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An Analytic and Systemic View of the Digital Transformation of Healthcare

Xuejuan J. Zhang

AN ANALYTIC AND SYSTEMIC VIEW OF THE

DIGITAL TRANSFORMATION OF HEALTHCARE

by

Xuejuan Joyce Zhang

A dissertation submitted in partial fulfillment

of the requirements for the degree of

Doctor of Management in Strategic Leadership

in the

School of Business

at

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2023

Doctoral Dissertation Committee:

4/24/2023

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ABSTRACT

Industry 4.0 represents a digital revolution that is driven by technologies that blur the lines between the physical and digital worlds. Industry 4.0, the latest industrial revolution, is poised to have a profound impact on all aspects of society. In order to understand how the healthcare industry is being transformed by the convergence of the physical and digital realms, a systems perspective is taken in this study. Two research questions are addressed regarding the opportunities and interventions that can be provided by both analytical and systems conceptions of digital transformation. I use a systemic literature review approach to address the research questions. A sample of studies between 2000 and 2022 is analyzed. Existing studies mostly examine the effects of new digital technologies on healthcare providers. However, digital transformation also presents significant challenges, such as data privacy, ethical concerns related to AI-based automated decision-making, and equity issues related to e-health. Solutions to major challenges at both micro and macro levels can be derived from the existing theories and tools of systems thinking. For instance, systems thinking's continuous learning and adaptation capabilities can be useful for healthcare organizations to develop the required digital capabilities. Furthermore, the interconnectedness of subsystems and stakeholders in systems thinking can be combined with digital twin technology to investigate the dynamic interactions among key stakeholders, leading to the development of new regulatory policies.

DEDICATION

This thesis is wholeheartedly dedicated to my beloved father, Dacheng Zhang, who has always been my source of inspiration and strength.

I dedicate my thesis to my husband, Dr. Tao Sun, and my daughters, Meixi Sun and Jingxi Sun, for their endless love and support and for being the best companion in this journey.

To my mother and brother for their endless love and support.

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I would like to express my sincere gratitude to my supervisor, Dr. Larry Starr, for his guidance and support throughout this journey. Dr. Starr's expertise and encouragement have been invaluable in shaping my research and developing my skills as a scholar.

I would also like to thank the committee members, Dr. Syd Havely and Dr. Michael Li, who generously shared their time and insights with me. Without their contributions, this study would not have been possible.

My deepest appreciation goes to my family and friends for their unwavering support and understanding during this challenging time. Their love and encouragement have kept me motivated and inspired during this academic quest.

Finally, I would like to thank Thomas Jefferson University for providing me with the resources and opportunities to pursue this research. This dissertation represents the culmination of my academic journey, and I am honored to have had the opportunity to contribute to the field.

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CHAPTER 1

INTRODUCTION

Dissertation Challenge

In the United States, the healthcare industry has played increasingly important roles in the economy and society. Over the past two decades, key players in the U.S. health system have adopted digital technologies in their various functional areas. Numerous efforts and initiatives have emerged, from installing electronic health record (EHR) systems to building mobile phone apps and experimenting with disruptive technologies such as Big Data Analytics and Artificial Intelligence. However, most of these initiatives were developed with a linear analytic mindset; there was no overall-whole systems perspective regarding the general trend of the transformation of the healthcare industry in a digital era. Therefore, in this dissertation, I address the following general challenge: What are the implications of framing the challenges, i.e., problems and opportunities of the digital transformation of the healthcare industry using analytic thinking and systems thinking? How do these different approaches to thinking explain how challenges are understood and interventions are made?

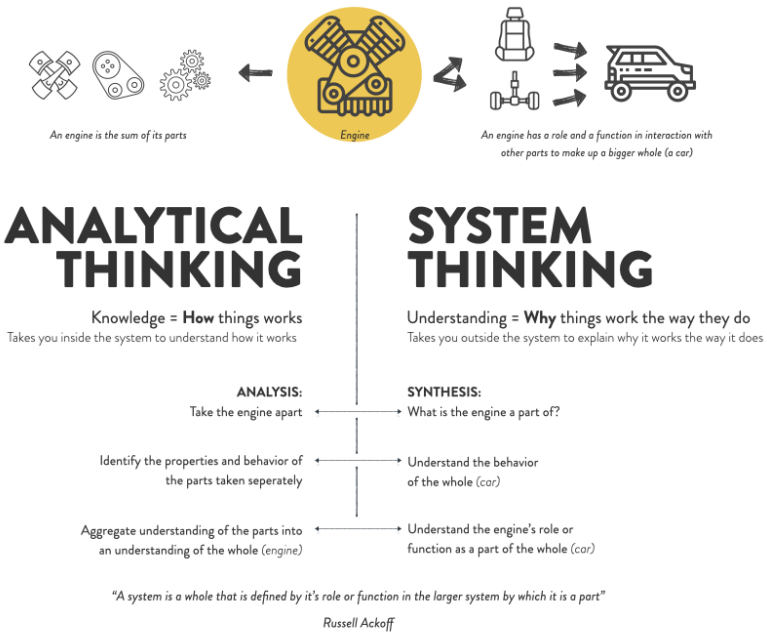
Ackoff (2004) compared two major patterns of thinking, one that uses the processes and steps of analysis and is referred to as analytic thinking; the other that applies synthesis and is called systems thinking. [1] Indeed, analysis and synthesis are different and complementary. From ancient Greek, the word *analysis* (ἀνάλυσις) means "a breaking-up" or "an untying" and is the process of simplifying, reducing or deconstructing a topic (or substance) into smaller parts to gain better understanding. This has been an approach used in mathematics and logic for more than two thousand years (Beaney, 2012). Ackoff noted there are three steps when applying analysis to a problem: (1) Take the thing apart; (2) Identify the properties and behaviors of the parts taken separately; (3) Aggregate an understanding of the parts to an understanding of the whole. This process helps one to understand how something works.

Synthesis, from Greek word, *syntithenai*, means to put together or to mix different ideas, influences or things to make a whole that is different or new (Cambridge Dictionary, 2022). The steps of synthetic or systems thinking are: (1) Determine what is the thing of interest a part of (its

[1] This talk took place at Pratt and Whitney Rocketdyne, Canoga Park, CA The year was approximately 2004. Two short videos can be accessed at https://youtu.be/IJxWoZJAD8k; and https://youtu.be/UdBiXbuD1h4

containing whole); (2) Understand the properties or behaviors of the whole; (3.) Understand the properties, behaviors and function of the part within the whole. Synthesis and systems thinking help to provide an understanding of why a part and a problem acts as it does. Figure 1 (from Tenno, 2020) depicts these complementary differences of thinking.

Figure 1: Analytic and Systemic Thinking Processes



Digital transformation will continue to result in changes and disruptions with unprecedented scale and scope to our economy and society including within the healthcare industry. To better understand the impacts of digital transformation on the health care industry, it is crucially important to adopt a mode of thinking that is appropriate to this challenge. As has been often reported, Albert Einstein referred to the importance of changing thought patterns, i.e., "You can't solve the problems created by our current pattern of thought using our current pattern of thought." Thus, this dissertation addresses how digital transformation may be formulated (understood) and addressed (choices made) when applying analytic and systems thinking. The implications of this inquiry on the nature of digital transformation in the healthcare industry generate two research questions (RQs):

RQ1: What are the similarities and differences in the formulation of the problems and opportunities of the digital transformation of the healthcare industry using analytic thinking and systems thinking?

RQ2: What are some possible interventions and choices to the challenges arising from the analytic and systemic conceptions of digital transformation of the healthcare industry?

I begin by reviewing the history of industrial revolutions, which inform the current reality of digital transformation.

First Industrial Revolution

The term "industrial revolution" appears to have been first recorded in a letter on July 6, 1799, by French envoy Louis-Guillaume Otto, announcing that France had entered the race to industrialize (Crouzet, 1996). The industrial revolution referring to technological changes subsequently became common and, over the next 40 years, appeared in many sources and countries. For example, Friedrich Engels (1844) wrote of "an industrial revolution, a revolution which at the same time changed the whole of civil society."

Six factors were considered important for industrialization and the emergence of the *First Industrial Revolution* (1IR) in Britain (Dean, 1973): (1) high levels of agricultural productivity to provide excess manpower and food; (2) a pool of managerial and entrepreneurial skills; (3) available ports, rivers, canals, and roads to cheaply move raw materials and outputs; (4) natural resources such as coal, iron, and waterfalls; (5) political stability and a legal system that supported business; and (6) financial capital available to invest.

Britain industrialized in the 18th century and then exported the process to western Europe (especially Belgium, France, and the German states) in the early 19th century. The United States copied the British model in the early 19th century, and Japan copied the Western European models in the late 19th century (Dean, 1973).

Second Industrial Revolution

The period 1870 – 1914 is often called the *Second Industrial Revolution* (2IR) because of the large number of new technologies invented during this period. For instance, the invention and evolution of general-purpose technologies, such as electricity and the internal combustion

engine, were driving forces for the fundamental changes in production, economies, and societies (Taalbi, 2019).

Although 2IR is a direct continuation of 1IR, for many industries, it differs in many crucial aspects (Mokyr, 1990; 1998). First, 2IR had a significant impact on real wages and standards of living (Mokyr, 1998a). For example, it extended the rather limited and localized successes of the first to a much broader range of activities and products available to the middle and working classes (Mokyr, 1998a). Many people's daily life was changed by the advent of new transportation and communication technologies and the invention of medicine and medical instruments. 2IR had created a rural to an urban society in the U.S. The U.S. economy was subsequently affected by the development of the steel and oil industry.

On the other hand, industrialization created dissatisfaction due to low wages, dangerous working conditions, and long working hours (Mohajan, 2020)., Further, the geographical focus of the technological leadership of 2IR shifted away from Britain to the U.S. and other Western countries. Some argue that the American Industrial Revolution can be considered a geographic extension of 2IR (Mohajan, 2020).

The development of 2IR accelerated the mutual feedback between two major forms of knowledge: science and technology (Mokyr, 1998a). Mokyr (1998b) distinguished science and technology by defining science as "knowledge which seeks to catalog and explain natural phenomena and regularities" and technology as a "huge compilation of recipes, instructions, blueprints, and do-loops which constitute the totality of the techniques available to society." These two forms of knowledge are related in the sense that useful natural knowledge can map into novel techniques, which in turn provides better instruments with which better produce natural knowledge. The steady accumulation of useful knowledge had led to persistent and acceleration of technological progress in 2IR, compared to little and no scientific bases for most technological development in the first (Mokyr, 1998a).

The second Industrial revolution also significantly changed the nature of the organization of production. The growth of some manufacturing industries, such as steel, chemicals, and oil refineries greatly benefited from economies of scale and throughput, a term used to describe economic speed (Chandler, 1990; 1992; Mathew and Carroll, 1993). 2IR led to the rise of large, vertically integrated, bureaucratic firms, which did not exist first. New production technologies,

such as mass production with interchangeable parts, also contributed to the economies of scale and called for fundamental organizational changes in managing and coordinating increasingly complex production among different factories or different industries. Consequently, improved production technology gave rise to interdependent technological systems. Even though some of these systems (such as railroad and telegraph) existed earlier, 2IR made these large technical systems commonplace through a relatively higher level of coordination from governments and leading institutions (e.g., industry standards such as railroad gauges and electricity voltages) than that free markets can supply. "The notion that technology consisted of separate components that could be optimized individually became less and less appropriate after 1870" (Mokyr, 1998a, p2).

Third Industrial Revolution

The *Third Industrial Revolution* (3IR) is usually considered to have occurred in the second half of the 20th century. The term *Third Industrial Revolution* became popularized after Jeremy Rifkin's book of the same name was published in 2011 (Rifkin, 2011). Technological revolutions are mainly driven by information and communication technologies (ICT). Major development blocks of the third industrial revolution include factory automation, telecommunications, and biotechnology (Taalbi, 2019).

3IR differs from the previous two in several ways. First, underdeveloped countries, such as China, played important roles in 3IR, especially in the first two decades of the 21st century. For example, China and the U.S. take leading roles in the digital economy with giant technological firms that are comparable to each other (i.e., Facebook vs. Weibo, Amazon vs. Taobao), whereas the countries in other industrialized Western countries seem to be less advantageous positions This catch-up could result in major shifts in economic and political powers in the long run.

Second, the information and communication characteristics of 3IR have revolutionized the production system. Although there continues to be a lag between productivity and technological innovations (David, 1990), one outcome has been the birth of digital transformation which is generally viewed as a positive force (Hodson, 2018). Novel technologies, such as clever software, novel materials, more dexterous robots, new processes

(notably three-dimensional printing), and a whole range of web-based services, will shift the factory's focus from mass production to mass customization (Economist, 2012).

Digitalization has also changed nearly every aspect of organizational and business practices. For instance, computer algorithms play increasingly important roles in decision-making (Colson, 2019). Automation and smart production may change some jobs and corresponding responsibilities within an organization permanently (Segal, 2018).

Third, ICT as a disruptive force has revolutionized the economy and developed to become crucial to people's daily life and the functioning of society. For example, as the internet and smartphones become available to more people, more consumption and communications are made through digital channels. A growing proportion of global culture emerges online. More knowledge is produced and shared in the digital world. Moreover, digitizing government offers the opportunity to ease the pain of citizens who encounter the variability of human bureaucracy and help cut costs by making the provision of government services more efficient (Savage, 2018). In short, the digital revolution fueled by 3IR is remaking the world at an unprecedented speed and without the endgame in sight.

Fourth Industrial Revolution

Developed and emerging societies are now in the *Fourth Industrial Revolution* (referred to as 4IR or Industry 4.0) , a term coined and popularized by Klaus Schwab (Schwab, 2015; 2016), Founder and Executive Chairman of the World Economic Forum (WEF).[2] Industry 4.0 has received increasing attention from academia (Piccarozzi et al., 2018; Sony & Naike, 2019; Sony, 2020) and practitioners (Deloitte, 2020).

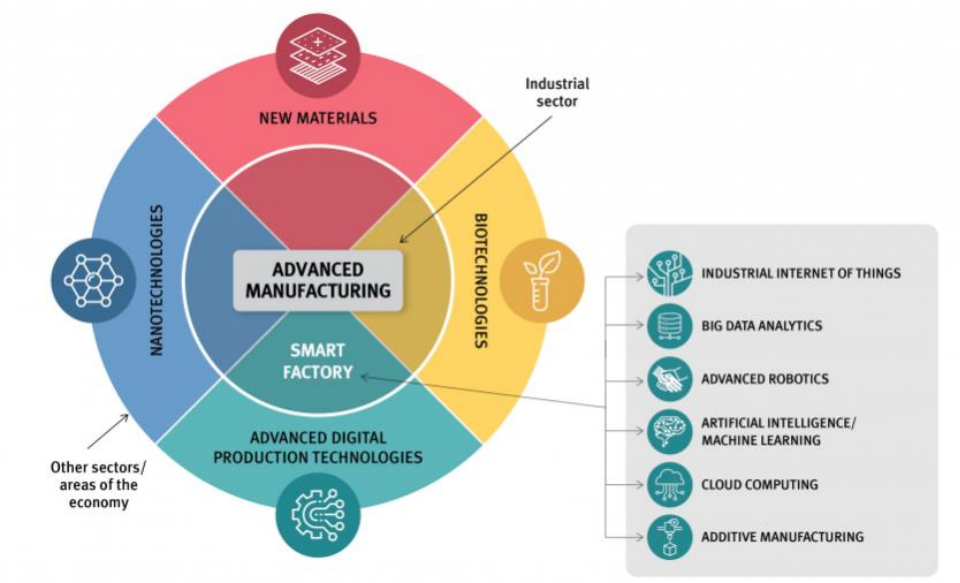
Schwab (2015) defines 4IR as "the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres." He argues that the fourth revolution, built on the third (that uses electronics and information technology to automate production), is distinct

[2] Note the term Industry 4.0 was initially proposed in a German government project which refers to the computerization of manufacturing. https://www.bmbf.de/bmbf/de/forschung/digitale-wirtschaft-und-gesellschaft/industrie-4-0/industrie-4-0 Today, the two terms, the Fourth Industrial Revolution and Industry 4.0, are often used interchangeably.

because of its velocity, scope, and systems impact. For example, 4IR is evolving at an exponential rather than a linear speed, and the speed of breakthroughs is unprecedented. Moreover, the effects of transformations are disruptive rather than gradual. The breadth and depth of these changes are transforming the entire systems of production, management, and governance. These transformational outcomes were not evident in the previous three industrial revolutions.

There is no unified definition of Industry 4.0. Davis (2016) defines 4IR as "the advent of 'cyber-physical systems' involving entirely new capabilities for people and machines." These include, for example, new forms of machine intelligence and breakthrough approaches to governance that rely on cryptographic methods such as the blockchain. Because Industry 4.0 has a very complex system of architecture for manufacturing, Lavopa and Delera (2021) define 4IR as "the convergence and complementarity of emerging technology domains, including nanotechnology, biotechnology, new materials, and advanced digital production (ADP) technologies." Figure 2 from UNIDO (United Nations Industrial Development Organization) shows that incorporating ADP technologies (e.g., industrial internet of things, big data analytics, advanced robotics, and artificial intelligence) into industrial production processes will give rise to the Smart Factory that learns as it works, continuously adapting and optimizing its own processes accordingly (Lavopa & Delera, 2021).

Figure 2:. UNIDO classification of 4IR (Industrial Development Report, 2020)



Piccarozzi et al. (2018, p.16) provide a more comprehensive definition: Industry 4.0 refers to the integration of Internet of Things technologies into industrial value creation, enabling manufacturers to harness entirely digitized, connected, smart, and decentralized value chains able to deliver greater flexibility and robustness to firm competitiveness and enable them to build flexible and adaptable business structures, [acquiring] the permanent ability for internal evolutionary developments in order to cope with a changing business environment as the result of a purposely formulated strategy implemented over time.

Sony (2020) conducted a comprehensive review of the strengths and weaknesses of Industry 4.0 for organizations (Table 1). The positive characteristics include (1) strategic competitive advantages created by new production process, smart products - new products that integrate IT, and the shift from product-centric to service-centric organization; (2) new technologies will enable organizations to develop the capability to appropriate, adapt, and integrate both internal and external resources through vertical and horizontal integration (i.e., efficiency) and thus to better achieve its goals (i.e., effectiveness); (3) new technologies may allow organizations to respond to external changes and manage uncertainties more quickly (quickness) in a more innovative way (innovativeness), which are two key aspects of organizational agility; (4) smart factory that is flexible, adapting, and continuously optimizing will be suitable to new product introduction; (5) the new architectures under Industry 4.0 that integrate intelligence in the production process may increase the short-run and long-run profitability through cost reduction and productivity growth; (6) new information technologies, such as automation, computing power and data analytics, will allow organizations to gather and process information about products and services. They can respond more timely and effectively to improve the quality of products, to better manage customers' expectations, and improve internal operation; (7) Industry 4.0 may better assist organizations in achieving environmental and social goals through energy efficiency, reduction of greenhouse gas emission, and enhancing the work-life quality for employees.

Table 1: Strengths and Weaknesses of Industry 4.0 (Sony, 2020)

	Strengths	Weaknesses
1	Strategic competitive advantage	The negative impact of data sharing in a competitive environment

2	Organizational efficiency & effectiveness	Total implementation of industry 4.0 is necessary for success
3	Organization agility	Handling employees' and trade unions' apprehensions
4	Manufacturing innovation	Need for highly skilled labor
5	Profitability	Socio-technical implications of industry 4.0
6	Improved product safety & quality	Cybersecurity
7	Delightful customer experience	High initial cost
8	Improved operations	
9	Environmental and social benefits	

The wide adoption of new information technologies has also raised concerns. These challenges include (1) privacy concerns due to collecting and sharing an enormous amount of personal data; (2) the architecture of Industry 4.0 is much more complicated, and the success hinges on the total implementation; (3) implementation of Industry 4.0 will require the restructuring of production process and organization and the reconfiguration of human labor, which may lead to the tensions among employees. (4) implementation of Industry 4.0 may also create new socio-technical problems, such as income disparity, rise in monopolization of tech firms, and technological unemployment due to higher requirements for labor. Moreover, the proliferation of the Internet and other web-based technologies may create new risks, such as cyber risks. (5) there is a high initial cost to implement Industry 4.0. In short, like other revolutions in history, the *Fourth Industrial Revolution* brings positive and negative impacts on the economy and society. Organizations must thrive by maximizing the benefits and minimizing the costs in the digital era.

Digital Transformation

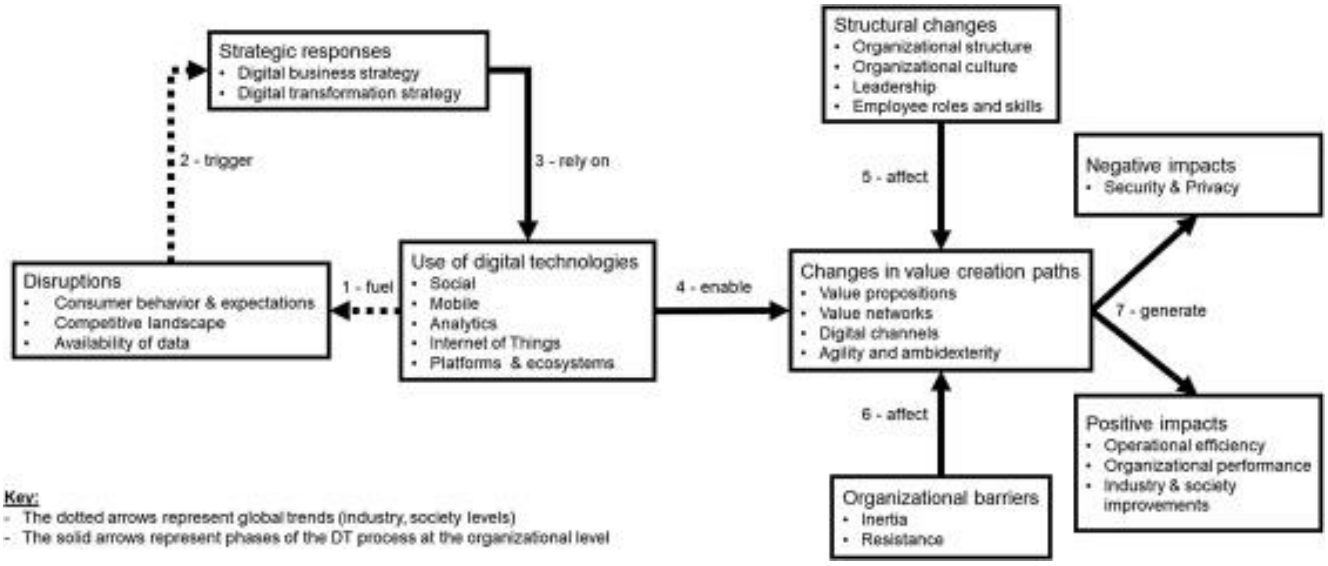
New digital technologies in 4IR are transforming society as a whole, which is facing fast and disruptive changes due to ubiquitous penetration into all industries and their impacts on nearly every aspect of individual life. For example, the advent of social networks (e.g., *Facebook* and *TikToc*) and the proliferation of mobile phones have fundamentally changed the way that people connect and communicate with each other personally and professionally. They have also changed the way through which organizations communicate with their customers and brand their products and services. In the academic and practice literature, these digital technology-enabled

transformations are usually called digitalization, digitization, or digital transformation. Increasingly, researchers use digital transformation (DT) to describe these revolutionary changes which exist at different levels of our society.

There is no unified definition of DT. For example, Vial (2019) reviewed 23 definitions of DT in extant literature which differ in the type of technologies and the nature of the transformation taking place. For example, Reis et al. (2018) define DT as "the use of new digital technologies that enable major business improvements and influences all aspects of customers' life (Reis et al., 2018, p.418)". This definition is based on three distinct elements of DT: (1) technological, i.e., DT is based on the use of new digital technologies; (2) organizational, i.e., DT requires a change of existing organizational process or creation of a new business model; (3) social, i.e., DT is a phenomenon that is influencing all aspects of human life (e.g., enhancing customer experience) (Reis et al., 2018).

Vial (2019) defines DT as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies (p.121)." Moreover, Vial (2019) proposes an inductive framework of DT with eight building blocks: (1) digital technologies; (2) disruptions; (3) strategic responses; (4) value creation path; (5) structural change; (6) barrier; (7) positive impact; (8) undesirable outcomes (Figure 3). That is, DT is conceived as a process where digital technologies drive the creation and the reinforcement of disruptions taking place at the society and industry levels. These disruptions trigger organizations' strategic responses, including the adoption of digital technologies to alter or recreate their value creation paths. To that end, organizations implement structural changes and overcome barriers that hinder their transformation efforts. These changes can lead to both positive impacts and undesirable outcomes for organizations as well as for individuals and society.

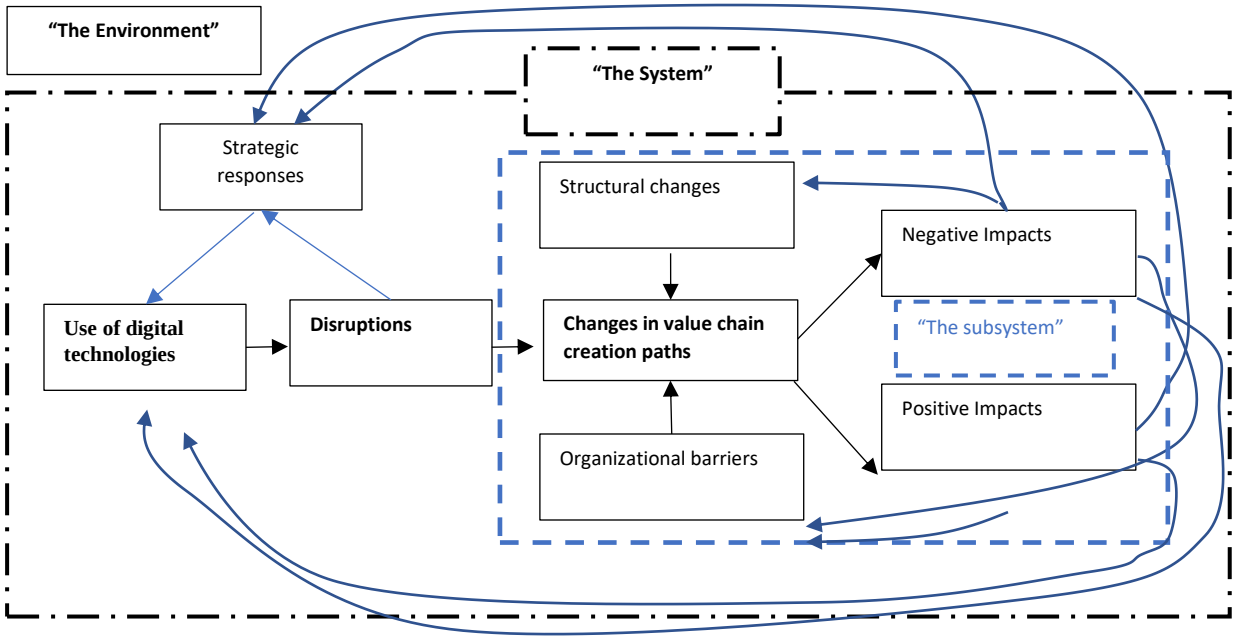
Figure 3: Digital Transformation Framework (Vial, 2019, p.122)

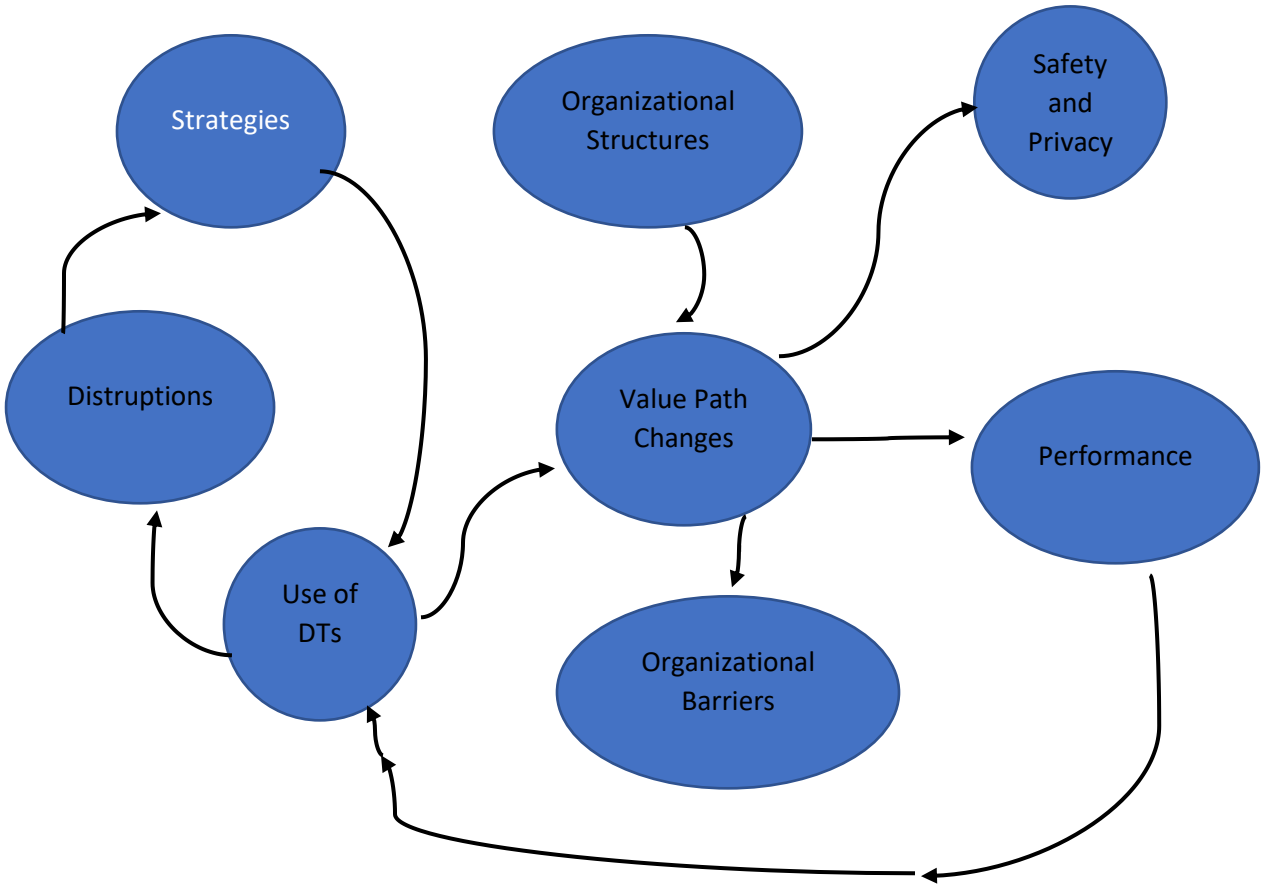


System influences of digital transformation

Figure 4 presents the same elements of DT but shifts the perspective from a primarily linear to a non-linear sequence by adding interdependencies and multiple feedback loops. Gharajedaghi (2011) noted that organizational systems may be characterized by their dynamic behavior, multiple feedback loops, and interdependencies. I argue that DT will result in fundamental changes to our society as a whole (or Big-Systems changes), specifically, political, economic, and social structures. The changes occurring inside these sub-systems are interrelated. One example is the advent of social media, which has changed the way people communicate within and across sectors of society. Social media influences the power dynamics between conventional and digital media, which gives individuals more influence and has reshaped strategy within the advertising industry. This shift in the framework is important to appreciate that organizational adjustments aimed at adapting to a digital environment are not simple or linear; rather, they take place in an unstructured and unordered context. That is, organizations and industries may be understood as complex adaptive and complex evolving systems which undergo systems transformations. Enterprises do not merely "adapt" to changing conditions in order to function and survive. They evolve and transform into new, unpredictable, and novel enterprises which change the context in which they function (Jackson, 2019).

Figure 4: Two versions of a system-informed digital transformation framework





The negative and positive impact that results from the use of digital technologies will motivate organizations to adopt new technologies that generate the most value for consumers and organizations. This perspective argues for changes in stakeholders' strategic responses. For example, negative impacts, such as privacy and ethical issues associated with the use of digital technologies (such as artificial intelligence and Big Data analytics), have already aroused concerns from the government and society. Governments and industry regulators have enacted a variety of standards to safeguard data privacy and assure the fairness of automated decision-making processes powered by AI. The strategic responses of stakeholders will determine how new technologies are deployed, hence driving the dynamics of disruption and the subsequent creation of value chains.

Given the complex interrelated nature of social and organizational systems with embedded reinforcing loops, the structural perspective of DT becomes important. This approach suggests that interactions will create disruptions and prompt strategic responses from stakeholders. Digital transformation will affect the health care value chain unevenly. More importantly, the changes to the health care value chain are interdependent. There will be feedback loops among the value chain components. For example, digital touchpoints created by mobile phone apps, smart products for health care, and digital payment systems can effectively reduce the distance between purchasers, fiscal Intermediaries, and producers. Therefore, the development of services and products and related fiscal solutions to meet patients' needs will be more integrated.

Dissertation Contributions and Audience

This dissertation intends to make several contributions. First, I present one of the first comprehensive literature reviews of the extant literature on digital transformation in the healthcare industry. This includes using a systems perspective to address the complexity arising from the digital transformation of healthcare. The results of this can be valuable to academic researchers who are interested in interdisciplinary studies to examine technological-related changes in the healthcare industry.

This dissertation can also be valuable for business leaders who want to navigate the complicated and complex situations informed by digitalization. To support this topic and audience, research is presented that provides detailed discussions of the cost and benefits of

technology-related changes in the healthcare industry. This discussion shed light on the constraints and barriers to technology-related changes in healthcare industry which may also be valuable for policymakers.

Dissertation Structure

Chapter 1 presents the background and context of the digital transformation in healthcare within the Fourth Industrial Revolution as well as models that illustrate the critical elements and their inter-relationships. Chapter 2 presents a literature review of models and frameworks relevant to the digital transformation of healthcare. Chapter 3 presents pilot studies that offer a background for the core methodology of this dissertation which is to frame the general challenge in terms of analytic and systems thinking. Chapter 4 presents the methodology and the responses to the two research questions by drawing on the context, literature review and frameworks, and pilot studies. Chapter 5 provides the discussion of the results and implications of my findings to key stakeholders.

CHAPTER 2

LITERATURE REVIEW: HEALTHCARE MODELS AND FRAMEWORKS

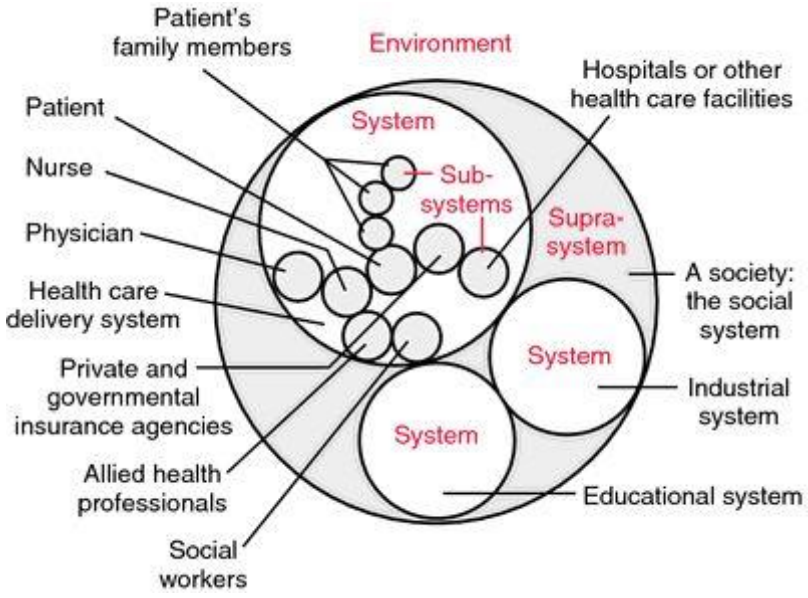
System Conceptions, Language, and Metaphors

The idea of a system, when applied to social and organizational enterprises, including the people within them, is a useful metaphor and framework for sense-making that has basic premises and assumptions. I adapt the definition in Ackoff (1999, p. 22); that is,

> A system is a whole defined by one or more functions and consists of two or more essential parts that satisfy the following conditions: (1) each of the parts can affect the behavior or properties of the whole; (2) none of the parts has an independent effect on the whole; the way an essential part affects the whole depends on what other parts are doing; and (3) every possible subset of the essential parts can affect the behavior or properties of the whole, but none can do so independently of the others.

This conception of a system includes internal subsystems and external containing (or supra) systems which can be industries (e.g., healthcare industries) and organizations (e.g., healthcare firms) operating in an environmental context that influence the essential properties and unique functions of the system through value-creation activities (Figure 5).

Figure 5: Healthcare system (Starr, 2018)



Subsystems may refer to individual healthcare firms at the granular level (e.g., deterministic systems as defined in Ackoff, 1999) and may also describe other stakeholders that are related to the value-chain. A system may also refer to a broad eco-system that co-produces through interactions among elements and subsystems unique functions (e.g., healthcare services) to society as a whole as suggested in Figure 6 by Visconti (2020) and Figure 7 by Shaw (2020).

Figure 6: Healthcare ecosystem (Visconti, 2020)

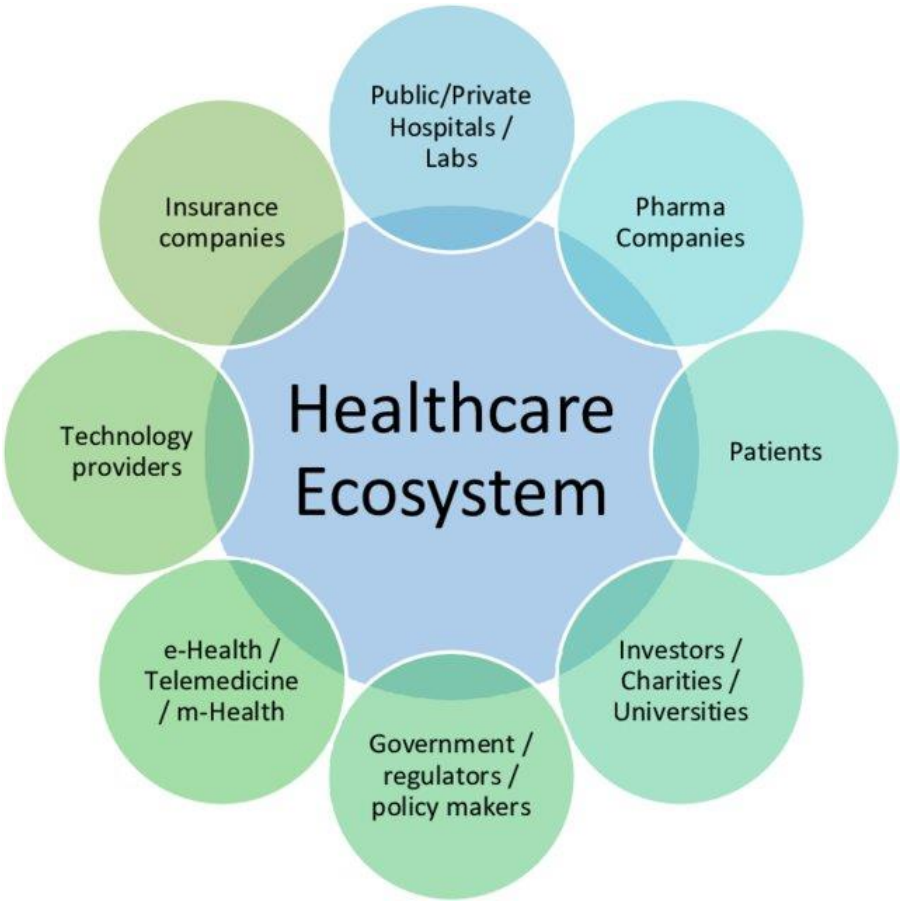


Figure 7: Healthcare ecosystem (Shaw 2020)

Transformation may begin at the organization-level (or the deterministic system) triggered by the disruptions. Ackoff (1999) argues "a system is transformed when the type of system it is thought to be is changed." Here the change of organization (or the deterministic system) can be due to (1) change of value it aims to create or (2) change in the ways to create value because of technical feasibility and/or operational viability. Ackoff (2004) further argues that transformation not only requires recognition of the difference between objective practiced and objective proclaimed but also requires "a transformation in the way we think." That is the shift from analytic to holistic and synthetic thinking that allows deriving properties of parts from properties of the whole.

Disruptions

Disruptions within functions and processes of current situations, not (only) new technology, will define the new status quo and hence the value (to consumers or society) and activities that will be entrenched in a value chain to generate that value most effectively and efficiently.

Stakeholder Reactions

Stakeholders will also affect the pathways that the value chain creates. That is, the establishment of new value chains or reorganization of current value chains will not be governed only by the economic evaluation framework (e.g., profitability and efficiency). Rather than that, it will be defined by legality and compliance (as established by the political system), as well as justice and fairness (determined by the civil society).

Positive and negative reinforcing loops

Negative impacts and positive impacts in Vial (2019) should not be the end of the organizational transformation. Instead, these negative and positive impacts will, at least, affect the use of digital technologies as well as the strategic responses from stakeholders.

Healthcare System

From the perspective of systems thinking, the healthcare industry is an inseparable part of modern society, which determines life quality and social well-being. For example, in its constitution, the World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 2020). Different countries employ different health care systems consisting of organizations, people, and resources to deliver health care to individuals and their communities.

Broadly speaking, a health care system includes a broad community of stakeholders (see Figure 5), including but not limited to public health services and the private health sector. Public health services, usually controlled by the government, focus on strengthening the capacities that provide conditions under which individuals can maintain and improve their health and well-being. The private health sector differs from public health services in at least two aspects: ownership and motivation. In terms of ownership, the private health sector is usually owned by individuals and organizations. In terms of motivation, the private health sector can be philanthropic or commercial and comprises for-profit and not-for-profit entities. There is not common definition for the private health sector. This creates some difficulties in clearly defining the coverage and the scope of the private health sector. But in general, the private health sector consists of stakeholders connected to the health service delivery to individuals, including hospitals, clinics, pharmacies, and health insurance providers.

WHO (2010) suggests that a well-functioning health system that meets individuals' needs and expectations shall include the following key components: (1) leadership and governance that ensures the health authority's responsibilities and defines the health policies, strategy, and plan; (2) health information system that provides timely intelligence on key aspects such as health challenges, trends, and needs, access to care and quality of service; (3) health financing; (4) human resources for health; (5) essential medical products and technologies; (6) service delivery.

Digital technologies have greatly transformed the functions of the key components of the health system. For example, the information technologies (such as the Internet and mobile communication system) have changed the way health-related information is collected, stored, shared, and analyzed by the stakeholders of the health system. Moreover, digital technologies have revolutionized medical products and technologies and the way of service delivery, leading to the concept of e-health and digital health. Finally, the broad adoption of new information-based products (e.g., wearables and mobile phone applications related to health) allows individuals to gain more access to a broad spectrum of health services and information, develop new needs for health servces and empowers individuals to participate in both personal and public health-related issues.

Value and Value Chain for Healthcare

The term value can have many definitions and interpretations depending on the context. For industries and businesses with the objective to satisfy customers' needs, it seems natural to define value around the customer. A commonly perceived value strategy is to coordinate the processes that lead to "customer" satisfaction. Value for health of satisfying care can be defined in a similar way. Porter (2010) suggests that value shall always be defined around the customer, and the value creation for patients shall determine the rewards for all actors in the system. More importantly, the value of health care shall be defined based on outcomes rather than the volume of service or the process of care used (Porter, 2010). Since outcome for health care is conditional-specific and multi-dimensional, the value for healthcare possesses some similar characteristics:

Value for healthcare is a combined effect involving the participation and contributions from various actors in the system. This property requires that the definition and measurement of value of care shall consider interests and accountabilities of all actors involved. Value for

healthcare can also differ for different groups of customers. For example, the value defined for primary care will differ from that defined for preventive care because different bundles of primary and preventive care will be applied

Value for patients can often be revealed over time because care activities are interrelated, and the outcomes, such as sustainable recovery and the need for further treatment, can only be manifested in the long term. This property requires accurately tracking the patients' outcome over time.

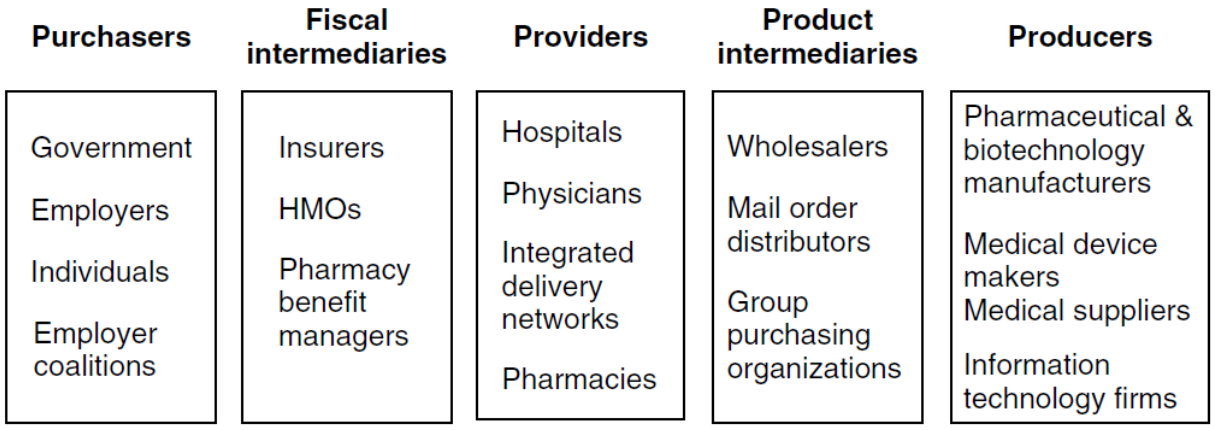
Value delivery comprises all activities involved in delivering product-service that are considered necessary to create customer satisfaction and maintain a long-term relationship with customers (Walter & Jones, 2001). A basic framework to analyze the value delivery is through value chain which identifies the structure and organization of value chain components. A value chain is a means by which business activities that transform inputs could be identified and analyzed (Porter, 1985). Different from supply chain thinking focusing on the sequences from inputs to final customers, the concept of value chain takes a reverse approach by identifying customers' needs and working backward through the process and infrastructure that will best satisfy these needs.

Value chain can be applied to organizations to explore the interrelationship and common characteristics that can be used to identify opportunities for cost reduction and product differentiation. A value chain can also be defined at a broad level. For example, value chain of the industry allows one to disaggregate a business into strategically relevant activities. And its value chain is part of a larger stream of activities carried out by other members of the channel suppliers, distributors and customers.

Burns (2002) provides a US health care value chain, a linear sequence that consists of two sets of intermediaries and three sets of key players (Figure 8). The three key sets of actors are the individuals and institutions that purchase healthcare, provide healthcare services, and produce healthcare products (purchasers, providers, and producers). Two sets of intermediaries separate these key actors: those firms that finance healthcare (offer insurance to the purchasers and handle reimbursement to the providers) and those who distribute products (from the producers to the providers). One underlying logic to the structure of this value chain is the flow of funds and the flow of innovation. That is, the fund flows from the left (purchasers) to the right

(producers), and the innovation flows from the right (producers) to the left (purchasers). And the two flows collide in the middle (provider) where the providers (e.g., hospitals and doctors) will decide what kind of innovations from the producers they will utilize depending on the limited funds they receive from the left.

Figure 8: The U.S. Healthcare Value Chain (Burns, 2002)



The Affordable Care Act (ACA) in 2010 aimed to shift the focus of the US health system to value-based health care through testing new models of health care delivery, shifting from reimbursement based on the volume of services provided to the one based on the value of care, and investing in systemwide improvements (Abrams, et al., 2015). Value-based healthcare is a healthcare delivery framework that incentivizes healthcare providers to focus on the quality of services rendered, as opposed to the quantity (CMS; Abrams et al., 2020). For example, the Hospital Value-Based Purchasing (VBP) Program rewards acute care hospitals with incentive payments for the quality of care in the inpatient hospital setting. Hospitals are scored on measures such as mortality and complications, healthcare-associated infections, patient safety, patient experience, and efficiency and cost reduction. Hospitals will be rewarded based on final scores that reflect how they perform compared with all other hospitals and how they improved over time (CAM,2020). Thus, the "value" in value-based healthcare is derived from measuring health outcomes against the cost of delivering the outcomes.

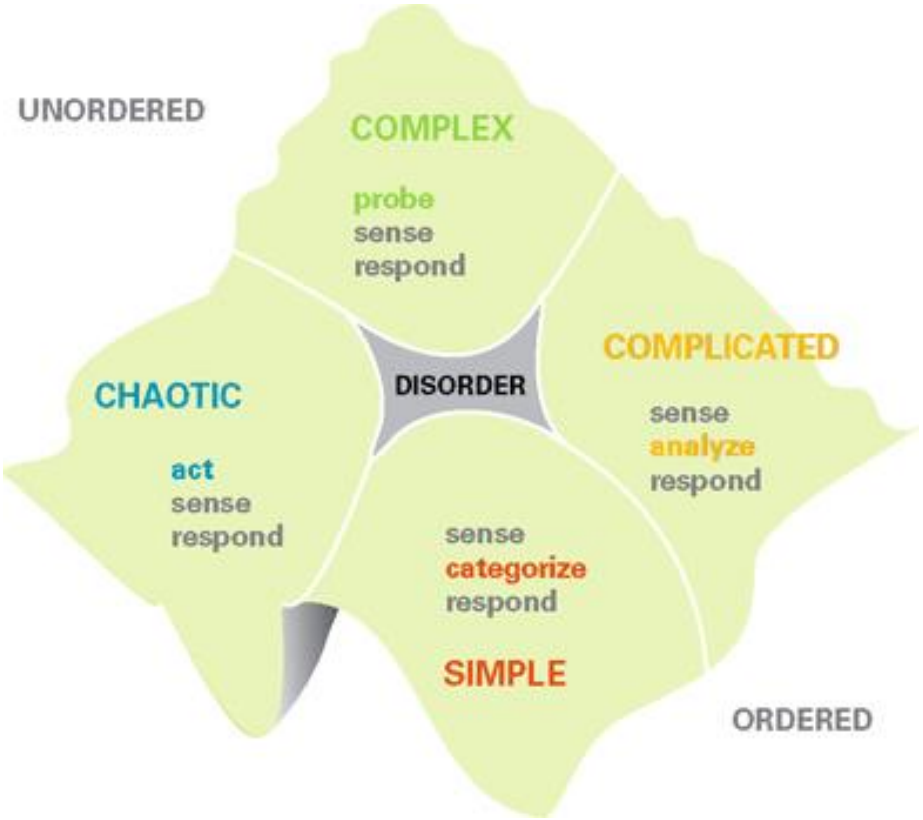
Healthcare value chain is a convenient way to describe the process and major stakeholders that play key roles in deliver services and create value for customers. However, the healthcare value-chain does not imply that the value creation process is conducted in a linear

fashion. Neither does it implies that the interactions among major stakeholders are linear. Rather the healthcare value chain describes the "status quo" of a complex value creation process with connected key stakeholders and complicated business processes.

Context of the Healthcare System

Snowden and Boone (2007) proposed a framework for decision making under different contexts or situations which they describe using the Welsh word *Cynefin* (pronounced kuh-nev-in) which roughly translates as a *domain*. This framework distinguishes five operative contexts based on the nature of the underlying cause-and-effect relationships (Figure 9).

Figure 9: Cynefin Framework (Snowden & Boone, 2007)



Simple (i.e., the realm of "known knowns") and complicated contexts (i.e., the realm of "known unknows") assume an ordered and structured environment where there are perceivable and understandable cause-and-effect relationships. Complex (the realm of "unknown unknowns") and chaotic contexts assume unordered and unstructured situations in which there

are no apparent cause-and-effect relationships and no understanding or experts. The fifth context is disorder which applies to the situation which is hard to be described in the previous four contexts. The framework suggests that leaders can make decisions based on aligning the method of problem formulation and method of problem-solving to the problem's context. That is, an analytic and evidence-based approach can be applied to ordered simple and complicated contexts, and a system (and patterns) and design-based approach can be applied to unordered complex and chaotic contexts. Indeed, Jackson (2019) noted that the only appropriate approach to addressing problems in a complex context is systems thinking.

This framework may be appropriate for understanding and addressing challenges within the digital transformation of the healthcare ecosystem. As noted by Snowdon and Boone (2007), applying the appropriate decision-making strategy first requires discerning the context (domain) in which a problem exists then formulating the problem with the appropriate premises and assumptions. I argue the healthcare ecosystem is in the domain of complexity.

Discerning Healthcare's Contextual Complexity

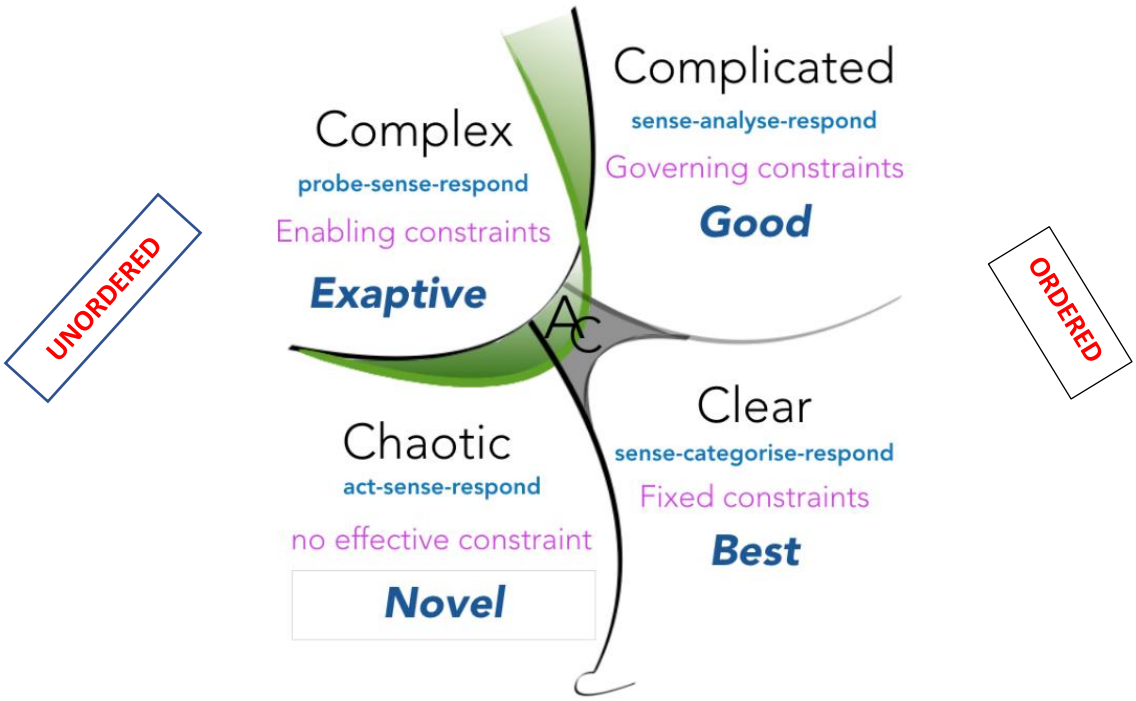
Snowdon and Boone (2007) and Snowdon et al (2021) noted that contexts in which problems and opportunities exist may be ordered and unordered. With the ordered context are challenges that are simple and complicated. With the unordered context are those that are complex and chaotic. To discern the differences, one may examine the cause-effect relationship and the constraints under which choices may be made. They further suggest that in complex and chaotic contexts, the relationships between cause, effect and constraints make it impossible to predict outcomes and for which there are no experts Rather, effective outcomes emerge by small experiments (trial-and-error "probes") and generation of novel reasoning (abductive, "what if?") rather than by analytic problem-solving methods such as by evidence-based science or use of best practices.

Words, complex and complexity have many meanings. For example, *Merriam-Webster* dictionary defines the work "complex" as "a whole made up of complicated or interrelated parts." This definition suggests that any system with interdependent components would have a certain level of complexity. This supports the many theoretical frameworks that approach complexity from different perspectives that have been proposed. For example, Stacey (1996) who applies a human social perspective proposed an agreement – certainty matrix to handle

change. Complexity will arise when either a situation is far from certainty or agreement among stakeholders of a problematic situation.

The Cynefin framework proposed by Snowdon and Boone (2007) and updated by Snowdon (2020) sorts the contexts of decision-making into broad contexts within which are five domains based on cause and effect. (Figure 10)

Figure 10: Updated Cynefin Framework (Snowdon, 2020)



When the overall context is reasonably well-structured and ordered, problems are referred to as simple and clear or complicated. When the overall context is poorly structured and unordered, problems are complex or chaotic. When the context does not fit these broad categories, it may be classified as disorder.

Some of the details of this framework include that simple contexts have clear and obvious cause and effect relationships, repeating patterns, fixed constraints, and consistent events and may be solved using best practices. Complicated contexts have cause and effect relationships that may not be apparent so expert diagnosis is required and good practices for solving may be applied.

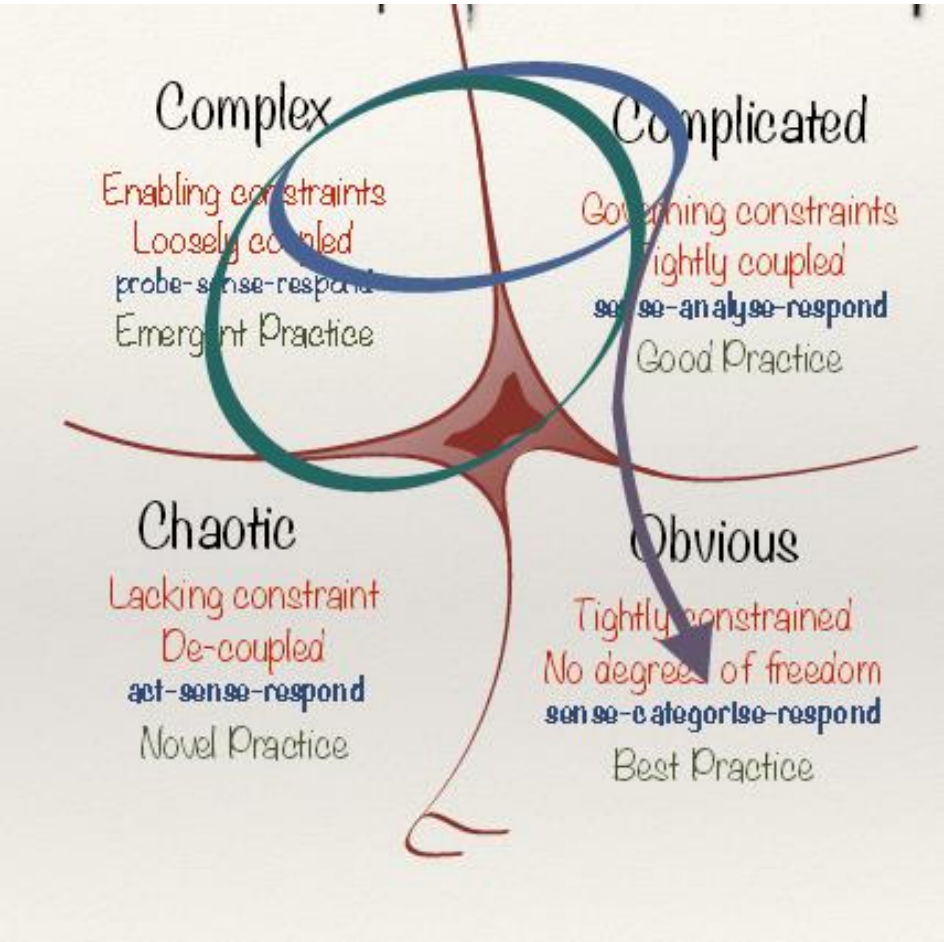
When a problem is complex, there is unpredictability, nonlinearity, competing perceptions and ideas, and no objectively right answers or experts. Solutions in such contexts are referred to as "exaptive" defined as "focused on radical re-purposing of existing capability often through processes that emerge due to the interactions among elements and parts. (Snowden, et. al., 2021, p. 60). When problems are chaotic, there is no clear cause and effect relationships, no discernible patterns, and high turbulence. To discover solutions in the chaotic domain, the approach is to seek methodologies that enable novel practice. (Snowden, D., Greenberg, R., & Bertsch, B. (2021). *Cynefin® weaving sense-making into the fabric of our world*. Singapore: Cognitive Edge - The Cynefin Co.)

The digitalization of health care is a complex process because it possesses the following properties: First, it involves a large number of interacting and inter-dependent elements including stakeholders and business processes among them. Second, the interactions are often nonlinear, and the outcomes are usually unpredictable e.g., whether and how the digital transformation (DT) will facilitate the transition to a value-based healthcare system is unclear. DT is a catalyst that not only triggers changes to the components of the healthcare value chain but can also revolutionize the value chain entirely. However, it can be very hard to predict which digital technology or which business model will revolutionize the operation of a particular value chain component, quantify the impacts caused by DT and foresee the outcomes of the digitalization of healthcare value chain. Third, the system is dynamic, and solutions can only arise from the interactions among circumstances (referred to as emergence) rather than be imposed. Fourth, the healthcare ecosystem has a long history (e.g., Medicare and Medicaid programs), and the past is integrated with the present; the elements evolve with one another and with the environment; and the evolution is irreversible. These characteristics argue that the healthcare ecosystem may be appropriately described as a complex evolving system.

However, DT will not affect the health care system evenly and not all changes produced by DT will occur suddenly in an unpredictable manner. For example, some components of the healthcare value chain (such as healthcare providers, and healthcare insurance firms) may be referred to as complicated because they are heavily regulated by various laws and regulations. The existence of laws and regulations can reduce the intensity of market competition and therefore potentially slow the changes caused by DT. More importantly, changes in laws and regulations must go through a time-consuming legislative process which can often take years if not decades to complete. These complicated properties suggest that some changes induced by DT

will happen gradually rather than unexpectedly. Furthermore, the existence of laws and regulations can also further limit the direction of change. That is, changes from DT could be path-dependent meaning that the adoption of digital technologies and business models may be dependent on compliance with the existing laws and regulations which is less unpredictable. In short, the above-discussed properties of the healthcare industry and its value chain components suggest that certain problems related to the digitalization of healthcare could be both complicated and complex some of which have apparent cause and effect relationships and some of which are not predictable. This may be diagrammed by Figure 11 which suggests that contexts are not "either-or" but may overlap and change for some kinds of problems. The image also reflects that as a problem is dynamic and as it is being addressed, complexity may shift into a complicated domain and possibly into an obvious/simple domain where a solution may be determined readily for some elements.

Figure 11: Shifting and overlapping problem contexts (cynefin as of 2014)



Applying the Cynefin framework, the approaches to analyzing DT and its impacts on the healthcare industry should align with the requirement of the context. To approach a complicated problem, the Cynefin framework suggests that one can rely on sensing, analyzing, and responding. In particular, expert diagnosis and intervention may be required for a complicated problem. However, if one has access to a panel of experts who offer conflicting advice, it may become apparent that the problem is better framed as complex. If expert advice is consistent that a particular best or good practice is appropriate, then this argues for engaging in analysis of current practices and the short and intermediate trends of the healthcare industry which fall into the category of complicated problems.

To frame and decide about problems and opportunities of DT in the long-run and at the system level requires shifting to a different mindset. Instead of routinely and consistently applying analytic reductionism, focusing on finding a one-size-fits-all solution or predicting a

linear outcome of the digital revolution, it is appropriate to apply systems thinking and use methodologies and tools that are informed by this cognitive approach. Shifting from an analytic to a systems mindset is not easy; it means focusing on the process of the current evolution and observing the important patterns that are created by digitalization. This is important because seeking emergence, rather than problem-solving, is what leaders must do in a complex context. Moreover, Snowden and Boone (2007) suggest that leaders can adopt more experimental modes of management in the complex domain. For example, leaders can conduct experiments by setting barriers (e.g., simple rules) with which the system can self-regulate within boundaries, or stimulating attractors that can provide structure and coherence. These experiments can help to explore the potential boundaries and constraints from which changes may emerge.

There are many experiments/probes currently being conducted by key stakeholders of the healthcare ecosystem. For instance, telemedicine – between patients and health practitioners – became increasingly popular during the COVID-19 pandemic in response to demands for social distancing and lockdowns. How other healthcare stakeholders (e.g., government payers and insurance companies) cope with this trend by changing policies and regulations will determine the value of this delivery channel of healthcare over time.

There are some anticipated opportunities that are worthy of consideration. For example, digitalization has the potential to change the healthcare system by transforming one or more of the five core components in the existing value system in the short run or transforming the entire healthcare system in the long run. Table 3 summarizes the potential forms of digital transformations to the value chain components, i.e., purchaser, fiscal intermediaries, provider, product intermediaries, and producer.

Table 2: Impacts of Digital Transformation on the Value Chain Components

Value Chain Component	Forms of Digital Transformation	Implications and Interdependencies
Purchaser	Empowerment; new delivery methods;	Quality of care; reduced cost; improved quality of life
Fiscal Intermediaries	Payment methods – Electronic payment system; more flexible payment/financing plans	New Products and services; efficiency improvement; cost reduction
Providers	Measurement and record – electronic health record;	Innovations in internal processes that improve the

	Delivery – Telemedicine/eHealth; Analytical tools (BDA/AI/Cloud/IoT)	efficiency; innovations in the access and quality of care provided.
Product intermediaries	New delivery platform	Efficiency and robustness
Producers	Innovative products based on IoT, such as wearables and services such as mobile phone apps	New Products and services; efficiency improvement; cost reduction

Value Chain Components

Purchaser. Digitalization will empower individuals in health care by providing them with new methods of delivering care and care management products and services. In particular, the introduction of digital touchpoints such as smart devices, mobile phones, and applications, social media will enhance communications between individuals and other key actors in the value chain such as insurance companies, health product producers, and product intermediaries, and facilitate the innovations to satisfy individuals' needs for care. Another big purchaser, the government, will benefit through cost reduction and overall quality improvement of healthcare for citizens.

Fiscal financial intermediaries. Digitalization will, in general, improve the efficiency of their operations and allow them to provide new products or new payment methods to finance the cost of care. How have payment methods changed? Are there any novel/emergent processes?

Providers. Digitalization can revolutionize methods of delivering care. For example, eHealth and Telemedicine have become increasingly important because it enables care delivery without restrictions of geography. Moreover, advanced digital technologies such as cloud and the Internet of Things can further help providers record, store, and share critical information more efficiently. This will be beneficial for transitioning to a value-based care model which requires accurate and timely measures of practitioner methods and patient outcomes. Moreover, new technologies such as big data analytics and artificial intelligence can be used to improve the efficiencies in many decision-making processes involved in care delivery.

Product intermediaries. Digital technology will provide new platforms for distributing products and services and lead to a more robust supply chain. For example, digital platforms revolutionize the interaction between consumers and product intermediaries by allowing product intermediaries to provide 24/7 and seamless service to consumers.

Producers. Digital technology will transform the producers' value chain as it does other manufacturing industries. For example, a new business model can be created using digital platforms to cocreate goods and services, access new capabilities, enable wider customer reach and increase revenues (Gisby et al., 2022). The traditional pipeline model (e.g., manufacturing, delivery, sales, and marketing) that connects the relevant parties in value chain can be replaced by digital platforms which can better facilitate the exchange of information and data about goods and services between customers and producers.

Digitalization can offer opportunities to create a new value chain to meet patients' needs for care. According to the American Medical Association (AMA), there are five steps healthcare providers can take to prepare their practices for value-based care (Terrell, 2016): (1) Identify your patient population and opportunity; (2) Design the care model; (3) Partner for success; (4) Drive appropriate utilization; and (5) Quantify impacts and continuously improve.

Transforming or creating a new value chain using digital technologies must be done with proper thought and planning because there are time-related challenges and uncertainties associated with digital transformation of the U.S. healthcare value chain:

In the short-run, incentives for the providers and the health plans offered by the financial intermediaries may be needed to facilitate the transformation to a value-based healthcare system. It is uncertain which new digital technologies are ready for adoption and which will depend on many factors (Terry, 2020). For example, many providers will have to balance fee-for-service and value-based care to maintain revenue and profit. Digital technologies can help make the transition seamless with an increased cost associated with the investment in healthcare IT infrastructure and data analytics. Moreover, the purchaser, especially the government, can have an undue influence on the adoption of new technologies. For example, the coverage of telehealth under Medicare can make this technology-related change last even after the COVID-19 pandemic (Terry, 2022).

In the long-run, digital transformation will interact with many elements of the complex healthcare ecosystem. It is hard to predict where the material change will happen and what the broader impacts, e.g., first-order and second-order impacts, would be. In such a complex ecosystem, data from different places will provide insights for patients, providers, and the system (Terry, 2022). However, the flow and utilization of data may face challenges due to regulations.

Moreover, digital disparity could arise in a more technology-driven healthcare system with more specialized applications. Patients may not have equal access to healthcare due to a lack of internet access, digital literacy, or trust in the tech system.

CHAPTER 3

PILOT STUDIES

Importance of Pilot Studies

I conducted five pilot studies that are related to the challenges and opportunities of digital transformation of the health care industry from different perspectives. The first perspective provided by Pilot study 1 is from the navigation of changes caused by digital transformation with an appropriate leadership model that requires adaptation, learning and a systems thinking mindset. Second, health care provider is a key stakeholder of the health care ecosystem in the U.S. The evolution of the business model that can meet customers' expectations, and requirements of current regulations, and can be sustainable in the long run provides a unique lens to examine the interactions between care providers, regulators, and customers. Pilot study 2 investigates a community-based health care model. Third, digital transformation will affect every aspect of health care industry. Pilot study 3 provides a comprehensive review of the opportunity and costs caused by the adoption of digital technologies (Big Data) for the key stakeholders in the value chain of health care. Moreover, digital transformation can cause both conflicts with existing regulations and emerging issues that are not considered by current regulations. By applying a systems thinking framework, Pilot study 4 conducts a case study on navigating the complexity of the adoption of digital technology (i.e., digital contact tracing) in the COVID-19 pandemic era. Furthermore, Pilot study 5 addresses two emerging issues related to the wide usage of digital technology – data privacy and ethical artificial intelligence.

In pilot study 1 (Spring 2018), I investigated and compared the extant leadership models and examined the key attributes of a systems thinker and a reflective learner. Digital transformation requires a change of pattern of thought. It also demands leadership that is suitable for navigating the complexity arising from digital transformation.

In pilot study 2 (Spring 2019), I conducted a case study of community-based integrated healthcare. This study helps me to better understand the stakeholders in the health care industry, the value creation, and the improvement of services and goods provided from a provider's perspective.

In pilot study 3 (Spring 2020), I conducted a comprehensive review of Big Data and Health care. Due to an increasing number of studies on big data and its applications in health care industry, it is necessary to conduct a systematic review of the extant literature to better understand the long-term impacts brought by new digital technologies. I examined the key technologies and the opportunities and costs brought by these new technologies to the key stakeholders of the health care ecosystem.

In pilot study 4 (Fall 2020), I applied a systems thinking framework to the responses to the COVID-19 pandemic (i.e., digital contact tracing). This study is important because it provides a unique opportunity to examine the challenges imposed by existing legal and regulatory frameworks on the adoption of new digital technologies in public health. I also use the Complex Project Analysis for the adoption of Digital Contact Tracing as an example of using systems thinking to address these challenges.

In pilot study 5 (Winter 2020), I examined two emerging issues related to the usage of digital technologies in healthcare: data privacy and ethical issue related to artificial intelligence.

Pilot Study 1: Learn to be a systems thinker and reflective learner

The first course that I took for my doctorate journey was Strategic Leadership Foundations, Concepts, and Methodologies. This learning experience provided me an opportunity to systematically review, reflect and synthesize my past business experience related to China in a cross-cultural context from an academic perspective. At that time (i.e., 2018), I thought that a globalized business environment creates both opportunities and challenges for a new generation of business leaders in the east and west world. In particular, the business leaders in China need to gain a deeper understanding of the advanced theories about strategic leadership to embrace the global business world, develop new business models, and lead a diversified business team with members from around the world.

I systemically reviewed and compared major leadership models, such as transformational leadership, authentic leadership, followership and leadership, E-leadership, and adaptive and complexity leadership. Although different leadership models focus on different sets of traits, characteristics, knowledge, and skill sets of a leader, the core of leadership is about making decisions that can influence others. Moreover, leadership is an art that sometimes can be

comprehended. These elements of a leader have been repeated in many legends and stories for hundreds of years. Upon completion of this interview, I was wondering how western researchers would conceptualize and operationalize leadership. Bearing these questions in mind, I started the exploration. Leadership is a classic multi-dimension topic that has universal appeals but lacks universal consensus despite numerous studies having been conducted over centuries. For example, Rost (1991) found that more than two hundred definitions of leadership had been proposed in the literature between 1900 and 1990. Fleishman et al. (1991) found that 65 different classification systems have been developed to define the dimensions of leadership in the past sixty years. One definition highlights certain key dimensions of leadership, i.e., "leadership is a process whereby an individual influences a group of individuals to achieve a common goal." (Northouse, 2016, p.6)

Leadership involves influence, suggesting that the leader must be able to affect the follower (e.g., attitude, value, and behavior). Leadership does not exist without influence. In the literature, influence has been examined against other synonymous, such as power, coercion, and management. Power is the capacity or potential to influence and is therefore closely related to leadership. Power can be derived either from a position or a rank in a formal organization (i.e., position power) or a person's characteristics that are likable by followers known as personal power (Northouse, 2016). How a leader uses his/her power and the power dynamic between the leader and follower have been the focus of many studies. Leadership is not coercion which often relies on threats and punishments to achieve influence on others. Northouse (2016) argues that coercion cannot be considered leadership because it cannot help to achieve common goals. From a relationship perspective, coercion is not leadership because it is based on negative feedback that will make the relationship between the leader and followers non-sustainable in the long run. Lastly, leadership, as an independent discipline, cannot be considered management. The goal of management is to achieve order and stability; leadership is about seeking adaptive and constructive changes. (Northouse, 2016)

Leadership is a process, meaning that leadership shall not be considered as personal traits, and it can be acquired by individuals. This dimension highlights that leadership is not a trait that a leader is born with but rather a discipline or a function that any individual can perform

with proper training. Moreover, the process view suggests that leadership is an interaction between a leader and follower rather than a one-way process.

Leadership occurs in a group. Northouse (2016) argues that group is the context of leadership. However, this argument could be misleading to a certain extent because this definition of the context of leadership is too narrow. Leadership is about a leader's influence on the collective behavior of a group. Therefore, a group is a necessary condition or a scenario for leadership to take place. But collective behavior of a group can be affected by many factors known as the context or environment. When the context changes, the scenario of leadership or the group will change as well. For example, historically group was considered a formal organization. But the proliferation of modern information and communication technology has enabled more efficient communications (e.g., communication between a leader and followers) without limitation of distance. As a result, the boundaries of groups and the boundaries between the virtual and real world have blurred. This context change gave birth to some emergent leadership models such as E-leadership (Avolio, Kahai, & Dodge,2000; Avolio et al., 2014).

Similar to the conceptualization of leadership, the classification of the leadership models proposed in the literature is not an easy task. According to Merriam-Webster, a model can be defined as "an example for imitation or emulation." 3 Leadership models provide a series of prototypes that individuals can use to acquire knowledge, skills, and behavior to lead. Disagreements regarding the classification of numerous efforts in determining what "works" for leadership can easily arise because there are so many effective leaders who have different leadership styles. By focusing on the key dimension of leadership, Starr (2020) provides a succinct classification of prevailing themes of extant leadership models based on the idea of "leadership as influence." There are three types of influence (1) indirect influence (through heroic traits and leading ideas for which followers follow); (2) direct influence (through leadership traits, behaviors, styles, and skills, known as competencies that influence followers); (3) relational leadership (though leader-follower social processes in which needs and interests of followers are discussed). Typical leadership theories that fall into the relationship leadership

[3] Retrieved from https://www.merriam-webster.com/dictionary/model on March 8th 2021.

categories include the most discussed leadership theories such as path-goal, leader-member exchange, transactional, and transformational.

Another example of classifying the existing leadership models is the practice I undertook by comparing seven leadership theories: authentic, adaptive and complexity, leader-member exchange, servant, transformational, cross-cultural, and E-virtual. I rated each theory along seven dimensions. Table 1 provides a summary of rating results. In this comparison, I ranked cross-cultural leadership and adaptive and complexity leadership first and second place, respectively. Cross-cultural leadership requires a leader to acquire a set of competencies in an increasingly globalized business world. These competencies include (1) understanding, business, political, and cultural environments worldwide; (2) the perspective, trends, and technologies of many other cultures; (3) the ability to work with people from many cultures; (4) the ability to live and communicate in different cultures; (5) ability to relate to people from other cultures from a position of equality rather than cultural superiority (Adler & Bartholomew,1992). Culture is essential to leadership today because the group where the leadership takes place is becoming increasingly diverse. Followers from different countries are configured by their own culture and social norms that will change the context of leadership and influence process.

Furthermore, the drastic social and economic transformation may create culture gaps in the different demographic cohorts. One example is Bill Gross's "getting old" twit. [4] In October 2017, Bill Gross, a famous entrepreneur, and inventor tweeted a picture of a 3.5-inch floppy disk on Twitter.[5] A kid replied to him "oh. You 3D printed the 'Save' Icon." With Millennials and Generation Z entering the workforce, a leader will have to learn their culture in order to lead them.

Moreover, adaptive leadership is the practice of mobilizing people to tackle tough challenges and thrive (Northouse, 2016). Adaptive leadership incorporates four different perspectives (1) a biological perspective suggesting that people develop by having to adapt; (2) a systems perspective suggesting that problems faced by leaders (and their followers) are complex

[4] Retrieved from https://twitter.com/bill_gross/status/920406104911233024?lang=en on March 8 2021.
[5] Bill Gross is a famous entrepreneur, inventor and public speaker in Pasadena, California. He is the founder of Technology incubator Idealab and 100 companies in last 30 years. One of the transformative changes that Bill has wrought is the "paid click", or cost-per-click (CPC) which is the backbone of internet monetization. Bill is also a member of the Board of Trustees of the California Institute of Technology and of the Art Center College of Design.

and have so many interconnected parts. There is no personal trait or competency in prevailing themes (e.g., influence perspective of leadership) that can explain how a leader can "solve" this kind of problem (Starr, 2020). (3) a service orientation that requires diagnosing problems and offering solutions; (4) a psychotherapy perspective emphasizing that people adapt through learning.

The experience of learning leadership systemically marked a new start for me. This experience also forced me to think and act from a different perspective. That is, besides asking "what" leadership models are, I need to ask more questions regarding "why" a particular model focuses on this trait and "how" a particular model is related to other models proposed in the literature. Upon the completion of this course, I had serval new perspectives on leadership. First, leadership may be viewed as a complex problem. A widely shared view of leadership is that leadership can be understood as a sum of different competencies (e.g., Beans, 2015). There is a presumed formula or equation in which leadership is the sum of a set of functional processes or core competencies. This perspective is appealing because different individuals can function as a "leader" by piecing together all the "mosaics" in the leadership equation and because it gives a sense of "optimizing leadership" through the improvement of individual components in the leadership equation via training. However, Starr (2020) terms this approach as linearity of competencies and argues that one potential issue with this approach is that there is no general agreement on the number of competencies leaders should possess. Adaptive leadership won the horse-race comparison of leadership models because it adopts a systems perspective which is essential in a fast-changing environment and because it served the purpose of strategic leadership, e.g., to negate the complex problem arising from various business projects.

Second, leadership is about change and adaptation. To be an adaptive leader, one must have a good understanding of the context of leadership. One important context in today's business world is the usage of information technologies. The adoption of new technologies constantly imposes adaptive challenges and problems that are not clearly defined or easy to identify and do not have a clear solution. Since there is no existing solution to emergent problems, there will be no ready leadership model to lead the change. A leader will have to learn first.

Pilot Study 2: An Integrated Healthcare Case

My business development experience in the US healthcare industry was the main motivation to choose a topic that explored the strategy for a healthcare clinic to expand in a less developed community. After I became a partner in a healthcare group, I learned from a much more in-depth, personal perspective, sometimes wrenching in its impact, that communities that face the challenges of poverty also experience predominance for health issues and healthcare disparity. While systematic healthcare incentives (financial and social) toward keeping people healthy have been implemented, in the short run, hospitals/medical centers/healthcare providers are battling with revenue decline. Theoretically, I was motivated to examine the convergence of community development and community healthcare to improve the social determinants of health and revitalize low-income communities.

In 2019 I conducted a case study investigating the design of integrated and location-based healthcare centers and their relationship to socially responsible business strategy. I analyzed a developed comprehensive healthcare center in Upper Darby, PA, and its newly invested developing identical center in Chester, PA.

According to the World Health Organization (WHO, 2008), "The organization and management of health services so that people get the care they need, when they need it, in ways that are user-friendly, achieve the desired results and provide value for money" (WHO, 2008); "Integrated health services" can refer to multi-purpose service delivery points – a range of services for a catchment population is provided at one location and under one overall manager; Integration can also refer to the vertical integration of different levels of service - for example, district hospitals, health centers, and health posts. (WHO, 2008)

Practically, this pilot study aimed to explore an efficient financial and investment model for the comprehensive, location-based healthcare center and joint community development health initiatives. I examined two main features of this integrated healthcare model, i.e., the integration of primary care and secondary care and the integration of health care and community care. I then examined how such an integrated healthcare model can facilitate local community development in terms of its common cause, shared vision and strategy, joint delivery, and joint financing. Several hypotheses were developed, including the integrated location-based medical and healthcare services provided by the comprehensive healthcare center that can effectively

meet residents' medical and healthcare needs; an integrated healthcare model would enable the healthcare provider to partner with community development organizations to improve lives in low-income communities, e.g., an integrated healthcare model is better positioned to build the competency of coordinating with a strategy that benefits the community, such as improving aging health management. My findings and building this case, which indicates effectively going beyond the traditional community hospital setup and strategically aligning healthcare services, has important implications for government and policymakers, healthcare researchers and practitioners, healthcare facilities, healthcare investors, and various stakeholders in community development. Data collection survey questionnaires were also developed.

Pilot Study 3: A Comprehensive Review of Big Data and Healthcare

To better understand the digital transformation in the healthcare industry, I conducted a pilot study regarding big data analytics in the healthcare industry in Spring 2020. I reviewed the meanings and characteristics of BDA and analyzed the opportunities and challenges brought by the BDA to the key stakeholders along the value chains in the healthcare ecosystem (such as healthcare providers, healthcare payers, patients, and social services).

As the first independent study and the first literature review in my doctoral education, I faced several challenges. First was the choice of topic. Before I conducted this review, I knew little about big data and BDA except for a few hot words (such as big data, artificial intelligence, machine learning) in the media. And I knew some technological concepts could be difficult without certain background. However, I still chose this topic because the inter-disciplinary study may be valuable both from an academic perspective and a practical perspective. For instance, the global leadership model proposed by the University of Cambridge Institute for Sustainability Leadership suggested that a leader operating with a global perspective and in a complex context should have the seven characteristics described in Table 6: capacity to be a systems thinker, proficiency in navigating complexity, open-minded, long-term thinker, interdisciplinary, inclusive, and globally conscious (Visser & Courtice, 2011). In particular, "open-minded" requires a leader to "actively seeks new knowledge and diverse opinions, questions received wisdom, including being willing to have one's own opinion challenged" (Visser & Courtice, 2011, p.5). Moreover, "interdisciplinary" requires a leader to "Sees the relevance and inter-

connectedness of the political governance, physical sciences, technology, business, and other disciplines" (Visser & Courtice, 2011, p.15).

Second, choosing a perspective to complete this review was a problem to me because there is a growing number of studies examining the impacts of BDA on the healthcare industry. It could be very easy to lose the focus of this review when these were "silo" types of views that focus on one type of stakeholders (e.g., hospitals or physicians) but ignore other parties and studies overly focusing on various emerging technologies. After reviewing the prior literature, I decided to take a systems view and focus on the potential impacts on the value creation process for the stakeholders in the healthcare industry. Only a systems view can allow us to understand the interconnectedness between new technologies and the current ecosystem. And the adoption and evolution of new technology will depend on its potential to create values for the stakeholders.

If the usage of modern information technologies (such as the internet and other electronic platform-based social media) has changed the way of communication and therefore the ways of influence, relational dynamics, and leadership style, the advent of a big data era may require more for strategic leadership. First, although a leader in this new era may not have to be a data scientist, they must acquire the relevant knowledge and skill related to data science. Second, a leader in this new era must be a good communicator because more information and stakeholders are involved in the decision-making process. A leader must be careful about the power dynamic related to automated decision-making or semi-automated decision-making process regarding the use and application of big data analytics in problem-solving. Algorithms can be accurate and biased at the same time (e.g., the denial of health insurance application for high-risk groups with pre-existing conditions or non-healthy lifestyle that is discovered by big data). A leader must hold an even higher level of value and ethical standards. Big data presents options; humans make final choices and decisions; hence strategic leadership is ultimately a human, humane, and ethical decision-making process that wisely considers many tools, including big data and now AI.

This independent study experience was important to me because I gained first-hand experience of collaborating with other researchers. I learned to identify the area of collaboration and research topic. I also learned to collaborate with other scholars by effectively

communicating, defending, and refining research ideas, build and maintain a research agenda to conduct in-depth research on time. This research experience facilitated my transformation to a researcher with deeper and more reflective thinking and writing skills that is appropriate at a doctoral level.

Pilot Study 4: Response to COVID-19 Pandemic

In the fall semester of 2020, as part of an independent study course, I applied a systems thinking framework to the COVID-19 pandemic's influence on digital contact tracing, which was supposed to help us to contain this disease. I also examined; how healthcare regulation and governance of big data analytics and healthcare data protection functioned during the pandemic.

COVID-19 pandemic is the "once-in-a-life" or "hundred-year storm" event that imposed many challenges and tests on all countries. Contact tracing is one measure to fight this pandemic. Empowered by advanced digital technologies, digital contact tracing and exposure notification have produced improved outcomes as reported by Fetzer and Graeber (2021). However, the authors also noted that social failures contributed to the outcomes: the random breakdown of contact tracing led to more illness and death. Conservative causal estimates imply that relative to cases that were initially missed by the contact tracing system, cases subject to proper contact tracing were associated with a reduction in subsequent new infections of 63% and a reduction in subsequent COVID-19–related deaths of 66% across the 6 weeks following the data glitch.

We were more or less facing many of these challenges 100 years ago during the 1919 Spanish influenza. However, the situational contexts were significantly different: a century ago, the World War was ending and the world was still in the *Second Industrial Revolution*, far from instant global communication/all-day news and social media services that promoted information/misinformation.

I used four types of project complexity (this is your link to the earlier chapter where you define a complex context and complexity) proposed by Remington and Pollack (2007) (i.e., structural, technical, directional, and temporal complexity) to analyze the adoption of COVID-19 tracing apps in the U.S. The structural, directional, and temporal complexity regarding digital contact tracing is all ranked high because of lacking a grand strategy, coordination of federal and state government, and collective efforts. In contrast, the technical complexity is ranked at a

medium level not because we do not have a disposable technology but because the related legal and ethical issues of data privacy complicate the choice and use of technologies.

Even though many different technologies can be used for contact tracing, it was the regulations and policy debates regarding personal privacy that determined the type of technology that was adopted. More importantly, whether digital contact tracing is successful or not depends on factors in a more extensive and complex system, such as the related quarantine measures and financial resources at both the federal level and the state level, people's trust in digital technology, the public health system, the political debates related to the COVID-19 pandemic, and the leadership of the federal government.

This, argues for a systems approach that is adaptable, flexible, and continually changing, in its approach to solving problems, as the COVID-19 pandemic has so clearly demonstrated as epidemiologists, infectious disease experts, and bio-statisticians attempted to predict the spread, morbidity, and mortality of the virus. As Wharton's Phil Tetlock found, documented in *Super forecasters*, the more data that is learned, the more theories, hypotheses, and uncertainties, can be traced. A systems approach takes these recommendations to heart in conceptualizing an ideal design. And more importantly, an effective complexity leadership at the very top that allows navigating the related political, legal, and administrative complexities is essential for the operationalization of such a design.

Several lessons were learned from this project. First, the COVID – 19 pandemic reminds us that we need systems thinking in combating complex problems at hand. Most of the time, the ultimate success of complex projects depends upon how well we navigate the complexities which not only arise from the problem itself but also arise from its interactions with its context (e.g., political environment, public opinion, institutional capability, etc.) The COVID -19 crisis possesses all characteristics of VUCA, i.e., volatility, uncertainty, complexity, and ambiguity (Bennett & Lemoine, 2014). That is, it is a complex problem because this situation has many interconnected parts, such as health, economic, social, political, and cultural parts. There is a high level of uncertainty because the change of situation happens fast and constantly even though the basic cause and effect are known. That is, we know the cause is the novel coronavirus, but we cannot fully reduce the ongoing uncertainties associated with the containment of the novel coronavirus because the COVID-19 pandemic is constantly evolving.

Second, the adaptive leadership model may shed light on the response to the COVID-19 pandemic. When responding to the COVID-19 crisis, the leader is facing unpredictability, imperfect information, and typical "unknown unknowns," but has to make responses quickly. In the leadership literature, adaptive leadership is defined as "the practice of mobilizing people to tackle tough challenges and thrive" (Heifetz et al., 2009, p.14). This definition suggests that leadership is concerned with the behavior of leaders. Adaptive leaders engage in activities that mobilize, motivate, organize, orient, and focus the attention of others (Heifetz, 1994). The process of adaptive leadership incorporates ideas from four viewpoints: the systems, biological, service orientation, and psycho-therapy perspectives (Heifetz, 1994). In particular, the adaptive leader takes a systems perspective because the leader recognizes the fact that many problems are embedded in interconnected and interactive systems. Problems are viewed as multi-facet complex, dynamic because they can evolve and change and are inevitably connected to others (Northhouse, 2016).

To respond to COVID -19 more effectively, researchers try to refine the framework of adaptive leadership. Ramalingam et al. (2020) redefined adaptive leadership as "the ability to anticipate future needs, articulate those needs to build collective support and understanding, adapt your responses based on continuous learning, and demonstrate accountability through transparency in your decision-making process" (https://hbr.org/2020/09/5-principles-to-guide-adaptive-leadership). This definition is based on 4As: anticipation (of future needs and trends), articulation (of these needs to build collective understanding and support), adaptation (for continuous learning and adjustment of responses), and accountability (i.e., transparency in the decision making process and openness to challenges and feedback). Ramalingam et al. (2020) proposed five principles for adaptive leadership, including (1) ensuring evidence-based learning and adaptation; (2) stress-test underlying theories, assumptions, and beliefs; (3) streamlining deliberative decision making; (4) strengthening transparency, inclusion, and accountability; (5) mobilize collective action.

I applied Systems Thinking and Complex Project analysis to the Covid-19 pandemic and contact tracing in the U.S. The system perspective notes that interactions among the general public, the public health authorities, and the regulators create challenges such that a trade-off between the cost of pandemic and data privacy results. The apparent conflict is that the fast

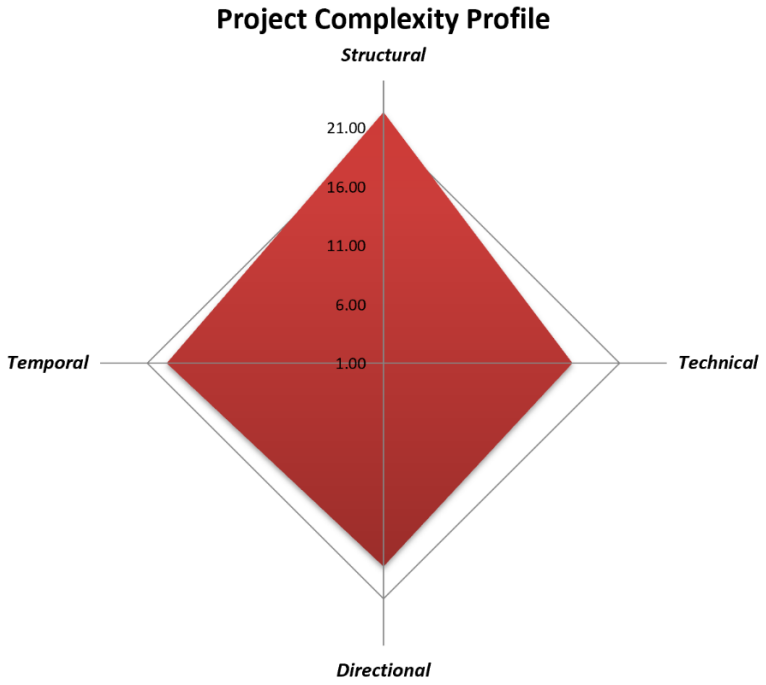
spread of COVID-19 leaves little time for legal and ethical debates on personal data privacy and remedies to a complicated U.S. health data privacy system. Remington and Pollack (2007) suggest four types of project complexity, i.e., structural, technical, directional, and temporal complexity that may describe how to understand the adoption of COVID-19 tracing apps in the U.S. (see Table 3). The structural, directional, and temporal complexity are all ranked high because of the lack of a grand strategy, coordination of federal and state government, and collective efforts. In contrast, the technical complexity is rated as a medium not because we do not have a disposable technology but because the related legal and ethical issues of data privacy complicate the choice and use of technologies. Figure 12 provides the project complexity profile for digital contact tracing.

Table 3: Mapping Project Complexity for Digital Contact-Tracing in the U.S.

Dimension	Evaluation	Project Complexity
Structural (number of dependencies)	• The fragmented state-by-state approach to developing and adopting COVID-19 tracing apps in the US greatly limits the effectiveness of such a tactic (Barber & Knight 2020, Timberg et al., 2020). • States have fewer incentives to invest in COVID-19 because the federal government does not provide them any financial support • Digital contact tracing must rely on other successful measures, including fast and cheap testing, quick follow-up, and effective quarantine and isolation procedures.	High
Technical (Impact of unresolved technical/design issues	• Bluetooth-based contact-tracing apps have some limitations. For instance, the current Apple-Google protocol emphasizes personal data privacy, and the apps do not collect key personal information such as location data, which is essential to containing the spread of COVID-19 from the public health perspective. • Legal challenges related to personal data privacy in the U.S., i.e., how to protect the information and entities involved in digital contact tracing.	Medium
Directional (ambiguity/lack of agreement on	• Fighting a pandemic like COVID-19 requires a clear vision and strong leadership,	High

goals)	quick responses based on scientific evidence, and collective efforts from the individuals and society as a whole. However, there is no clear direction regarding how and what to do to fight the pandemic. • The general public's trust and cooperation in the effectiveness of digital contact tracing and other public health measures (mask, social distancing, etc.)	
Temporal (Expected time delays at key project stages)	• The value and importance of digital contact tracing could change over time. For instance, the priority for contact tracing could be lower for states with high positive testing rates that combat the congested health care system. Moreover, the advent of the COVID-19 vaccine could also compete for the limited financial resources at both the federal and state level.	High

Figure 12: Project Complexity Profile for Digital Contact-Tracing in the U.S.



Big data analytics, along with the advanced analytical tools such as AI and ML, has the potential to change the landscape of the health care systems, for example, by optimizing workflows in healthcare providers, providing more accurate diagnoses, and improving the overall quality of services to patients and the general public. However, it also raises challenges for the regulators worldwide regarding how to minimize the potential "harms," such as data privacy, brought by these new analytical tools and decision-making models.

To do so, certain essential features of complex systems in health care must be considered. Unlike data systems, human systems are purposeful, self-organizing, and constantly adapt to change; they are driven by the interactions between systems components and governed by meaningful feedback; and they are nonlinear and hard or impossible to predict, with changes in one part of the system causing unexpected changes in other sub-systems. The development of big data analytics and its applications in various business decision-making processes share some similar features. For instance, analytical tools are fast evolving, and the ways that data are collected, shared, and analyzed are fast changing. Therefore, a "systems" perspective is vitally important (Gerke et al., 2020) and argues for consideration of the following recommendations for effective regulation of big data analytics in health care:

1. Due to the large number of elements that interact in nonlinear and dynamic ways, regulators should take a holistic view because the entire value chain of big data analytics can go beyond the traditionally defined health care industry with the participation of stakeholders outside the current laws and regulations.
2. Due to individual interactions, influences and relationships, organizations should embark on a continuous learning process to discover emerging patterns as a foundation for a more effective regulatory approach. Because big data analytics is fast evolving, and the context where big data analytics are applied is rapidly changing, there is no clear separation between the "benefit" and "harm." Regulators should understand the context, and this should be reflected in the history of the system. In particular, the risk assessment of the application of AI/ML must reflect the changes in external conditions and the system itself.

All stakeholders should realize that the people in the system shape the system and are influenced by the system. Regulators should emphasize a human-centric regulatory approach and

develop policies that will foster positive feedback (such as trust, and cooperation) from the people in the system.

Starr (2020a) summarizes the three traditional themes of leadership as indirect patterns of influence, direct patterns of influence, and patterns of relationships. Starr (2020a) further argues that a fourth theme – navigating differing contexts should be added, which requires "shifting to a different mode of thinking or mindset which informs complex problem formulation and intervention, enables the application of different methodologies, and offers new tools for leadership practice and research" (p. 20). Context can be viewed as the whole situation or environment that surrounds and informs a decision. Navigating the context requires a fundamental change of mindset. That is, leaders must understand the context of the problem at hand and know how they will adapt when the context changes (Snowdon & Boone, 2007). Therefore, instead of asking, "What should I do about this problem?" the leader should ask, "In what kind of context is this problem located?" and "What kind of problem is this?"

I argue that digitalization is a complex contextual characteristic that has changed the landscape of the economy and business practices. During my work in the past few years, I found that new technologies, such as Big Data, Artificial Intelligence, play increasingly important roles in the healthcare industry. Big Data Analytics (BDA) works not only as a catalyst but rather represents a destructive innovation (Christensen, 1997) that will revolutionize the entire healthcare industry. However, adoption is incomplete; there is a gap between healthcare practitioners and the concepts and applications of BDA in the healthcare industry.

Pilot Study 5: Healthcare In A Digital Era

The wide applications of Big Data Analytics have helped businesses and organizations to create value. But such benefits have corresponding costs. In a second pilot study conducted in December 2020, I examined two major issues that have gained increasing attention from the public and the regulators. First, the general public is getting more concerned about data privacy because a massive amount of personal data have been generated, collected, stored, processed, and analyzed by various parties. New forms of crimes using personal information, such as online crime, and personal identity theft, have created significant costs for individuals.

Second, the adoption of artificial intelligence (AI) and machine learning (ML) makes automatic decision-making possible. While the automated decision made by algorithms are much more efficient than human-based decision-making, the public becomes more concerned with the governance of AI-based decision-making by raising questions about the ethics and fairness of such a decision-making process that is quite often without human involvement. Typical ethical problems include Informed consent to use AI, Safety and transparency of AI in the clinical decision-making process, Algorithmic fairness, and biases (Gerke, Minssen & Cohen, 2020).

Focusing on the above-discussed two major issues, I systemically reviewed and compared the data privacy regulation in the U.S. and European Union and the emerging governance principles and frameworks regarding the application of AI in the European Union and Singapore. Regarding data privacy protection in the U.S., there are two significant features. First, the legal framework governing personal data privacy is complex and lacks uniformity at the federal level, and is best described as the "patchwork" (Mulligan, Linebaugh, & Freeman, 2019). That is, there are several data protection statutes at the federal statutory level which regulate certain industries and subcategories of data. These laws vary considerably in their purpose and scope, i.e., governed entities and data protection requirements. At the federal level, the principal law is the Health Information Portability and Accountability Act of 1996 (HIPPA). Each state defines its own privacy framework. Second, the U.S. regulatory approach of healthcare information can be characterized as a downstream regulation approach (Terry, 2017). The lifecycle or value-chain of data may be characterized as a linear sequence of collection, processing, storage and transfer, and final uses. HIPPA may focus more on disclosure collected data (i.e., "confidentiality") and may inadequately address the data collection that occurred upstream of the data life cycle (i.e., "privacy").

Regarding the regulatory framework of AI, because AI is one of the most critical applications of the data economy and can have a major impact on our society, governments and regulators have paid attention to the regulatory framework regarding AI. International organizations such as OECD, G20, and governments in Europe and Asia have proposed principles and regulatory frameworks in the past few years. For example, OECD adopted its Principles on Artificial Intelligence in May 2019, which is the first international standard agreed by governments. The set of Principles promotes the trustworthiness of AI-based on its

compliance with the law, human rights democratic values and diversity, transparency and responsible disclosure of adoption, human-centric approach for AI-based decision making, and responsible usage of AI by individuals and organizations.

Singapore implemented the first edition of the Model AI Governance framework (Model Framework) on January 23, 2019. Two principles for responsible AI were established: (1) decisions made by AI should be explainable, transparent, and fair; (2) AI solutions should be human-centric. The Model Framework proposes a risk-based framework to help organizations determine the level of human involvement required in AI-augmented decision-making depending on the probability and severity of potential harm caused by AI. AI applications with high probability and severity of harm will be regulated by the Model Framework.

The European Union (EU) set its policy options for AI in February 2020. Similar to OECD principles, European AI is grounded in its values and fundamental rights, such as human dignity and privacy protection. EU's AI regulatory framework adopts a risk-based approach to support that the regulatory intervention is proportionate (European Commission, 2020). Under this framework, an AI application should be considered high-risk where it meets the following two cumulative criteria: (1) the AI application is employed in a sector where, given the characteristics of the activities typically undertaken, significant risks can be expected to occur. (2) the AI application in the sector in question is, in addition, used in such a manner that significant risks are likely to arise. Several requirements would apply to high-risk AI applications only, including training data, data, and record-keeping; information to be provided; robustness and accuracy; human oversight; specific requirements for certain particular AI applications, such as those used for purposes of remote biometric identification (European Commission, 2020).

I benefited from this independent study regarding examining the regulation of data privacy and AI. First, I became more experienced in reviewing the literature. And I am more confident in my ability to identify critical gaps in the extant literature. I also enjoyed the academic exploration that is driven by my interest. Second, I learned to maintain a research pipeline that could be valuable for both academia and industry practitioners. For example, the working paper had over 300 downloads within two months of publication. Most importantly, I

found more workable topics, such as the way to mitigate gaps in ethical AI and the way of a leader to navigate the context of a significant data era, for my dissertation.

In summary, these five pilot studies helped me examine the framing challenges and opportunities of digital transformation (Research Question 1) and investigate how changes are understood and interventions (Research Question 2) are made from a variety of angles. First, Pilot study 1 helps me to address RQ1 because it provided me a foundation for leadership and help me to build a systems thinking mindset which are both important to navigate the change and complexity associated with digital transformation. Second, Eastwood (2022) argues that digital transformation boils down to three key elements: (1) data and technology architecture; (2) business model architecture; (3) human architecture (e.g., organization structures and incentive structures). Pilot study 2 allowed me to address RQ1 from the perspectives business model architecture and human architecture. Third, Pilot studies 3, 4, and 5 allows me to address both RQ1 and RQ2 from both data and technology architecture perspective and the business model perspective. For example, Pilot study 3 is a special case regarding the application of digital technology in public health (e.g., digital contact tracing for COVID - 19) that demonstrates the complex nature of social and political costs of digital technology. Pilot study 5 examines the wide adoption of digital technologies (i.e., AI) that not only disrupt the existing business models but also impose new challenges that call for regulatory responses (e.g., regulations on personal data and privacy). Moreover, pilot study 4 allows me to address RQ1 from the business model architecture perspective, i.e., how digital technologies, such as Big Data Analytics, will affect the components of existing healthcare value chains and give rise to new business models. However, inherent nature of digital transformation of health care is changing due to evolution of digital technologies, innovative ways of applying digital technologies, and responses from stakeholders (e.g., regulators). To better understand these changes, I will use more systematic approach to examine the opportunities and challenges in the following chapter.

CHAPTER 4

METHODOLOGY AND RESULTS

In this Chapter, I describe how I examined and evaluated the literature on the digital transformation of health care with reference to the two research questions; **RQ1**: What are the similarities and differences in the formulation of the problems and opportunities of the digital transformation of the healthcare industry using analytic thinking and systems thinking? **RQ2**: What are some possible interventions and choices to the challenges arising from the analytic and systemic conceptions of digital transformation of the healthcare industry?

An inductive approach to reviewing the literature on digital transformation of healthcare was applied based on the guidelines from Wolfswinkel, Furtmueller and Wildeorm (2013) This method is a five-stage approach (Table 4) for conducting a rigorous literature review that "invokes Grounded Theory as a method during the analysis stage (p. 47)." The five-step approach consists of (1) defining the scope of the review, (2) searching the literature, (3) selecting the final sample, (4) analyzing the corpus, and (5) presenting the findings. A discussion and implications of the results of this evaluation are in Chapter 5.

Table 4: Five-stage grounded-theory method for reviewing the literature (Wolfswinkel, Furtmueller, & Wilderom, 2013, p.47)

Number	Task
1. DEFINE	
1.1	Define the criteria for inclusion/exclusion
1.2	Identify the fields of research
1.3	Determine the appropriate sources
1.4	Decide the specific search terms
2. SEARCH	
2.1	Search
3. SELECT	
3.1	Refine the sample
4. ANALYZE	
4.1	Open coding
4.2	Axial coding
4.3	Selective coding
5. PRESENT	
5.1	Represent and structure the content
5.2	Structure the article

(1) Define the scope of the review

In the literature search, focus was directed to publications in the field of management, business, information systems, and other related areas such as operations research, health literacy and telemedicine. For example, search was conducted via *EBSCOhost* which provides products and services to libraries using the Academic Search Premier database. When searching in the ScienceDirect database, publications limited to the subject areas of Business, Management, Accounting, Computer Science, and Engineering were examined. Publications related to the topics of Management, Health and Telemedicine, Operations Research and Management Science, Supply Chain and Logistics, Economics were reviewed when conducting searches in the *Clarivate Web of Science* database. To ensure the quality of publications to be included in the systematic literature review (SLR), the first focus was on peer-reviewed articles. Furthermore, the time frame for publications was restricted to between 2000 and 2022 because the concept of digital transformation and IR 4.0 began to emerge and materialize after 2000.

(2) Search the literature

To examine the current state of the literature on the digital transformation of healthcare, a systematic literature review (SLR) was conducted in November 2022. An initial electronic literature search was conducted over three major databases: *EBSCOhost*, *Elsevier Science Direct*, and *Clarivate Web of Science*. The search strategies are detailed in Table 5. The keyword combinations 'digital*' and 'healthcare' both in either title or abstract ensured the relevant studies were identified. Asterisks were placed at the end of 'digital' point to variations of the word 'digital' enabled British or American English spelling and variations regarding words based on its root, such as digitalization, digitalization, digitalized, digitalized, and digitally.

Table 5: Electronic Literature Search Strategy

Database	Keywords	Search Methods
EBSCO Academic Search Premier	(1) Digital* (TI title) AND healthcare (AB Abstract) (2) Digital* (TI title) AND healthcare (TI Title)	Time frame: 2000-2022 Source: peer-reviewed journals Language: English
Elsevier ScienceDirect	'digitalization' AND healthcare in Title, abstract, keywords (search engine recognizes the British and American English spelling)	Time frame: 2000 – 2022 Article type: review articles; research articles Subject areas: Business, Management, Accounting; Computer Science; Engineering
Clarivate Web of Science	(1) Digital* AND healthcare (Title) (2) Digital* AND healthcare (Abstract)	Publication Date: 2000 – 2022 Citation Topics Meso: 6.3 Management; 1.273 Health Literacy & Telemedicine; 6.294 Operations Research & Management Science; 4.84 Supply Chain & Logistics; 6.10 Economics

(3) Select the final sample

Sample selections of the literature subsequently led to documents for the final review. Table 6 diagrams the procedure and criterion for the selection of the final sample. Originally, 1430 studies were identified from the *EBSCO Academic*, *ScienceDirect,* and *Web of Science* distributed as 600, 485, and 345, respectively. To construct the final sample, the studies were merged from and duplicates were removed. This produced a combined and non-duplicated sample of 438 studies. From these, manual screening was performed of the title, abstract, keywords, and content of studies Studies to which full access was not granted were excluded as were studies with subjects and contents not relevant to our research questions. The final sample of 159 studies resulted from this process.

Table 6: Sample Selection Process

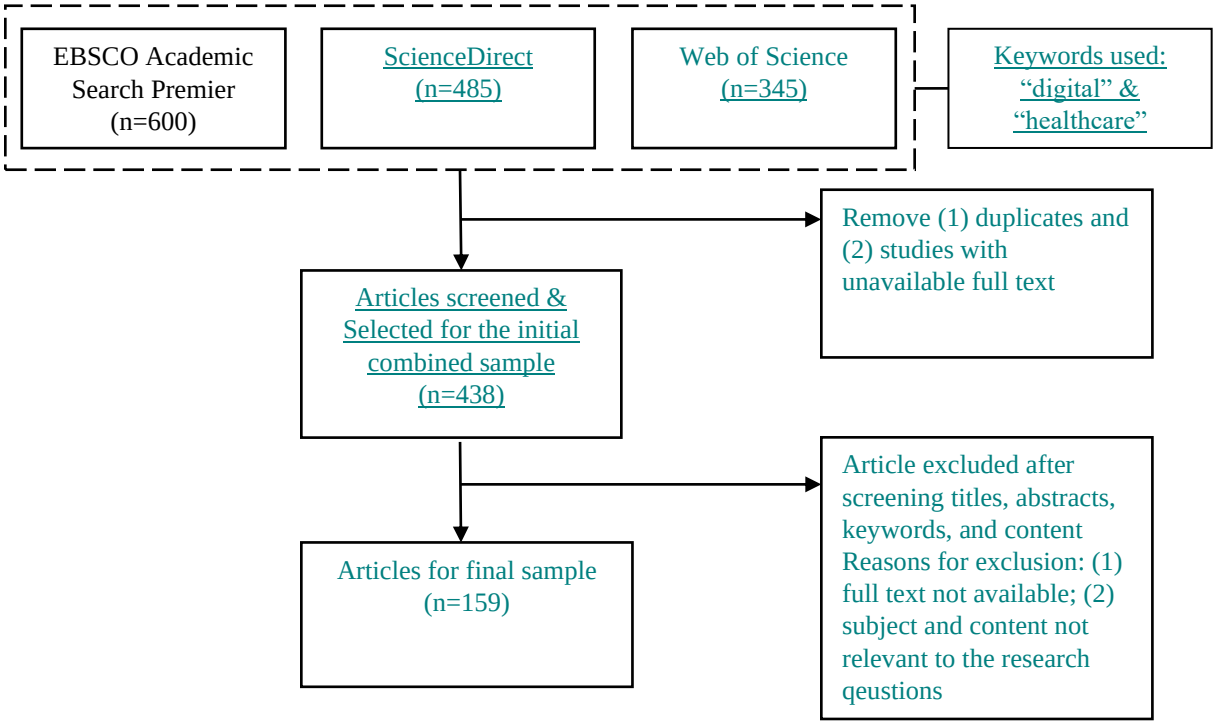
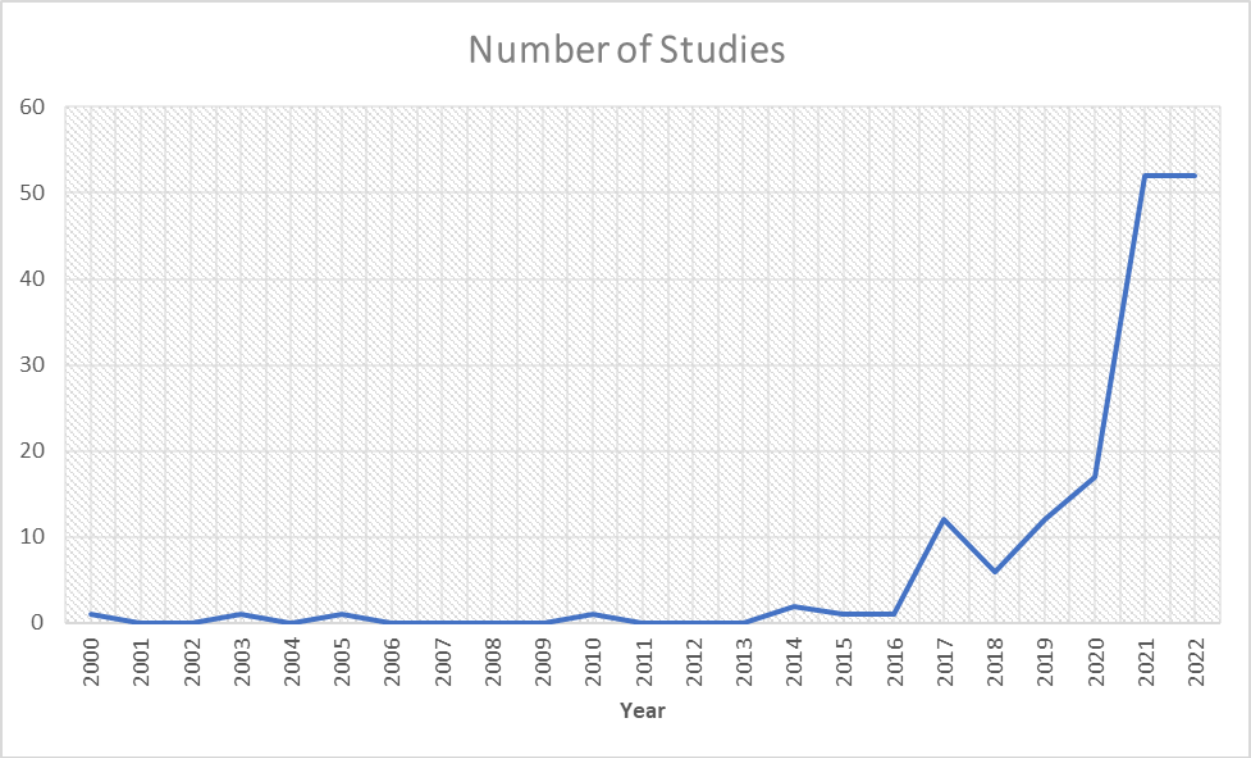


Figure 13 provides the number of studies included in the final sample by year. As shown, regarding the digitalization of healthcare before 2017, there were only 8 included studies published. In contrast, there were 52 studies in 2021 and in 2022. However, this increase was not due to shifted ~~its~~ attention to digital transformation in the healthcare industry; rather studies published before 2010 focused on the IT infrastructure and the adoption of digital technologies, such as ring sensors (Yang & Rhee, 2000), medical images and medical data (Cao et al., 2003), and handheld computers (Lu et al., 2005), with a focus on the healthcare providers. The new digital technologies continually diffuse to the healthcare industry in the past decade at an accelerated speed. New digital technologies have greatly changed the landscape of the healthcare industry as reflected in the explosion of academic publications in the past two years.

Figure 13: Plot of the number of studies included by year



(4) Analyze the corpus

The Grounded theory approach was adopted to guide analysis. This meant that the literature review was "guided by the principle of reading for theoretical sensitivity in order to achieve emergence" (Wolfswinkel, Furtmueller, & Wilderom, 2013, p. 52). Open coding is used to extract "higher-abstraction level type categories from sets of concepts/variables" (Wolfswinkel, Furtmueller, & Wilderom, 2013, p. 51) from textual data. Specifically, categories that are given special attention were (1) digital technology-related changes/disruptions that happened at the key stakeholders; (2) digital technology-related changes/disruptions that happened to the healthcare ecosystem; (3) benefits and costs associated with technology-related changes/disruptions; and (4) boundaries and constraints that facilitate or delay these technology-related changes/disruptions.

Relevant review studies of digitalization and healthcare were analyzed first. These review studies are usually found after 2018 and cover a variety of key aspects or stakeholders of

healthcare system, including (1) the conceptual framework of Health 4.0, impacts of Industry 4.0 and new technologies on the healthcare system (Aceto et al., 2020; Cavallone and Palumbo, 2020; Jayaraman et al,2020; Ahsan and Siddique,2022; Karatas et al., 2022); (2) operations of healthcare (Tortorella et al., 2020) and management issue (Gjellebæk et al., 2020) (3) patient-care relationship (Andreassen et al.,2018), (4) User's needs and expectation (Iyanna et al., 2022); (5) public sector service(Papavasiliou et al., 2020)

Importantly, several studies highlight the cost of Health 4.0 and the negative impacts of Industry 4.0 on healthcare and users. Cavallone and Palumbo (2020) identify five "dark side" of Health 4.0 are identified: (1) inequality of care due to the requirement of resources of Industry 4.0; (2)negative impact on providers' organization identification and commitment; (3) lack of human touch and interplay in Industry 4.0; (4) underestimating of the complexity of patients' needs and expectation; (5) little attention paid to bioethics. Papavasiliou et al. (2020) identified several end user's difficulties with public health services including security concerns, digital literacy, and access, face-to-face communication, assistance, difficulty accessing. These are summarized in Table 4.3.

Table 7: Summary of Survey Papers Related to Digital Transformation of Healthcare

Year	Authors	Key Aspect/Stakeholder of Healthcare Ecosystem	Key theme/findings
2018	Andreassen et al. (2018)	User and healthcare providers	digitalization of healthcare (e-health) can change patient-provider relationships, new patterns such as respatialization, reconnection, reaction, and reconfiguration will emerge.
2020	Jayaraman et al. (2020)	users and healthcare providers	New technologies and knowledge base for Healthcare 4.0; and major application areas including IoT wearable remote health monitoring, Ambient-assisted living, smartphone applications, clinical health care management, empowering communities in Healthcare 4.0 using social data, privacy and security of health data.
2020	Gjellebæk et al. (2020)	Healthcare providers	Lack of knowledge and training can be a barrier to the diffusion of ehealth. Several strategies are proposed for middle management to overcome this hurdle, including a shift to learning-oriented leadership and adaptive management, to help employees to cope with the complexity of ehealth.
2020	Aceto et al. (2020)	Three major technologies for Healthcare 4.0, their scenarios in applications in the healthcare system	Identified key benefits and challenges of three major technologies, IoT, Cloud computing, and Big Data
2020	Papavasiliou et al. (2020)	Public sector digital service	ehealth changes the interactions between users and the service provider. Digital service designers and policymakers shall better create services by meeting the needs and expectations of users, including security concerns, digital literacy, and access, face-to-face communication, assistance, and difficulty accessing.
2020	Cavallone and Palumbo (2020)	Industry 4.0, AI, and IoT impacts on healthcare	New technologies are revolutionizing the design and delivery of care, enhance the quality and effectiveness of care. Five "dark side" of Health 4.0 are identified: (1) inequality of care due to the requirement of resources of Industry 4.0; (2)negative impact on providers' organization identification and commitment; (3) lack of human touch and interplay in Industry 4.0; (4) underestimating of the complexity of patients' needs and expectation; (5) little attention paid to bioethics.
2021	Tortorella et al. (2020)	Healthcare providers	consolidate Healthcare 4.0 technologies in the extant literature into 10 groups
2021	Kraus et al. (2021)	Healthcare system	Identify five clusters of relevant academic studies:(1) patient-center approach; (2) operational efficiencies of healthcare organizations; (3) organizational factors and managerial implications; (4) workforce practices; (5) broader socio-economic aspects.
2022	Karatas et al. (2022)	The intersection of Industry 4.0, Big data, and healthcare operations	82 studies covering the applications of Big Data and Industry 4.0 in e-heath systems around the world between 2014 and 2022
2022	Iyanna et al. (2022)	End-user	End-user barriers for e-health innovations, including task-related, patient-care barrier, system barrier, and organizational barrier.
2022	Ahsan and Siddique (2022)	Technologies related to Healthcare	identified seven clusters of extant studies: (1) conceptual framework of healthcare 4.0; (2) schedule problems; (3) security issues; (4) COVID-19; (5) digital supply chain; (6) blockchain technology; (7) artificial intelligence

To gain a better understanding of the topics of the relevant studies, text-mining techniques were applied to examine the keywords and abstracts of the studies in the final sample separately. Figure 14 provides the frequency plot of the keywords. The top ten keywords of sampled studies are “artificial intelligence,” “digital health”, “digital transformation,” “supply chain,” “big data”, “digital technologies,” “business model,” “deep learning,” “electronic health,” and “social media”. These high frequencies word reveals that the adoption and application of emerging digital technologies (such as artificial intelligence, big data, and data analytics) and digital platforms (social media) in the healthcare industry and the impacts on the business model and business process (e.g., supply chain) has attracted the attention of researchers. Moreover, Figure 15 depicts the frequency plot for the abstracts of sampled studies. The top words identified in the corpus include “healthcare”, “digit”, “health,” “data,” “system,” and “use”.

Figure 14: Word Frequency Plot for Keywords

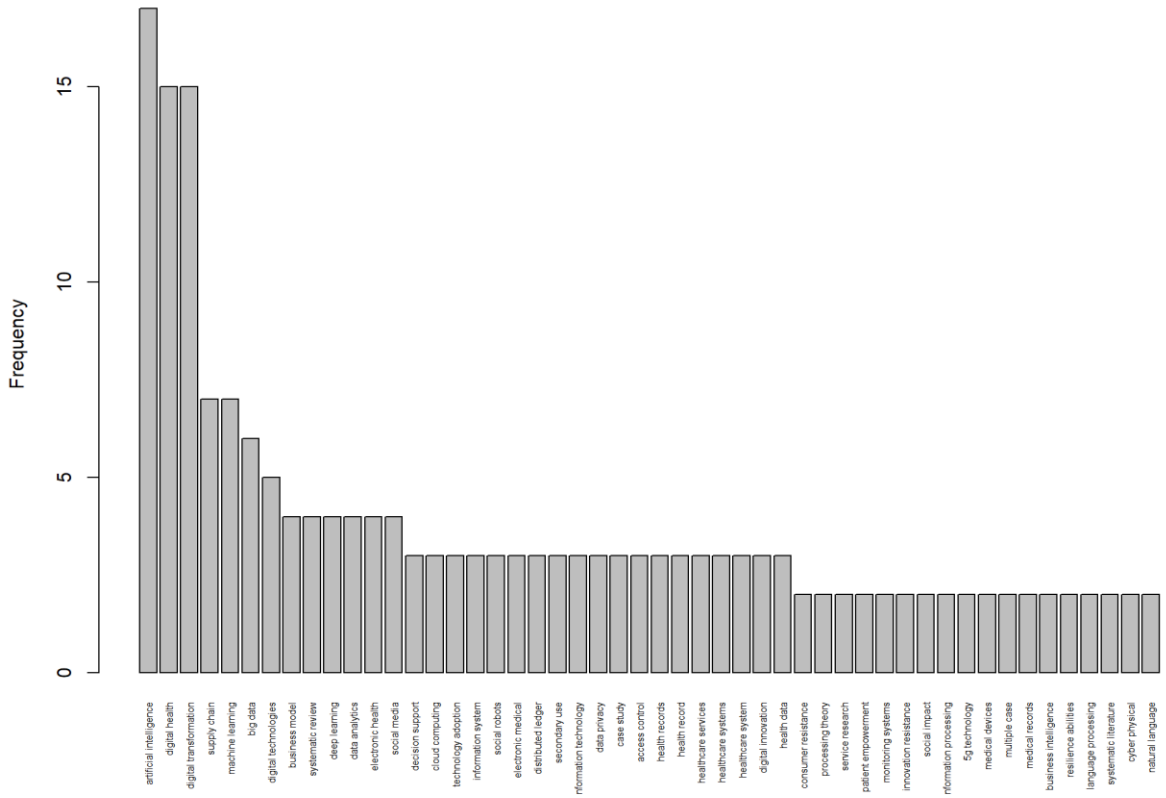
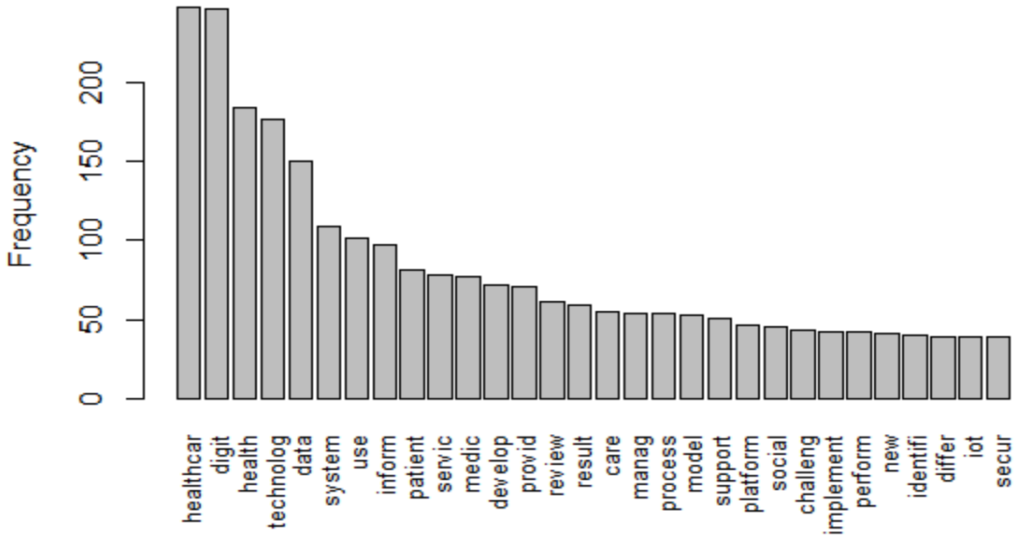


Figure 15: Word frequency Plot for Abstracts



Based on our initial analysis of the review papers of digitalization of healthcare, we develop the following coding scheme:

(1) Health 4.0 and eHealth: a conceptual framework for the new digitalized healthcare system

(2) Disruptive technologies: the trigger and technological foundation for the digitalized healthcare system, including Big Data, IoT, cloud computing, blockchain, artificial intelligence, and machine learning.

(3) Ecosystem: a system perspective for digitalized, interconnected healthcare system consisting of nested subsystems, such as provider networks, Internet, and various internet-based platforms, users, and social networks.

(4) Patient-centric and human-centric: a human-centric approach for digitalization of healthcare that can meet the needs and expectations of end-users (patients and individual users)

(5) Organizational capacities: the ability of healthcare organizations to develop and design new forms of care and delivery methods for care, the ability to adopt disruptive

technologies to re-design its structure, and operating processes, and cope with the complexity of digitalization at all levels within an organization.

(6) Benefits: digitalization can improve the treatment and diagnosis, especially for the efficiency and effectiveness of care

(7) Costs/barriers: digitalization and the disruptions brought by digitalization can cause new costs to all stakeholders. It may create inequality among end-users due to access and technological literacy issues. It can cause new problems and risks with significant economic and social costs, such as data privacy, bioethics, ethical issues related to the use of artificial intelligence and machine learning, and the undue power of certain organizations and platforms in the digital market.

Based on the initial review and text-mining results, the summary of the open coding is presented in Table 8 First, the key conceptual frameworks that describe digitalized healthcare were summarized. Next, the disruptive technologies that are considered as the key drivers of the digital transformation of the healthcare industry were identified. These digital technologies affect the healthcare industry at both the micro and the macro levels. At the micro level, digital transformation will affect healthcare providers with significant benefits (such as quality of care, efficiency of operation, etc.) and costs (financial, legal, and ethical challenges). Another micro-level key stakeholder is patients/consumers because digital transformation changes their roles in the healthcare ecosystem through changes to healthcare-related products and services. These significant changes can provide patients/consumers with better access to care in a cost-efficient way. However, the costs may arise due to digital literacy, resistance to innovation, and personal privacy issue. Turning to the macro-level, digital technologies change the landscape of the healthcare ecosystem by a shift to a patient-centric system that promotes value-based and customized bundles of products and services. This paradigm shift will change the value positioning and value creation of stakeholders. Last, digital transformation brings both benefits and costs to the healthcare ecosystem. Discussion of these clusters of findings in prior literature is provided separately.

Table 8: Open Coding for systemic review

Themes	Conceptual framework for digitalized healthcare	Disruptive technologies	Benefits	Costs
Micro Level	Healthcare providers/hospitals	Innovation, business model	quality, efficiency	Financial, legal, and ethical challenges Organizational challenges – dynamic capability, value creation
	Consumers/patients	Empowerment, changes to product and service	Access, cost-efficient, personalized product	Digital literacy, resistance to digital innovation, privacy
Macro Level	Healthcare Ecosystem	Patient-centric, value-based care, Value co-creation, public health,	Equity, collaboration,	Financial, legal, and ethical challenges; Digital divide

Distinguishing Analytic and Systemic Research

Starr (2021) suggested four premises unlike the mode of thinking that may be used to differentiate analytic vs systemic research. While Starr addresses their application to leadership, the categories are appropriate for digital transformation of healthcare. The first premise is the *approach to reasoning*. Analytic research presents deconstructive reasoning in which an explanation of the role of parts explain by adding up to the whole of healthcare transformation. Systems research reasons that healthcare transformation is understood from interactions among and between elements within the transformation process as well as influences from the organizational system.

The second is the *explanation of cause*. Analytic research focuses on linear, additive cause-effect with well-defined causes and predictable effects. Systems research rather investigates the evolution of a system with non-linear relationships and unpredictable outcomes and emergent characteristics.

The third is the *relationship* of elements. Analytic research assumes a linear and proportional relationship between elements. As a result, a change to one element will create a change in the output in a constant rate that is predictable and sequential. Systems research assumes nonlinearity and nonproportionality. That is, the change in the outcome caused by a change of one element can be nonlinear and unpredictable.

The fourth is the *decision-making* and *problem-solving methodology*. Analytic research aims to solve a problem using inductive and deductive reasoning (and reductionism). Systems research sorts to design, creativity, and innovation using abductive reasoning (and expansionism) to generate a solution for a problem.

Conceptual Framework Related to Digital Transformation of Healthcare

Digital transformation of healthcare has reached a critical point where numerous conceptual frameworks have been invented to describe this digitalization process. Table 9 provides a list of concepts used in the literature. First, the digitalization of healthcare is considered an integral part of a larger industrial, economic, and societal change. For example, the terms *Health 4.0*, *Medical 4.0*, and *Health 5.0* are used to describe the significant advancements in healthcare that are created by industrial revolutions such as Industry 4.0 or Industry 5.0. Second, certain concepts, such as eHealth and mHealth, are defined by either the general enabling digital technologies (i.e., ICT) or specific technology infrastructure (i.e., mobile wireless technology). Third, several concepts that further describe the digital healthcare market segments are becoming popular as well. For instance, the term *telemedicine* refers to the delivery of clinical healthcare services whereas the term *telehealth* refers to the delivery of both clinical and non-clinical healthcare services by healthcare providers (Elliot, 2020). Fourth, digital transformation has significantly changed the ways of traditional medical practices in diagnosis, treatment, rehabilitation, and prevention, which is termed *Precision Medicine* (Denicolai & Previtali, 2020).

Table 9: Conceptual frameworks related to the digital transformation of the healthcare industry

Concepts	Definition
eHealth	eHealth is the use of information and communication technologies (ICT) for health, locally or at a distance (WHO, 2005). It is recognized as one of the most rapidly growing areas in health today.
mHealth (mobile health)	use of mobile wireless technologies for public health and is an integral part of eHealth (WHO, 2020)
Health 4.0 / Healthcare 4.0	A manifestation of Industry Revolution 4.0 in the healthcare sector
Health 5.0	Industry 5.0 is regarded as the next industrial revolution, its objective is to leverage the creativity of human experts in collaboration with efficient, intelligent, and accurate machines, in order to obtain resource-efficient and user-preferred manufacturing solutions compared to Industry 4.0. (Maddikunta et al., 2022)
Medical 4.0	Medical 4.0 is the fourth medical revolution, employing emerging technologies to create significant advancements in healthcare. (Haleem et al., 2022)
Telehealth	Telehealth generally refers to a healthcare provider's use of information and communication technology (ICT) in the delivery of clinical and non-clinical healthcare services (Elliot, 2020)
Telemedicine	Telemedicine generally refers to a healthcare provider's use of ICTs in the delivery of only clinical healthcare services (Elliot, 2020)
Telecare	Telecare concerns those products and services that can monitor people's activity changes over time and call for help in emergency situations where there are movement/non-movement sensors, falling sensors, and fire/smoke alarms. (Oderanti et al., 2021)
Precision Medicine	PM is often defined as a new approach to disease prevention, diagnosis, and treatment grounded on an individual's specific profile; genes, lifestyle, and environment (Denicolai, &Previtali, 2020)
Internet of Medical Things (IoMT)	IoT application in healthcare (Yaacoub et al., 2020; Tarikere et al., 2021)

Enabling Digital Technologies in Healthcare

A variety of information and communication technologies were adopted in the healthcare industry since 2000. These technologies enable the digital transformation of the healthcare industry. A cluster of prior literature discusses these enabling technologies and its wide applications in the healthcare industry, including artificial intelligence (Dicuonzo et al., 2022), distributed ledger technologies and blockchain (Benil & Jasper, 2020; Frizzo-Barker et al, 2020; Massaro, 2021), wearable technology (Ferreira, et al., 2021), cloud computing (Miah et al., 2017), big data analytics; Internet of Things (Dhanvijay & Patil, 2019; Secundo et al, 2021; Park et al., 2022; Ashfaq et al.,2022); digital platforms (Bez et al., 2022); social media and web-based platforms and social media based surveillance system (Gupta&Katarya, 2020); natural language processing (Li et al., 2022; Downing & Perakslis, 2022); 5G cellular technology (Rahman et al.,2022); virtual reality and metaverse (Song & Qin, 2022); enabling technologies under

Industry 5.0 (Maddikunta et al., 2022); healthcare robots (Mahdi et al.,2020; Mbunge et al., 2021); medical data mining to extract knowledge and unknown patterns (Idri et al.,2018).

Digital technologies, and the implementations of digital technologies in healthcare are constantly evolving in a non-linear fashion. And the outcome of the adoption of a particular technology relies on the joint efforts of multiple stakeholders and can only be realized in the long run. Therefore, forecasting or predicting the outcomes of the technologies is impossible. Rather, it is appropriate to adopt an adaptive perspective in the digital transformation of the healthcare industry.

Digital technologies carry both benefits and costs, and therefore provide stakeholders with opportunities and impose challenges. For example, a fundamental issue about digitalization is inclusion, i.e., awareness, acceptance, understanding, and equal participation in opportunities. Apparently, the digital transformation of healthcare imposes stringent restrictions on both the digital infrastructures (e.g., IT infrastructure) and digital capability and skills (e.g., how to use the Internet and mobile phones). This means many stakeholders (e.g., patients, labor workforce) who do not meet these requirements will be left out of this transformation. Digital technologies can impose other challenges, such as dehumanization due to automated decision-making by AI, privacy, and ethical issues related to data sharing and data mining.

CHAPTER 5

DISCUSSIONS AND IMPLICATIONS

This dissertation has examined characteristics of the digital transformation of healthcare by addressing questions of epistemology and cognitive mode; namely, how people think about and describe the topic in the academic and practice literature. The two research questions emerged from this approach: **RQ1**: What are the similarities and differences in the formulation of the problems and opportunities of the digital transformation of the healthcare industry using analytic thinking and systems thinking? **RQ2**: What are some possible differing interventions and choices to the challenges arising from the analytic and systemic conceptions of digital transformation of the healthcare industry?

To address and respond to these questions, Chapter 2 Literature Review presented the healthcare ecosystem, the main stakeholders, the interactions of stakeholders through value chains, and a systems thinking perspective in discerning the complexity of the healthcare ecosystem due to the complicated interactions and dependencies among stakeholders. This was followed by Chapter 3 Pilot Studies which described a set of studies carried out over a one-year period that examined four main topics related to the digital transformation of the healthcare industry. These were appropriate leadership for managing complexity and change; an integrated healthcare provider model that is adapted the local socio-economic needs; a review of a key digital technology (big data and big data analytics) and its application in the healthcare industry; and the issues related to digital contact tracing in handling the COVID-19 pandemic. Chapter 4 Methodology and Results utilized a literature examination process to identify recent research on the applications of digital technologies in the healthcare industry and potential impacts on the healthcare ecosystem and stakeholders. This chapter summarizes what may be learned from and the implications of this research and responds formally to the two research questions.

What Was Learned from This Research

Recent research focused on the time frame between 2000 and 2022 because the concept of digital transformation and IR 4.0 began to emerge and materialize after 2000. I identified that these publications clustered around healthcare providers, healthcare consumers, and the healthcare ecosystem. In this chapter, I discuss the potential impacts.

Impact of Digital Transformation on Healthcare Providers

Healthcare providers are significantly affected by digital transformation in the context of 4IR. Similar to previous industrial revolutions, the adoption of digital technologies in healthcare providers' operations greatly improves the overall quality and effectiveness of healthcare services and products for both clinical and non-clinical services. Digital technologies, such as IoT, big data, and cloud computing, allow healthcare providers to collect and store more data regarding the health records of patients. The development of big data analytics enables knowledge creation, application, and synthesis (Idri et al., 2018; Zhao and Canales, 2021; Deepa & Khilar, 2022; Negro-Calduch et al., 2021). Digitized medical practices (Stephanie & Sharma, 2020), and improvement of the digital clinical decision support system (Cunha et al., 2022; Sly et al., 2022; Li et al., 2022; Basile et al., 2022). These outcomes have enabled ~~so that~~ healthcare providers to further improve the services related to diagnosis, treatment, and rehabilitation for certain diseases (Idri et al., 2018) and for the targeted populations (Nikou et al., 2022). Furthermore, digital health records can be shared and used by various provider stakeholders (e.g., pharmacies, pharmaceutical companies, tech companies, etc.) through various means such as openEHR (Cunha et al., 2022), OminPHR (Roehrs et al.,2017), health data space (Hussein et al., 2022), and medical cloud server (Benil & Jasper, 2020). This "secondary use of data" (Hussein et al., 2022) fosters knowledge discoveries and innovations in healthcare at a larger scale (Giacalone et al., 2018; Chae, 2019; Zahid et al., 2022).

A second influence is that digital technologies, such as 5G cellular technologies, and web-based platforms, significantly change care delivery methods. Namely, care can be delivered without time and geographical constraints. These innovative care solutions include remote patient monitoring, ambient assisted living (Ahmed and Kannan, 2022; Landolfi et al.,2018), and in-home service (Tsiotsou & Boukis, 2022; Choukou et al., 2021). The general trend is that care can be delivered through a physical-cyber model based on an infrastructure sustained by digital technologies.

A third outcome is that the data-driven approach can also help healthcare providers to improve their operations. For example, by leveraging big data and data analytics in business intelligence, healthcare providers can perform better intelligence management (Landolfi et al.,2018) to improve operational efficiency. For example, the development of effective KPI to

enhance value-based care (Schiavone et al., 2022), improvements to the supply chain (Beaulieu & Bentahar, 2021; Benzidia et al., 2021), and enhanced resilience of hospitals (Tortorella et al., 2021; Garcia-Perez et al., 2022) have emerged.

However, digital technologies also have dark unintended side effects that can increase the costs of healthcare providers in digital transformation. That is, digital technologies can threaten privacy, erode security, and impose ethical challenges because data play an essential role in the digital transformation of the healthcare industry. Privacy issues surrounding health data have gained increased attention over the years (Park & Chung, 2017; Maher et al., 2019; Yang et al., 2019; Lv and Qiao, 2020; Ray et al., 2020). To address this issue, governments in US, Europe, and China have strengthened personal data and privacy protections by passing new laws and regulations which will significantly increase the compliance costs for healthcare providers. Moreover, health information systems become increasingly complex with new functions being built into them and a huge amount of data being stored in them. Security of the IT infrastructure and security of medical and personal data are important for the functioning of healthcare providers in a digital era (Yaacoub et al., 2020; Mashaly, 2021; Bhavin et al., 2021). To maintain a universal cyberspace with global standards for privacy, security, and interoperability is a big challenge for healthcare providers. Moreover, the wide adoption of artificial intelligence in automated decision-making also raises ethical challenges because decisions made by algorithms that are poorly designed or trained can be biased and therefore fuel inequality (Dicuonzo et al., 2022; Čartolovni et al., 2022). OECD countries and the European Union have begun to regulate the usage of artificial intelligence to reduce its potential damage, which adds to the compliance cost of healthcare providers.

Besides the costs associated with digital technologies, healthcare providers face the challenges related to developing new capabilities for a digitalized healthcare industry. These capacities include (1) knowledge related to digital competition pathways to develop individual organizations' digital strategy and digital initiatives (Velthoven et al., 2019); and (2) capabilities and competencies for managing knowledge, innovation, and co-creation of values with technology firms and other stakeholders (Kokshagina, 2021; Jimenez et al.,2021; Mežnarec & Bogataj, 2021). For example, the healthcare workforce and its professionals need to possess the required digital skills (Jimenez et al.,2021; Mežnarec & Bogataj, 2021). On the other hand, the

healthcare providers also need to be more agile to the change of value creation in the healthcare ecosystem (Peltier et al., 2020), and manage the innovations based on adaptive complex networks with other innovators in the ecosystem (Denicolai & Previtali, 2020).

Implication for Healthcare Providers

Digital transformation has significant implications for healthcare providers, as it affects various aspects of their operations. The adoption of digital technologies improves the overall quality and effectiveness of healthcare services and products, as well as creates new opportunities for innovation and knowledge creation. For instance, big data analytics, IoT, and cloud computing enable healthcare providers to collect and store more data regarding the health records of patients, which fosters knowledge discoveries and innovations in healthcare at a larger scale. Digital technologies also change care delivery methods, allowing care to be delivered without time and geographical constraints, which significantly increases access to care. Furthermore, the data-driven approach can help healthcare providers to improve their operations by leveraging big data and data analytics in business intelligence, supply chain management, and enhancing the resilience of hospitals.

However, digital transformation also has dark side effects, such as increasing the costs of healthcare providers due to privacy, security, and ethical challenges. Privacy issues surrounding health data have gained lots of attention, and governments have passed new laws and regulations, which will significantly increase the compliance costs for healthcare providers. Moreover, the security of the IT infrastructure and medical and personal data are important for the functioning of healthcare providers in a digital era. Additionally, the wide adoption of artificial intelligence in automated decision-making also raises ethical challenges because decisions made by algorithms that are poorly designed or trained can be biased and therefore fuel inequality. Besides the costs associated with digital technologies, healthcare providers also need to face the challenges related to developing new capabilities for a digitalized healthcare industry, including the knowledge related to digital competition pathways, capabilities and competencies for managing knowledge, innovation, and co-creation of values with technology firms and other stakeholders, and possessing the required digital skills. Therefore, healthcare providers need to carefully consider the implications of digital transformation and develop strategies to address the associated challenges while embracing the opportunities that digital technologies offer.

To leverage the full potential of digital healthcare, organizations need to have certain capabilities that enable them to adapt to the rapidly changing environment and foster innovation. The following organizational capabilities are suggested to effectively navigate digitalized healthcare:

(1) Agility for Change: The healthcare industry is dynamic, and organizations need to be agile and responsive to change. This requires a culture that is open to change and continuous improvement, as well as processes that enable rapid decision-making and implementation.
(2) Knowledge Creation and Innovation Management: Digital healthcare involves the development of new technologies and solutions that require specialized knowledge and expertise. Organizations need to foster a culture of innovation and provide employees with the necessary tools and resources to create and share knowledge.
(3) Highly Skilled Labor: Digital healthcare requires highly skilled labor, including data analysts, software developers, and cybersecurity experts. Organizations need to attract and retain top talent by providing competitive compensation packages, opportunities for professional development, and a supportive work environment
(4) Flexible and Adaptive Structure and Process: Digital healthcare requires a flexible and adaptive structure and process to support innovation and respond to changing market demands. This requires the ability to quickly adapt to new technologies and business models, as well as the willingness to experiment and take risks.
(5) Corporate Culture: Digital healthcare requires a corporate culture that values innovation, collaboration, and continuous learning. This includes a focus on customer-centricity, data-driven decision-making, and a commitment to ethical and responsible practices.

Impact of Digital Transformation on Healthcare Consumers

Industry 4.0 and its global digital context impacts many aspects of people's lives. Healthcare is no exception. The biggest change brought by the digital transformation of the healthcare industry is how consumers utilize healthcare services and products. This is because digital transformation can improve people's access to care and the quality of care that they receive. In particular, digital health system and digitalized care services and delivery (e.g., teleconsulting, on-cloud health clinic) can provide easier access to care where these had been

lacking or difficult: in developing countries and rural areas (Ramaswamy et al., 2022; Mbunge et al., 2021; Miah et al., 2017).

Another trend is the empowerment of consumers through digital technologies. The wide applications of internet-based platform or web-based platform, and built-in functions in mobile phone apps allows a 24-7 interaction between care providers and consumers so that consumers can provide feedback to care providers regarding their expectations and experiences (Bez et al, 2022). With more data from consumers, care providers can design more customized products and services. More importantly, the advent of social media enables the C-2-C communication among consumers which will further disseminate health information and improve patient and consumer engagement (Sharma & Kaur, 2017).

Third, consumers are experiencing a bundle of physical-cyber combined products and services related to care that are provided by traditional and non-traditional providers. For example, big tech companies, as non-traditional providers, provide care services and product bundles using wearable technologies. Consumers can use smart wearable devices (e.g., Apple watch) which can be connected to mobile phone applications on their smartphones to perform a wide range of self-monitoring. And mobile phone applications can further provide targeted suggestions on diets, exercise, sleeping, and personal lifestyles. During this process, the generated data can be further utilized by multiple stakeholders to develop targeted services. Digital transformation has led to a dramatic shift in the value chain, which is moving upstream from recovery and surgery to prevention and monitoring (Denicolai & Previtali, 2020).

Fourth, besides improving the quality of care provided by private providers, digital transformation also improves the overall quality of care (Popkova & Sergi, 2022). Specifically, the COVID-19 pandemic between 2000 and 2022 demonstrated the capabilities of digital technologies and e-health solutions in addressing this public health crisis and served as a catalyst for the acceleration of the digital transformation of healthcare (Siriwardhana et al., 2022; Alhasan & Hasaneen, 2021; Jain et al., 2021; Secundo et al., 2021). Overall, the digitalized health system is one aspect of the fundamental change in our society under Industry 4.0 (Gerli et al., 2021).

Similar to healthcare providers, patients and consumers are facing the negative impacts of digitalized healthcare. First, while personal data are collected through traditional ways, more and

more data dare generated and collected in a passive way that consumers may not be aware of (Maher et al., 2019). An increasing amount of health care records, along with other personal data, are stored and shared in the digital space. This raises data security issues for individuals in a data-centric health system (Lv and Qiao, 2020; Zahid et al., 2021). Also, in a data-centric health system, data are shared, used, and re-used by many stakeholders. This can raise concerns about data ownership (Yang et al. 2019). Furthermore, consumers may face biased automated decisions made by poorly trained computer algorithms which will cause them harm (Aerts & Bogdan-Martin, 2021). Digital literacy, digital capabilities, and other socioeconomic factors of consumers will also cause a digital divide, which will in turn affect the equality of access to care in a digitalized health system (Nguyen et al., 2017). Moreover, consumers' resistance to digital technologies due to a lack of trust, and anxiety for perceived risky technologies can impede the development of eHealth (Iyanna et al., 2022; Talwar et al., 2022).

Implications for Healthcare Consumers

Digital transformation of the healthcare industry has implications for healthcare consumers in several ways. Firstly, it can improve people's access to care and the quality of care they receive, particularly in developing countries and rural areas. Secondly, digital technologies empower consumers by allowing 24/7 interaction with care providers and enabling C-2-C communication among consumers, which disseminates health information and improves engagement. Thirdly, consumers can use physical-cyber combined products and services, such as smart wearable devices, which provide self-monitoring and generate data that can be utilized to develop targeted services. Fourthly, digital transformation improves the overall quality of care and can address public health crises. However, there are negative impacts on healthcare consumers, such as data security and ownership concerns, biased automated decisions, digital divide, and resistance to digital technologies due to a lack of trust and anxiety.

Impacts of Digital Transformation on the Healthcare Ecosystem

The biggest positive impact of digital transformation is a shift from an organization-centric to a patient-centric system. Patient-centric or people-centered care is a critical feature and necessary condition of the healthcare system worldwide. For example, WHO promotes that the

quality of healthcare shall be "effective, safe, and people centered." [6] Digital transformation allows biomedical innovation and knowledge discoveries to improve the effectiveness and safety of care. More importantly, the IT infrastructure enables the key stakeholders, including traditional authorized providers and non-tradition providers, to share digitalized health records of patients and to provide a bundle of products and services from a multi-dimensional view of the patient health state (Serbanati et al., 2011; Denicolai & Previtali, 2020). However, digital transformation may not entirely solve the access issue due to the digital divide (Miah et al., 2017; Nguyen et al., 2017). Health inequalities will only partially be alleviated by building capacity in ICT infrastructure and eHealth; different socio-political and economic conditions continue to challenge national health systems (Seddon & Currie, 2017).

The digitized healthcare ecosystem is a complex system with interconnectivity among processes, people, products, and services. It is also a contextual blend of the physical and virtual worlds in which a bundle of tangible and non-tangible products and services is offered by both traditional and non-tradition providers. Some researchers argue that a defining feature of the digitalized healthcare ecosystem is an innovative network that connects multiple domains, stakeholders, and supplies and is nonlinear, multi-agents, and multi-directional in nature (Denicolai & Previtali, 2020). More importantly, the digitalized healthcare system consists of evolving bundles of interlinked business models, and fast-learning healthcare systems based on heterogeneous knowledge-based services (Denicolai & Previtali, 2020).

Three important characteristics of the digitized healthcare system include that it is a data-driven model and process, it uses a multi-stakeholder architecture, and it has a value-chain structure of digitalized care solution.

Data–driven model and process

Data play a critically important role in the digital transformation of the healthcare system. First, data and data analytics change the existing healthcare practices to data-driven models in healthcare delivery and biomedical research (Cano et al., 2017). Data analytics also help providers to improve the efficiencies of their operational process. A significant recent trend is the

[6] This definition is extracted from https://www.who.int/health-topics/quality-of-care#tab=tab_1

so-called digital twins[7]which is a digital counterpart of the physical object being studied (Landolfi et al., 2018). Second, the sharing and re-use of various sources of health information by other stakeholders can facilitate the development of disruptive products and services. However, the developments of these new and innovative solutions are usually non-linear and hard to predict. The biggest challenge for the data flows is that personally identifiable information and health data regulation (e.g., HIPPA, GDPR) do not allow for data sharing. In addition, incompatible health systems can also create slow communication and communication gaps. Some researchers argue that further convergence of digital technologies can help to address these challenges (Farahani et al., 2021).

Multi-stakeholder architecture

Public entities, local communities, and citizens as key actors, and interplays regard collaborations and governance among subsystems and multi-domains such as knowledge, R&D systems, supply chains, physical and cyber networks, and platforms. The relationships among key players and subsystems can be non-linear and multidirectional, which further increases the complexity of the whole system.

Value-chain Structure of Digitalized Care Solution

Traditional value position of healthcare can be narrowly defined as a product or service-oriented perspective. That is products and services that can bring value to patients. More broadly, value creation can be affected by an array of factors, such as the technical dimension (apparatus, procedures), the non-technical dimension (relationships between patients and health unit personnel), and the environmental aspect (place of implementation) of healthcare as factors that impact the quality of healthcare. Or value creation is determined by the benefits such as economic benefits, technical benefits, humanity benefits, and emotional benefits when contemplating value for patients (Myszewski & Sinha, 2019). A defining feature of digitalized care is a bundle of physical and digital products and services. Moreover, digitalized care is an open and adaptive solution based on a rapid learning healthcare system (Denicolai & Previtali,

[7] A digital twin is a perfect digital copy of the physical object being studied. A twin would enable intake sensor data and simulate conditions quickly, understand what-if scenarios clearly, predict results more accurately, and output instructions to manipulate the physical world (Deloitte, 2020). Accessed at: https://www2.deloitte.com/us/en/insights/focus/tech-trends/2020/digital-twin-applications-bridging-the-physical-and-digital.html

2020) and an intelligence network surrounding the manufacturing, delivery, and maintenance chain(s). As a result, the value creation of digitalized healthcare system consists of evolving bundles of interlinked business models that are based on fast learning and innovation management. The success of a particular solution depends not only on the effort of one key player (e.g., healthcare provider) in this value-creation network but also on the efforts of other connected players as well. These changes in value chain of digitalized healthcare impose several challenges on healthcare providers' capabilities, i.e., collaboration, learning, knowledge and innovation management, and adaptation to fast changes and complexity.

Responding to the Research Questions

In this dissertation, two research questions were posed. This first is **RQ1**: What are the similarities and differences in the formulation of the problems and opportunities of the digital transformation of the healthcare industry using analytic thinking and systems thinking?

RQ1: Analytic and systems approaches to digital transformation

Analytic thinking and systems thinking are complementary approaches to problem-solving and decision-making that can be applied to the digital transformation of the healthcare industry that change the way of care. Analytic thinking may focus on identifying specific problems related to the implementation of digital technologies in healthcare, such as data security, data privacy, and data quality. This approach may also focus on identifying opportunities for digital technologies to improve specific aspects of healthcare, such as patient monitoring and treatment outcomes. While analytic thinking may focus on specific problems and opportunities related to the implementation of digital technologies, systems thinking emphasizes the ecosystem, interconnectedness, and complexity of the healthcare industry and the need for collaboration, coordination, and adaptation among stakeholders.

Systems thinking is a holistic approach that views problems as interconnected parts of a larger system. This approach emphasizes the relationships and interactions among different elements of the system and recognizes that changes in one part of the system can have unintended consequences in other parts of the system. Systems thinking may focus on understanding the complex web of relationships and interactions among different stakeholders in the healthcare system, such as patients, providers, payers, and regulators. Systems thinking can

also be used to understand the disruption caused by digital transformation. Disruption shall be better described as a process during which an incremental innovation can result in a breakthrough innovation, or many incremental innovations can lead to a transformational innovation in the healthcare ecosystem.

I have argued that the healthcare system may be better understood as a complex adaptive system (CAS). This means the system and its transformations are composed of individual agents and other elements that interact with each other and with their environment in non-linear and dynamic ways. The system is open, rather than closed: digitalization of healthcare system greatly expands the boundary of the ecosystem by including more stakeholders, disrupting previous barriers, and increasing the interactions among stakeholders while also imposing new challenges for stakeholders.

Approaching healthcare's transformation through systems thinking is a way of approaching complex problems by looking at the whole system rather than focusing on individual components. It involves understanding the patterns and relationships between the parts of a system and how they interact with each other and with their environment. The extant theories and tools of systems thinking can be applied to the digital transformation of healthcare in addressing numerous challenges.

Compared to analytic thinking, systems thinking can help to better understand the evolution and changes in the digital transformation of the healthcare system. CAS is characterized by emergent behavior, which means that the behavior of the system cannot be predicted by simply studying the behavior of its individual components. Instead, the behavior of the system emerges from the interactions between the agents and their environment. By understanding these patterns and structures, we can develop strategies for managing and adapting to complex systems.

Moreover, several systems approaches, methodologies, and tools can help healthcare organizations in addressing challenges related to complexity management, change management, knowledge, and innovation management, which are essential for them to adapt to digital transformation.

The second research question is **RQ2**: What are some possible differing interventions and choices to the challenges arising from the analytic and systemic conceptions of digital transformation of the healthcare industry?

RQ2: Differing interventions and choices to the challenges of differing conceptions

Regarding the RQ2, the analytic conception of digital transformation of the healthcare industry focuses on the existing sequence of stakeholders in the value chain. This perception can be useful in offering linear, casual solutions to mitigate the negative effects related to the digitlization of the healthcare industry, such as enhancing collaboration and partnerships between stakeholders to improve patient outcomes, reduce costs, and increase efficiency, enhancing data security and privacy and addressing the ethical issues along the existing value chain and data life cycle.

The systems conception of the healthcare ecosystem can be useful to address the issues related to complexity and emergent features that are very hard to predict at both the micro and macro level. For example, at the micro level, adaptive leadership and continuous learning can help the organization and employees to build capabilities on which they can develop new digital strategies to adapt to the changing landscape of digital healthcare. At the macro level, due to the complexity and interconnectedness of the healthcare ecosystem, co-creation between different stakeholders are essential to achieve effective digital transformation. Moreover, systems thinking can provide an anticipatory approach to ecosystem governance that involves collaboration among different stakeholders to identify emerging technologies, anticipate their impact on the healthcare ecosystem, and develop policies and regulations that are responsive to the rapid pace of technological change, which often outpaces regulatory frameworks. Since the systems conception recognizes the digital transformation's interactions with the broader social, economic, and political context, it can be useful in addressing the regulatory and legal barriers related to reduce resistance to digitalization, advocate equity and access to digital health technologies, and performa ongoing monitoring and assessment of the impacts of digital transformation on different stakeholders within and beyond healthcare ecosystem, and using this information to make proactive decisions. Four systems-informed conceptions for sense-making and two intervention tools are relevant and are described.

Cynefin Framework: The Cynefin Framework (Figure 11, page 27) categorizes challenges into two broad domains each with two implications. For a structured and ordered domain, challenges may be addressed as simple (obvious) or complicated. For an unordered and unstructured domain, problems are complex, and chaotic. In the varying contexts of the digitalization of healthcare industry, different parts, or different levels of operations of the healthcare system may fall into different domains. Table 10 presents the four domains and suggests corresponding transformational changes. Some changes (such as an operational process) can be simple and easy to manage. However, some changes can be complex (e.g., the development of new policy) or chaotic (e.g., the development of a new business model). To address both kinds of challenges requires mindset agility to shift between analytic to systemic thinking and practices.

Table 10: Cynefin framework and Digitalization

Domain	Characteristics	Parts or Operation of Healthcare
Simple	systems are predictable and cause-and-effect relationships are clear	Basic administrative tasks such as scheduling appointments or ordering supplies
Complicated	systems are predictable, but cause-and-effect relationships are not immediately clear	Developing new medical technologies or implementing complex clinical pathways
Complex	systems are characterized by nonlinear relationships and emergent behavior	Development of patient care or healthcare policy, where there are many different factors to take into account, and the outcome is not always predictable
Chaotic	systems are highly unpredictable and require immediate action to stabilize	Use new technology to develop new business models for care and care delivery in order to meet emerging demand for care

Collaboration among stakeholders: Systems thinking can help healthcare stakeholders to collaborate more effectively by promoting a shared understanding of the interdependent relationships between different parts of the healthcare system. By taking a systems approach, stakeholders can identify areas of common interest and work together to achieve shared goals. For example, a hospital system may use systems thinking to better understand the needs of patients and develop more collaborative relationships with other providers in the community.

Knowledge and innovation management: Systems thinking can support knowledge and innovation management by promoting a more holistic understanding of the healthcare system and the factors that influence it. By taking a systems approach, stakeholders can identify the sources of knowledge within the healthcare system, such as best practices, clinical guidelines, and patient feedback, and work to integrate this knowledge into their decision-making processes. For example, a healthcare organization may use systems thinking to develop a knowledge management strategy that integrates data from electronic health records, patient surveys, and other sources to support evidence-based decision-making.

Transformational leadership and capability building: Transformational leadership is a style of leadership that focuses on inspiring and motivating employees to achieve shared goals and objectives through innovation and change. In the context of digital transformation of healthcare, transformational leadership is essential to successfully navigate the challenges of developing new capabilities in technologies and operational processes and engaging with multiple stakeholders. One of the key challenges faced by healthcare organizations in digital transformation is the need to develop new capabilities in technologies. This requires transformational leaders to create a culture of innovation and experimentation, where employees are encouraged to explore new technologies and approach to care delivery. Leaders must also provide the necessary resources and support for training and development to ensure that employees have the skills and knowledge needed to work with new technologies. Another challenge in digital transformation is the need to transform the business model to accommodate new technologies and the participation of multiple stakeholders. This requires transformational leaders to develop a shared vision and strategy for digital transformation that is aligned with the needs and goals of all stakeholders, including patients, providers, payers, and regulators. Leaders must also foster collaboration and communication among stakeholders to ensure that everyone is working together towards the shared goal of digital transformation.

Tools: A large body of theories and tools of systems thinking can be very useful in addressing complicated problems in healthcare (Peters, 2014). Extant systems thinking tools, such as agent-based modeling and scenario planning, can be combined with new digital technologies, such as digital twins, to improve healthcare operations and policy development. Agent-based modeling (ABM) is a simulation technique that models the behavior and

interactions of autonomous agents, such as individuals, groups, or organizations, within a complex system. In healthcare, ABM can be used to model the behavior of patients, healthcare providers, and other stakeholders, as well as the interactions between them, to better understand the dynamics of the healthcare system. Digital twin technology is a virtual replica of a physical object, system, or process that can be used to simulate and analyze the behavior of a real-world system. For instance, digital twin technology has the potential to revolutionize healthcare operations management by providing real-time insights into the performance of healthcare systems, facilities, equipment, and process. Combining ABM with digital twin technology can provide a more comprehensive and accurate representation of the healthcare system. ABM can model the behavior of individual agents within the system, while the digital twin can simulate the system as a whole. This allows for a more detailed and realistic understanding of the system's behavior and the potential impact of interventions or changes.

Scenario analysis, on the other hand, is a tool used to explore and evaluate different potential future scenarios based on a set of assumptions and variables. One challenge imposed by the digital transformation is the fast evolution of digital technologies and applications based on these technologies often move beyond the limits and constraints of extant regulatory frameworks. Moreover, because of the integration of information infrastructure and data flow among multiple stakeholders, the traditional boundaries among stakeholders become less clear due to digital collaboration. This impose the challenge on the governance on the digitalized healthcare ecosystem. In healthcare policy-making, scenario analysis can be used to assess the potential outcomes of different policy options or changes under different circumstances and assumptions. Combining ABM and scenario analysis can provide a powerful tool for transforming health policy-making. ABM can be used to model the behavior of stakeholders in response to different policy options or changes, while scenario analysis can be used to evaluate the potential outcomes of those options or changes under different scenarios. For example, policymakers can use ABM to model the behavior of patients, healthcare providers, and other stakeholders in response to a policy change, such as the introduction of a new healthcare technology or the implementation of a new payment system. Scenario analysis can then be used to evaluate the potential outcomes of that policy change under different scenarios, such as changes in patient behavior or shifts in the healthcare market.

Final comments

Industry 4.0, like the three industrial revolutions before it, will have a profound impact on every aspect of our society. To better understand the convergence of the physical and digital realm in healthcare industry, I take a systems perspective to examine the digital transformation in healthcare industry. Particularly, I address two research questions related to the opportunities and interventions to digital transformation that can be offered by the analytical and systems conception. I find that majority of extant studies focus on the impacts of new digital technologies on healthcare providers. Beside the opportunities, digital transformation also impose serious challenges, such as data privacy, ethical issues related to automated decision making based on AI, and equity issues related to Ehealth. I also propose that the extant systems thinking theories and tools can be used to offer solutions to several major challenges at both micro and macro levels. For example, a key strength of systems thinking is continuous learning and adaptation. Therefore, adaptive leadership combined with a systems thinking mindset can be very useful for healthcare organizations to develop required capabilities in a digital era. Because systems thinking focuses on the interconnectedness of subsystems and stakeholders, it can be very helpful to be combined with latest digital technologies such as digital twins to study the dynamic interactions among key stakeholders to develop new regulatory policies.

There are several limitations of this study. First, I use the systemic literature review to examine the recent literature on the digitalization of healthcare industry. Similar to previous studies, I use specific conditions to determine the relevance of studies and search related literature in mainstream databases. The coverage of the relevant studies could be different if I use different screening conditions and other database. Second, the clusters of relevant studies are identified by the proposed code schemes that is based on the systems conception of the healthcare ecosystem and therefore can be objective and restricted. Third, I focus on the implications of digital transformation for key stakeholders of healthcare ecosystem. This does not imply that the digital transformation would have little impact on other stakeholders.

Looking into the future, there are several interesting directions to expand my research. First, because of the highly dynamic nature of the evolution of digital technologies and digital transformation, new patterns, new connections, and new challenges will emerge. Therefore, a continuous monitoring and assessment of the healthcare ecosystem will be necessary for

practitioners and regulators to understand future change and its drivers and adjust strategies accordingly. Second, digital transformation will not affect stakeholders evenly. And not all innovations will be successful. The process of digital transformation of healthcare industry provides an idea setting to further examine the dynamics of competition between new entrants and incumbents, and gaming between market participants and regulators using theories such as disruption and innovation.

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