integrated electronic health record system.
2. Electronic prescriptions.
3. An electronic appointment booking system; and
4. An underpinning IT infrastructure with sufficient capacity to support the national applications and local systems. (Department of Health, 2002)

The programme governance was centralised around a single Department of Health Director – initially this was Sir John Pattison who I met and presented the PACS concept to. Sir John reported back to the Permanent Secretary in the Department for Health as well as the NHS CEO. The plan was to then appoint an overall programme director at national level and for each of the 28 Strategic Health Authorities appointing a Chief Information Officer (Campion-Awwad, et al., 2014). The aim was to ensure that each of the local NHS organisations was involved in the programme and minimise the risk of a disconnect from the outset. This was supported by the establishment of a clinical care advisory group to be chaired by

Professor Peter Hutton to represent the wider clinician's views and advice the overall programme.

As part of any large-scale government programme a Gateway Review Process had been established and administered by a separate government department – Office of Government Commerce (OGC). The first gateway in the process is Gate Zero. The programme was evaluated to assess its fitness for purpose to move to the next stage. The programme passed but the OGC did raise concerns on the lack of stakeholder engagement and the need for the programme to recognise that at its heart it was a change management programme and needed detailed planning for this (Campion-Awwad, et al., 2014).

9.3.2. Phase 2: Specification and Procurement

The first part of the procurement work was to produce an Output Based Specification (OBS). The OBS describes to potential suppliers what is required from the systems being purchased in an output style – i.e. what the system should deliver and not how it should deliver it. This process I know from personal experience can take several months working with end-users, stakeholders, and the wider team to ensure that the OBS is not only correct but if delivered would meet the end-users' needs and be accepted by them. The document is also used to evaluate the bidder's responses and is one of the key documents.

The NPfIT OBS was developed through amalgamating documents from previous and local procurements (Campion-Awwad, et al., 2014). I was involved in this from a PACS perspective and the work that had taken 6 months to develop in Southwest London (Corkett, 2002) was the basis for the OBS used for PACS when it was added to the scope of NPfIT. The NPfIT OBS was sent out for consultation with only two months for comments (Campion-Awwad, et al., 2014). The shortness of the review window was recognised by the Public Accounts Committee (PAC) in their 2007 review as too short.

In September 2002 a new Director General of NHS IT was appointed, Richard Granger, he came from a management consultancy background with experience of large-scale public-sector projects including the London congestion charge – but no healthcare experience (Campion-Awwad, et al., 2014). Granger led the procurement programme at a rapid rate and appointed five Local Service Providers (LSPs) as the prime contractors for the 5 NHS regions as well as National Application Service Providers (NASPs) for central systems such as email and networking. The LSPs and NASPs were global IT technology companies (BT, Fujitsu, CSC Atos, and Accenture). Granger has been accredited with driving a very hard and service orientated contracting model where the suppliers were placed under enormous pressure to deliver no matter what. The consequence was also however associated with the issues of Group Think and intolerance to challenge (Campion-Awwad, et al., 2014). On a personal basis I can support these findings, the atmosphere during this stage was almost to the point of bullying and it felt like there was two realities, the NPfIT view of the NHS and then the end-users, stakeholders, and local management views.

Each of the LSP prime contractors partnered with sub-contractors who would supply the actual systems with companies such as Cerner, IDX and iSoft. The expected and contracted timescales for delivery were extremely tight with large supplier penalties for non-delivery. The situation was made worse because the current systems the suppliers had didn’t meet all the OBS requirements and a large amount of development was needed.

9.3.3. Phase 3: Implementation

Just when the NPfIT was entering its implementation phase there was an almost constant change of senior leadership within Department of

Health and the NHS with senior clinical advisors and civil servants leaving after a relative short period of time:

> '*Dr Halligan would remain as SRO for just six months before resigning in September 2004, to be replaced by Alan Burns who in turn would serve only another six months from November 2004 before departing, with the post to be filled by Richard Jeavons in March 2005. In March 2006, the man who Sir John Pattison had reported to, Sir Nigel Crisp, would also depart, retiring from the NHS and Department of Health. The seemingly constant rotation of senior management and leadership impacted NPfIT through the loss of corporate knowledge and leadership, and through the diffusion of accountability and responsibility for the programme'* (Campion-Awwad, et al., 2014, p. 22).

With this constant change of leadership, the LSPs and NASPs were also undergoing change of the sub-contractors who were perceived to be not delivering with penalties and missed payments affecting the earnings of the companies. By 2006 one of the LSP's themselves was leaving and the work having to be transferred to another LSP to deliver the contract. At a local level all of these changes felt as it was happening around and to us but not with us. The knock-on effect was that there was very limited funding for any local project to be delivered whilst we waited for NPfIT to deliver.

There were some successes in this time the national prescription service and the New National Network (N3) were delivered by 2007 ahead of schedule (Campion-Awwad, et al., 2014). The PACS programme was successfully delivered and resulting in the whole of England having the system by 2010. This compares to only 18 hospitals having new electronic health systems delivered by 2007 (Campion-Awwad, et al., 2014).

At a local hospital level the pressure to maintain existing systems, which were out of date when NPfIT started in 2002 and had been maintained throughout the programme at local effort were causing real problems. The pressure was mounting, and PAC reported in 2007 that local hospital systems should be upgraded rather than wait for the new central systems which were behind schedule. I was working as a deputy CIO at this stage at a Strategic Health Authority and this conflict between local needs and requirements and the central driven operation were clear to see and experience. The impact of constantly trying to manage the large-scale central contract with limited local resources and buy in from clinicians and end-users was causing a blame game culture to develop.

9.3.4. Phase 4: the beginning of the end

From my experience of being involved in the programme at a local level I can trace the beginning of the end of NPfIT to the resetting and then the final cancellation of the contract between Fujitsu and NPfIT which began in 2007 and ended with Fujitsu contract being terminated in 2008. In January 2008 Richard Granger also left his role and his responsibilities were split between two new roles. From the beginning of the programme a number of consistent themes were never resolved including a standardisation of coding used within the systems, privacy and data sharing agreements and local clinical engagement. These all added to the problems faced by NPfIT (renamed to Connecting for Health) and its suppliers. By 2010 the budget for the programme was reduced by the Treasury and local hospital trusts were given more freedom to select system they wanted (Campion-Awwad, et al., 2014). For the remaining LSPs their contracts were allowed to run down rather than be cancelled. Connecting for Health was finally abolished in 2013.

Campion-Awwad et al summarised the themes for the failure of the programme into the following categories:

- Haste
  - An unrealistic timetable
  - No time to engage with users and privacy campaigners
  - Inadequate preliminary work
  - Failure to check progress against expectations
  - Failure to test systems
- Design
  - Failure to recognise the risks or limitations of big IT projects
  - Failure to recognise that the longer the project takes, the more likely it is to be overtaken by new technology
  - Sheer ambition
  - The project is too large for the leadership to manage competently
  - Confidentiality issues
- Culture and Skills
  - A lack of clear leadership
  - Not knowing, or continually changing, the aim of the project
  - Not committing necessary budget from the outset
  - Not providing training
  - A lack of concern for privacy issues
  - No exit plans and no alternatives
  - Lack of project management skills
  - Treasury emphasis on price over quality
  - IT suppliers depend on lowballing for contracts and charge heavily for variations to poorly written specifications

    (Campion-Awwad, et al., 2014, p. 36)

From my personal experience NPfIT was a success and failure, the PACS programme was an outstanding success and recognised globally for what it had achieved. This I put down to the early work engaging with the radiologists and radiographers to ensure that the specification and eventual system would work for them and deliver the benefits. The N3 network was a major success allowing data to flow relatively securely across the NHS in England. Other programme like NHS email is still going strong today and electronic prescription service has grown too far wider capabilities. I also witnessed the wasted money and effort of trying to force systems onto the NHS without understanding the beliefs, norms and ethics that exist.

The result was a programme deemed ‘a fiasco’ and the bulk of £12billion of investment written off with the view that the programme was run like a military procurement programme whose leadership under Richard Granger was ‘just do it’ which placed him at logger heads with the physicians and almost everyone in the health service (Wachter, 2015, p. 17). I hope lessons can be learnt as the new model of more central IT control is being exerted.

9.4. Appendix D Open Coding of Pilot Study

Code No.	Code work	interpretation	Candidate				
			1	2	3	4	5
1	relationship	Having a good relationship with key stakeholder	1				
2	Lacking engagement	Seen as negative to the project	1	1			
3	Amount of time	Access to the right people with correct time is seen as key to success	1	1			
4	Project governance		4		1		
5	Benefits		2				
6	Right requirements		1			1	
7	Influence	The level of influence that the stakeholder has	1				
8	Poor governance		2		1		

Code No.	Code work	interpretation	Candidate				
9	Networking senior people	Work was wone through networking but needed wider support	2	1			
10	More resource	NHS needed for resources than they had anticipated	2				
11	The tool will not solve the problem for them	The answer has to be more than just technology	1			1	
12	Deployment problem	If set up wrong in design and built will fail at implementation	1		1		
13	People that were put in were not at the operational level	Ensuring the correct stakeholders are engaged	1				
14	Work on the ground	Deal with stakeholders who would use the system	1			1	
15	Commercially viable option hasn't been there	Lack of internal governance on decision making	1				1

Code No.	Code work	interpretation	Candidate				
16	Bypass process and just jump on the nice shiny thing and do it		1		1		1
17	Full market analysis research	Lack of right information and expertise	2		2	1	2
18	Governance gateways	Set up at the beginning	1				
19	Regular check backs	Regular check in with the clients	1				
20	Lack of skill		1				
21	Lack of process	Internal process for the control	1	1	1		
22	insufficient stakeholders	In the process	1	1			
23	Lost the champion	Who is leading from customer side	1	1			
24	Wasn’t socialised wide enough		1				

Code No.	Code work	interpretation	Candidate				
25	Engage any other partner	Only one early partner was leading on the work with them	1				
26	Didn’t engage enough people around it		1	1			1
27	Engagement	Lack of engagement	1				
28	Requirements gathering		1				1
29	Focused on individuals rather than broader group of individuals		1	1		2	1
30	Some functionality gets missed		1				
31	Business analysis		1	1			
32	Process map		1				
33	Didn’t look enough at the problem we are trying to solve		1	1			

Code No.	Code work	interpretation	Candidate				
34	Map the solution		1				
35	How is it going to solve it		1				
36	What problems are we trying to solve		1				
37	What benefits do we provide		1				
38	Due diligence		1				
39	Clear benefits case		1				
40	Baseline		1				
41	Time and motion study	Lack of this has caused issues on benefits	1				
42	Drops from the vision of the executive sponsor		1				
43	Only one requirements workshop	Not sufficient to capture everything	1				

Code No.	Code work	interpretation	Candidate				
44	They need to commit to the change management part		1				
45	Idea to delivery with limited input from user	From this initial concept to the product being released very little input from the user of the system	1			1	
46	Articulating the change plan for each of these steps		1				
47	What are they going to do humanly differently		1				
48	Resources to support the framework		1				
49	Visualise the data in a way that made sense	This was how the stakeholders could see the data		1			

Code No.	Code work	interpretation	Candidate				
50	People here suggesting it and letting them think it was their idea			1			
51	Not an appetite to deliver them effectively	Referring to the NHS as customer		1			
52	Three main stakeholders: Providers of information Users Payers	Context of who you need to win over		1			
53	Rush to try and solve the problem	In context of what has gone wrong with approaches to the design		1			
54	Small groups of people actively involved	In refence to how it works in small companies but gets lost as you grow		1			
55	User groups have been lost	Lack of user's groups seen as an issue		3	1	1	

Code No.	Code work	interpretation	Candidate				
56	Have a road map and don't build discrete products			1			
57	Developers and designers worked had no structured format				1		
58	Handed off only at completion time	Back to the customer			1		
59	No testing of the actual users				1		
60	Process wasn't followed				3	1	
61	Garbage in garbage out				1		
62	Improve product development cycles				1	1	
63	Based on knowledge of a				1	1	

Code No.	Code work	interpretation	Candidate				
	limited number of people						
64	10% involvement of end-users				1		
65	Involvement of end-users at late stages in the process	Seen as negative			1		2
66	Communication	Internal and external			1		
67	Communication, process, and people	Three key considerations			1		
68	Make it user centred				1	1	
69	Ad hoc process used for design, build deliver					1	
70	Lack of documentation in process					2	
71	Lots of rework					1	

Code No.	Code work	interpretation	Candidate				
72	Requirements were subjective					1	
73	Product not fit for purpose					1	
74	I doubt there was any design					1	
75	Agile approach was better					1	
76	Right personas in the room					1	
77	Not thinking about the change element					1	
78	Never sense checked the idea with anyone actually wants or needs it						1
79	No requirement exercise						1
80	We could never teach anybody the really weird	Referring to bespoke development					1

Code No.	Code work	interpretation	Candidate				
			1	2	3	4	5
	way to use the system						
81	Built completely for one customer						1
82	More sophisticated than we need to						1

Table 39 Open Coding of Pilot Study.

9.5. Appendix E: Open Coding of Problem Scoping Data Collection

Code No.	Code work	interpretation	Candidate				
			1	2	3	4	5
1	Doesn't just affect PCs as most people think		1		1		1
2	Affects users trying to serve the patients		1		1		
3	Impact dependent		1				

Code No.	Code work	interpretation	Candidate				
	upon where attack is seen						
4	Budget	Senior people don't see funding cyber security as a key issue	2	1	1	1	
5	Lots of tools but no one window showing the risk	There are multiple tools used to monitor and detect issues but no one single window on the entire problem	1		1	1	2
6	Lack of knowledge	There is a general lack of knowledge within the NHS on the risk	1	1	1	2	1
7	Told to deploy systems even if not cyber safe		1			1	1
8	Not involved in procurement		1			1	1
9	education		1	1			1
10	Old systems	Java 6 years out of date but have to keep it as	1	1		1	1

Code No.	Code work	interpretation	Candidate				
		medical device is running on it					
11	Central support – CareCERT		1			1	1
12	Manual checking	CareCERT to physical device	1	1	1	2	
13	No policy of procedures to follow		1				
14	Automated processes in vulnerability management	Maximise the use of technology to solve the issue	2	4	2	1	
15	Secure in itself	Any new system must be secure in itself	1		1		
16	Flexible	To meet the NHS culture	1				
17	Visual on the wall	Easy to see what the risks are for all staff	1		1	1	1
18	Easy to understand reports for trust boards		1				1

Code No.	Code work	interpretation	Candidate				
19	Mobile alerts	All staff have mobile phone and used to seeing alerts on these	1		2	1	1
20	Software normally off the shelf	Not designed for NHS so often has to be retrofitted	1				
21	Mobile device management	Increasing risk from mobile devices	1	1	1		
22	Resources to react	Sufficient resources to react and manage cyber risks		4	3	1	3
23	Old systems	NHS has lots of old clinical systems		1	3	1	
24	Lack of cyber specialists	NHS pay bands won’t attract cyber specialists		2		2	2
25	Staff awareness of cyber risks is low			1	2		
26	Staff understanding of standards	When staff purchase new systems do, they understand the cyber risk		1	1	1	

Code No.	Code work	interpretation	Candidate				
27	Excel sheets	Current alerts from central NHS are excel sheets		1			
28	Alerting to the key issues	Seeing the real issues from all of the noise		1	1		
29	Seamless process	Not impact system users		1			
30	Use of AI	Can be used to improve the system		1			
31	Reactive not proactive	We tend to react to issues rather than be proactive to the risk			2	1	
32	No national direction	Lack of central guidance			1		
33	Communicate	How do we communicate the risk and message on cyber			1		
34	Systems purchased without cyber assessment	Staff buy new systems with no cyber assessment			2	1	
35	Exec support	Not an IT issue but wider exec team need to own the issue			1		

Code No.	Code work	interpretation	Candidate				
36	A lot of manual processes	Currently a lot of work is manual			2		
37	Suppliers need to take more responsibility	System suppliers must take more responsibility for their own cyber risks					1

Table 40 Open Coding of Problem Scoping Data Collection.