

# Digital Health in Singapore: Building an Ecosystem Conducive for Innovation-Driven Enterprises

by

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Submitted to the System Design and Management Program  
In Partial Fulfillment of the Requirements for the Degree of

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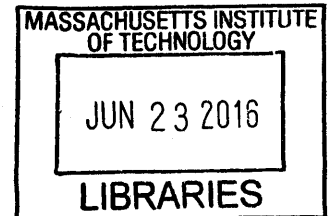
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## **Abstract**

Healthcare is undergoing a digital revolution. In Singapore, business-friendly policies, strong information technology capabilities, and a world-class healthcare system seem to provide the necessary ingredients for digital health businesses to thrive. However, the depth of digital health start-up activities still pales in comparison with more mature ecosystems like Boston. Some challenges of the digital health sector include requiring an understanding of a wide set of stakeholders, facilitating cross-disciplinary innovation across patient care and digital technologies, and propagating innovation in hospital environments. The digital health innovation-driven enterprises ecosystem in Singapore is explored through an in-depth analysis of Singapore hospitals as a key stakeholder and an assessment of healthcare hackathons' suitability in addressing the present gaps. A set of recommendations are presented that could help to promote activities conducive to digital healthcare innovation and entrepreneurship in Singapore, which include extending key stakeholders' networks as well as enhancing access to key human resources and mentoring during the early stages of start-up formation.

Thesis Supervisor: Prof. Fiona Murray

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## Acknowledgments

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## **Chapter 1: Introduction**

With Singapore’s recent drive towards increased economic sustainability and productivity<sup>1</sup>, there has been a renewed and strengthened focus on innovation-driven enterprises (IDEs) in the information and communication technologies (ICT) sector to diversify the economy and provide solutions for the nation’s demographic and urban living challenges. Additionally, Singapore has recently launched the “Smart Nation” campaign to harness opportunities for ICT to support better government services and quality of life, and to support IDEs in these domains. Digital health is one such ICT subsector that straddles these initiatives. Potentially, such IDEs could leverage the capabilities of Singapore’s high quality healthcare system, while also resolving the impending challenges in healthcare costs and quality.

### **1.1 Defining Digital Health**

“Digital health” as a concept first appeared in academic literature at least 15 years ago. In “Digital Health Care—The Convergence of Health Care and the Internet”, Seth Frank discusses how the continued proliferation of the internet will radically improve medical care faster than any previous information systems or communications tool. He outlined many benefits of this technology, chief among them being increased access to healthcare and cost savings. (Frank 2000)

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<sup>1</sup> Coordinated by the National Productivity and Continuing Education Council (NPCEC).

Like other consumer industries, digital technology's transformation of healthcare continues today, accelerated by advances in big data, social networking, mobile connectivity, and processing power. Eric Topol refers to this convergence of technologies and medicine as begetting the "digitization of human beings", an end larger than the "digital medicine" that Frank envisioned (Topol 2013). According to Rock Health, one of the most prominent digital health seed funds, digital health companies are those that "build and sell technologies—sometimes paired with a service, but only when the technology is, in and of itself, the service" (Gandhi 2013).

This thesis takes digital health to encompass the space at the intersection of healthcare and technology that Topol and Rock Health describe: digital technology solutions that go beyond medicine and across healthcare to also include wellness and administration. From the perspective of hospitals and healthcare systems, digital health will encompass healthcare IT, but also include: innovations in remote healthcare monitoring and diagnosis, workflow streamlining, patient engagement, as well as the use of big data in health that facilitates clinical research and new models of care.

## **1.2 Primary Research Objectives**

The objectives of this thesis are twofold. The first objective is to identify the strengths and weaknesses of the Singapore digital healthcare IDE ecosystem, and also provide insights on how the ecosystem can be improved. As hospitals are such a pivotal stakeholder in this ecosystem, this aim will be achieved by doing case study

on a particular hospital in Singapore, KK Women's and Children's Hospital (KKH), and comparing it with a similar hospital in Boston, the Boston Children's Hospital (BCH). Boston's healthcare ecosystem is known for nation-leading hospitals and vibrancy in digital health startups. While KKH and BCH operate in very different environments, this case study is meant to provide context for KKH's innovative and entrepreneurial capacities, as well as give concrete examples of successful digital health innovation and implementation practices. Data for this case study will be sourced from publicly available data pertaining to the hospitals, a bibliographic study to understand stakeholder network strength and research diversity, as well as a set of interviews with relevant leaders and physicians in each hospital to compare internal policies, resources, cultures, and attitudes.

The second objective is to understand if and how healthcare hackathons could potentially enhance Singapore's ecosystem for fostering digital health innovation and entrepreneurship. An opportunity to study this arose in the form of a digital health hackathon held in Singapore in July 2015. Through a post-event survey, participants were asked to assess the effectiveness of the healthcare hackathon in raising awareness of digital health opportunities, as well as in educating for digital health innovation.



## **Chapter 2: Literature Review**

### **2.1 Innovation Driven Enterprises**

The link between entrepreneurship and economic growth is well established (Audretsch, Keilbach, and Lehmann 2006; Acs 2006). Entrepreneurs start new enterprises, and these new enterprises in turn create new jobs, intensify competition or unveil a new market, and may increase productivity through technological change. Further, entrepreneurs take on the high-risk venture of translating new knowledge to economic gain with relatively few resources, but with potentially large gains.

However, not all entrepreneurship activities are created equal. There are the familiar Small and Medium Enterprises (SMEs), which are created to serve local markets with traditional goods and/or services. These “mom and pop” shops provide valuable services and employment opportunities for the community, but are not fast growing or scalable enough to be a substantial growth engine for the larger economy (Aulet and Murray 2012).

Contrastingly, IDEs are based on innovation (technological or otherwise), seek to compete in the global market, and typically require a diverse ownership base that includes a variety of external capital providers (Aulet and Murray 2013). IDEs have also been shown to have a job multiplier effect: creating five jobs for every direct IDE job (Moretti 2012). Finally, an IDE’s success looks radically

different from a SMEs. While SMEs tend to grow at a linear rate, IDEs typically lose money at the beginning as investment is necessary to develop the innovation that is at the core of the business, but have the potential for exponential growth if successful.

The lens of the IDE is especially suited to an analysis of digital health entrepreneurship in the Singapore ecosystem. IDEs' potential for exponential growth sets these risky ventures apart from SMEs, and allows them to be considered as a powerful growth lever for the economy; an important consideration as Singapore grapples with the potential of economic growth that depends less heavily on foreign direct investment (FDI). The success stories of Silicon Valley's internet companies and Boston's biotechnology startups are testaments to the impact that IDEs and an IDE-friendly ecosystem can have.

### **2.1.1 Ecosystem Approach to Entrepreneurship**

There are many different paradigms to consider entrepreneurial environments for characterization and comparison. Often also referred to as an innovation ecosystem, this framework of a "system of innovation" — the premise that innovative performance is based on the flow of technology and information among people and organizations — was introduced in 1985 (Lundvall 1985). This framework has also been used to describe and characterize the external factors important to entrepreneurs' success (Engel 2015; Fetters, Greene, and Rice 2010; Shirley 2013; Suresh and Ramraj 2012). Using the metaphor of an ecosystem to study

entrepreneurship highlights the interconnectedness of the players, and emphasizes that individual members rarely succeed alone in a vacuum.

### **2.1.2 Network Strength**

The strength of this interconnectedness and the level of information exchange has been shown to strongly facilitate innovation (Jansen, Van Den Bosch, and Volberda 2006; Luoma-aho and Halonen 2010). Another way these innovation networks have been studied has been through the concept of clusters. Porter highlighted how clusters — “geographic concentrations of interconnected companies and institutions in a particular field” — play a significant role towards a company’s competitiveness and success (Porter 1998). Clustering has been shown to have a positive correlation to innovation, due mainly to the easier communication and increased network-based value creation that arises from geographical proximity (Mercan and Goktas 2011).

The personal decision to pursue a new business venture is also closely intertwined with the strength of the cluster. Being connected to both resources and demand enables the entrepreneurial process by triggering the entrepreneur to explore particular business opportunities (H. A. Aldrich and Whetten 1981; Butler and Hansen 1991). Further, the opportunity to act is typically viewed by the entrepreneur time limited, and speed of implementation is often dependent upon resources from the immediate ecosystem (Zander 2004).

### **2.1.3 Network Diversity**

For entrepreneurs, access to a network of varied stakeholders is crucial for success, especially given the new venture's relatively resource-scarce state when compared to its established competitors. Entrepreneurship, especially in IDEs, depends on the available specialized labor, equipment, facilities, and financing available from these external networks (H. E. Aldrich and Ruef 2006; Shapero 1975).

### **2.1.4 MIT's Regional Entrepreneurial Acceleration Program**

As a participant in the MIT Regional Entrepreneurial Acceleration Laboratory (REAL) in 2014 led by Professor Fiona Murray and Dr. Phillip Budden, we analyzed regional entrepreneurial ecosystems and their respective acceleration strategies using a comparative and contextual approach. This class introduced me to the MIT Regional Entrepreneurial Acceleration Program (REAP) framework, which is particularly notable for three reasons: its intent is to drive the growth and impact of IDEs; it differentiates between innovation capacity and entrepreneurial capacity when considering the strengths and weaknesses of an ecosystem's framework conditions; and it focuses on the interaction between five key stakeholders as the precursor for the success of IDEs: besides entrepreneurs, these include academic, government, established enterprise, and "risk capital" stakeholders.

Each of the stakeholders plays a different role with regards to the entrepreneur (Budden and Murray 2014):

- Academic: A source of innovation and human capital, as well as opportunities for knowledge and technology transfer.
- Government: Ability to enact policies and programs that affect the business environment, availability of support for new ventures, and society's perception of entrepreneurs.
- Established enterprises: A source of demand and human capital, as well as opportunities for knowledge and technology transfer.
- Risk capital: A source of financing that is amenable to the high risks undertaken by IDEs.

The REAP framework and program go beyond the academic. REAP is a global initiative “designed to help regions accelerate economic growth and job creation through innovation-driven entrepreneurship”. Structured as a two-year program, teams from partner regions are formed from the five major stakeholder groups previously mentioned<sup>2</sup>. This stakeholder centric model allows acceleration strategies to not only be tailored to a region's specific needs, but also enables the identification of the right actor(s) based on each stakeholder's inherent strengths.

### ***Innovation and Entrepreneurial Capacities***

The REAP framework highlights two distinct capabilities for entrepreneurial ecosystems: innovation capacity and entrepreneurial capacity. In the framework, Murray and Budden define Innovation Capacity (I-Cap) as the “ability to develop

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<sup>2</sup> Source: MIT REAP website, <http://reap.mit.edu/about/>.

new-to-the-world-innovations from inception through to the market,” and Entrepreneurial Capacity (E-Cap) as the “ability to start and build new to the world businesses from inception to maturity” (Budden and Murray 2014). Without entrepreneurial capacity, an ecosystem doesn’t have sufficient propensity to transfer new ideas, technologies and innovations into commercially viable businesses. Without innovation capacity, new businesses formed will tend to be of the lower impact SME variety, as opposed to the IDEs that are required for economic growth.

Discrepancies in these two capabilities play out in many entrepreneurial ecosystems. This framework is especially useful when studying Singapore, where significant investment in public R&D has increased innovation output, but with much less impact on new enterprise formation. As an example, this can be seen in the INSEAD Global Innovation Index, where Singapore is ranked 1st in innovation input and 2nd in human capital & research, but 13th in new business formation (Scott and Vincent-Lancrin 2014).

## **2.2 Hospitals’ Role in the Ecosystem**

Hospitals play a unique and multi-faceted role in the digital health IDE ecosystem, the richness of which may not be replicated elsewhere in other industry clusters. Firstly, hospitals are a key source for many framework conditions of this ecosystem - including people, infrastructure, policy, culture, community, and demand. Today, with hospitals seeing digital health and healthcare IT as a way to improve patient

care outcomes and improve efficiency, some hospitals are even providing funding for nascent digital health solutions, whether to be piloted at their premises or as an outright investment (Chase 2012).

Secondly, hospitals represent two stakeholders in the REAP model. As teaching hospitals are a key source of research for new medical interventions, they play the academic stakeholder role. As large entities that purchase and implement technologies at a significant scale, hospitals also act as an established enterprise stakeholder. This dual role as key innovator and significant technology user in the ecosystem means digital health IDEs often require direct interaction with hospitals to progress.

Hospitals can also be a fertile source of “opportunity discovery”. Opportunity discovery is the process by which entrepreneurs can find situations in which products or services can be sold at greater than their cost of production (Casson 1982; Hsieh, Nickerson, and Zenger 2007; Shane and Venkataraman 2000). As a significant source of healthcare delivery, hospitals are a location through which healthcare solutions and businesses ideas can originate, with hospital staff and patients often being the most intimately aware of the challenges that can be addressed. While hospital staff may not themselves need to become entrepreneurs for such opportunities to evolve into businesses, their involvement in testing new digital health business ideas may be key to the success of such enterprises (Shapiro and Angelo 2014).

### **2.2.1 Innovation in Healthcare**

*“In health care, invention is hard, but dissemination is even harder.” (Berwick 2003)*

Globally, healthcare systems are dealing with many issues simultaneously, including maintaining access and quality, containing costs, aging populations, and rising public expectations. Being a high-reliability organization, hospitals and healthcare systems must enable their managers and healthcare professionals to make informed and accurate decisions in an unpredictable and dynamic environment (Thakur, Hsu, and Fontenot 2012). Nemeth and Cook described the success of these organizations as depending on “the accurate, timely description of process and conditions” (Nemeth and Cook 2007). Additionally, the milieu that healthcare organizations operate in is a complex one, relying on multifaceted interactions between patients, payers (e.g. health insurers, companies, individual patients), providers (e.g. physicians) and suppliers (e.g., pharmaceuticals, medical device manufacturers) (Thakur, Hsu, and Fontenot 2012). This combination of ambiguity and complexity can often stymie the application of innovation in healthcare (Aslani and Naaranoja 2013).

Definitions of innovation in literature often focus on what is new, whether with regard to an organization’s external offering of product or service to the user, or to the implementation of new internal processes or organizational structure, or both (Damanpour 1991; Evangelista and Sirilli 1995; Lynn and Gelb 1996). In healthcare systems, innovation is rarely undertaken for its own sake and often must



compete with and contribute towards the healthcare organization's primary aims, which Williams summarized as "efficiency, equity and coverage" (Williams 2011). At the same time, these innovations must ensure or improve patient safety and outcomes. For the purpose of this study, healthcare innovation is taken from Thakur *et al* as "changes that help healthcare practitioners focus on the patient by helping healthcare professionals work smarter, faster, better and more cost effectively" (Thakur, Hsu, and Fontenot 2012).

As to the nature of healthcare innovations, Aslani and Naaranoja describe these as falling into four main categories (Aslani and Naaranoja 2013):

1. Product/service innovation: a new good or service that improves the healthcare organization.
2. Process innovation: new or improved method of operation, including the introduction of relevant equipment and/or software.
3. Delivery innovation: a new form of delivery or marketing method that requires significant changes in "service design or packaging, health service placement, and care costs."
4. Organizational/administrative innovation: new business practices, internal structures, or relations with external stakeholders.

### **2.2.2 Diffusion of Innovations into Healthcare**

However, while a solution may have been demonstrated, the diffusion of innovations into the healthcare environment can be slow and frustrating (Williams

2011). Literature abounds with examples where – despite significant and sustainable proven improvements in patient care and costs – healthcare professional and providers did not adopt, or even fought against, an improved product, process or delivery often because of an unsupportive culture, low levels of involvement and buy-in from key users, or lack of support from leadership (Flamm et al. 1997; Weiss et al. 1997; Nugent et al. 1999; Berman et al. 1997).

An organization’s predisposition to innovative ideas is dependent on internal factors, such as organizational culture, and external environments, such as competition (Becker and Whisler 1967). An important combination of this two is the “market-oriented business culture”, which literature notes is important for the successful identification of customers needs and competitors capabilities, and consequently ensuring that the innovation being developed or implemented has clear customer value (Deshpande and Webster Jr 1989; Slater, Mohr, and Sengupta 1995). Thakur *et al* describes a healthcare organization’s openness to and adoption of innovative ideas as based on three key factors: “new technology, organizational characteristics (e.g. cultures, etc.), and market environment” (Thakur, Hsu, and Fontenot 2012).

At the individual level, the innovation must be perceived as having a positive impact to the people involved. The variance in the “rate of spread” can be predicted by perceptions of an innovation by between 49% and 87% (Rogers 1995). Berwick describes innovations as spreading faster when they have five perceived attributes:

benefit to the individual and/or mission; compatibility with existing values, beliefs and needs; simplicity of the proposed solution; trialability that enables testing of the solution; and observability that allows potential adopters to witness the impact that the change has on others first (Berwick 2003).

Additionally, certain individuals are more likely to create and adopt innovations rather than others. The classical model for innovation adoption was described by Rogers as the “diffusion of innovations” theory (Rogers 1995 p.xvi). Rogers called innovators the “cosmopolite” (Rogers 1995 p.196), and they are unique from the rest of the population by their “venturesomeness, tolerance of risk, fascination with novelty, and willingness to leave the village to learn” (Berwick 2003). While early adopters do not tend to invest as much energy into remote and innovative connections as the first group, they constantly interact with innovators and “have the resources and risk tolerance to try new things”. Crucially, they are also opinion leaders who report on their experiments with innovations, and are closely observed by the majority. For healthcare, the identification of “innovators” and “early adopters” are crucial to accelerate the pace of innovation dissemination. (Berwick 2003)

At the organizational level, studies highlight that the relationship between management and employees should be positive for innovation to be rolled out effectively and successfully. Specific to a healthcare organization, high level of employee interactivity (Fitzgerald et al. 2002), and a bottom-up approach rather

than a top-down approach is recommended to ensure extensive information sharing and successful innovation implementation (Thakur, Hsu, and Fontenot 2012). Flatter structures and decentralization of decision making within the context of healthcare “microsystems” can also encourage innovation to take place in this more organic bottom-up manner (Nelson et al. 2002).

Other factors, such as tolerance for failure, praise (or criticism) given to innovators, as well as policies and resources for innovation, provide environments in which innovators can be nurtured. The presence of leaders and innovation “champions” are also key: besides setting the culture and tone of the work environment, they can spur innovation to be undertaken or implemented; track implementation; and provide a “business case”, feedback, support, and guidance to stakeholders (Rogers 1995).

### **2.2.3 Success of Digital Health in Hospitals**

At its core, good healthcare delivery depends heavily on the timely use of information (Halford, Obstfelder, and Lotherington 2009; Nemeth and Cook 2007; Sanderson 2007). When physicians made house visits in the past, the standard of healthcare delivery depended on the ability of the individual doctor to recall his or her patients’ ailments, and the quality of the patient-doctor relationship. The modern practice of healthcare in today’s multi-provider system is heavily dependent on IT to support the appropriate delivery of relevant information as well

as the resultant decision made. Billing and healthcare records for patients are two of the earliest such IT systems used in hospitals (Thakur, Hsu, and Fontenot 2012).

Failure of ICT implementations in healthcare is not uncommon, with one study estimating the rate of failure at 75% (Littlejohns, Wyatt, and Garvican 2003). Studies indicate that while medical students and interns often reported benefits from new ICT systems, more senior doctors tended to be more ambivalent to the technology, often citing the inconvenience of change or the difficulty of operating the new technology as mitigating the improvements (Morrell, Podlone, and Cohen 1977; Lindquist et al. 2008). Case studies have shown that the range of individual and organizational factors previously discussed has significant bearing towards the successful implementation of ICT in healthcare. This includes the usefulness and ease of use of the new system (Ruxwana, Herselman, and Conradie 2010); identifying appropriate innovators and early adopters (T.-T. Lee 2004); market-orientation of leadership and the organization (Rowe et al. 2004); and commitment from both the ICT vendor team and acceptance by key user groups (Constantinides and Barrett 2006).

To increase the likelihood of an innovation's success, the third-wave business process design principles note that the process redesign or change should include representatives from each involved or affected department (Smith and Fingar 2003). With all representatives empowered in this process to assist the design and roll out of the ICT system, this enhances the innovation process, encourages

continuous improvement in the field, and strengthens the collective commitment to the innovation (Thakur, Hsu, and Fontenot 2012).

## **2.3 Hackathons**

A portmanteau of “hack”<sup>3</sup> and “marathon” (Lamela et al. 2013; DePasse et al. 2014), hackathons emerged towards the end of the 1990s as an event, typically lasting at least 24 hours and up to several days, where a large number of people engage in collaborative computer programming. While the precise origin of the term is unclear, the Calgary-based OpenBSD Project held one of the first of such events in 1999 to integrate what were then the latest internet protocols on their free UNIX-based computer operating system (OpenBSD 2015). Today’s hackathons encompass a wider range of activities than the invite-only, code-heavy, developer-exclusive nature of the first such events<sup>4</sup>. While today’s hackathons still tend to be a software developer-centric, hackathons became more widespread in other fields in the mid- to late-2000s (Briskin 2013). Beyond coding, hackathons today are also used to refer to events dedicated to finding solutions for diverse and often difficult challenges, including hardware, health literacy, sustainability, and marketing, to name a few (Calco and Veeck 2015; Henderson 2015; Johnson and Robinson 2014; Leclair 2015; Shandrow 2013).

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<sup>3</sup> From the earlier definition “to write computer programs for enjoyment”, and without the contemporary implications of illegal computer entry. Source: <http://www.merriam-webster.com/dictionary/hack>

<sup>4</sup> Which still operates in much the same way to this day.

A key characteristic of contemporary “social good” hackathons is the grouping of a broad range of subject matter experts together with technical experts, “builders”, and innovators (Chowdhury 2012; DePasse et al. 2014; Henderson 2015). This allows teams to form that have a deep understanding of the issue, the potential to develop new and break-through perspectives, and also the ability to quickly prototype and refine the proposed solution. What these types of hackathons have in common with traditional coding-focused events is the expectation for collaborative and intensive work within a limited period of time, and the expectation that each team needs to demonstrate a prototype at the end of the event.

## **Chapter 3: Background of Singapore and Opportunities in Digital Health**

*"I concluded an island city-state in Southeast Asia could not be ordinary if it was to survive." – Lee Kuan Yew, From Third World to First (K. Y. Lee 2000 p.24)*

Singapore's rise "from third world to first" is well known; the city-state is recognized as "possibly the most successful case of development among emerging economies in the 20<sup>th</sup> century"(L. Y. C. Lim 2014). The focus of the government on rapid economic growth has had lasting effects on the nation's IDE ecosystem and healthcare system. This chapter will use Singapore's economic trajectory since its founding to contextualize and give an overview of its existing entrepreneurship ecosystem, healthcare system, and the opportunities for digital health.

### **3.1 Singapore's Economy: From Independence to Maturity**

No recounting of Singapore's economic success can be done without mention of her founding Prime Minister (PM), the recently departed Lee Kuan Yew. At Singapore's founding in 1965, his broad vision was to create a "First World oasis in a Third World region" (K. Y. Lee 2000 p.7). PM Lee's firm belief in the government's strategic role set in place many of the policies, agencies, and programs that still exist in Singapore today.



### 3.1.1 Initial Conditions and Growth

Besides the strong leadership from the still-dominant People's Action Party, three "initial conditions" played a key role in Singapore's success: 1. Advantageous geographical position and port at the nexus of intra-Asian and international trade routes that allowed its role as a regional entrepôt within South East Asia; 2. An "entrepreneurial, largely immigrant" population already engaged in trade with their nearby countries of origin; and 3. Infrastructure and systems of government left by its former British colonial masters (Cahyadi et al. 2004; L. Y. C. Lim 2014; Porter, Neo, and Ketels 2009; Vietor and White 2014; World Bank 1993).

However, success was not ensured. The presence of labor unrest (Chia 2008); lack of natural resources coupled with a small domestic market (L. Y. C. Lim 2014); slow GDP growth and high unemployment (L. Y. C. Lim 2014); and the announced withdrawal of the British military services in 1971 which would lead to an 18% drop in its GDP and the unemployment of 90,000 people if unchecked (Porter, Neo, and Ketels 2009), counted against the new nation. Thus, the foremost concern for PM Lee and his fledgling cabinet was the economy – "how to make a living for our people" (K. Y. Lee 2000, 23).

Similar to the other three "Asian Tigers"<sup>5</sup> of Hong Kong, South Korea, and Taiwan, the Singapore government undertook an export manufacturing development strategy. Unlike the other three, it adopted a very high reliance on

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<sup>5</sup> As categorized by the World Bank's 1993 study of *The East Asian Miracle* (World Bank 1993).

multinationals as compared to local enterprises, and an immigration policy that allowed these companies to relatively freely import foreign labor and talent (L. Y. Lim 1983). This was complemented by Singapore's openness to foreign direct investment (FDI) and the practice of industrial policy (Wade 1990), as epitomized by the Economic Development Board's (EDB) pivotal investment-promotion role in attracting FDI for export-oriented manufacturing within chosen industrial sectors (L. Y. C. Lim 2014). Other government agencies also facilitated rapid industrialization by creating the conditions for increased productivity and successful growth. Most obvious among these were the infrastructure agencies: the Port of Singapore Authority (PSA), Changi Airport, Jurong Town Corporation (industrial estates), Public Utilities Board (PUB), etc. Continued institutional innovations and changes in investment promotion-focus led to sustained robust economic growth through to the end of the 2000s (see Table 1).

**Table 1. Singapore's economic growth from founding to the 2000s.**

	<b>1960s</b>	<b>1970s</b>	<b>1980s</b>	<b>1990s</b>	<b>2000s</b>
Economic focus (EDB 2015)	Labor intensive	Skill intensive	Capital intensive	Technology intensive	Knowledge and Innovation Intensive
Average GDP growth rate per year (Department of Statistics Singapore 2015)	10%	15%	11%	9%	7%
Selection of new economically-relevant government agencies and government linked companies (Cahyadi et al. 2004)	EDB, PSA, Changi Airport, Jurong Town Corporation, PUB	Development Bank of Singapore (DBS), Singapore Airlines (SIA), Sembawang Shipyard	National Computer Board (NCB), Trade Development Board (TDB)	National Science and Technology Board (NSTB), Standards, Productivity and Innovation Board (SPRING Singapore), Infocomm Development Authority of Singapore (IDA)	Agency for Science, Technology and Research (A*STAR), National Research Foundation (NRF), International Enterprise Singapore (IE Singapore)

### **3.1.2 Investment in Information and Communications Technology**

With such rapid industrialization, the 1980s saw Singapore face a different set of economic challenges: a tight labor market coupled with the emergence of other South East Asian economies (K. Y. Lee 2000). Thus began a focus on developing a highly-skilled workforce that would allow the country to move up the manufacturing value-chain, as well as build a presence in service industries (Cahyadi et al. 2004). Industries related to Infocomm Technology (ICT) were key to this strategy, and the National Computer Board was established by the government

in 1981 to facilitate workforce training in the relevant information technology (IT) skillsets (Wong 1999).

This focus in ICT marked the beginning of over 30 years of ongoing, concerted government effort to use ICT as a platform for economic development, but also on building a globally competitive ICT industry<sup>6</sup>. This led the way for early investments in ICT infrastructure, IT literacy programs, and extensive e-government initiatives to increase government capabilities as well as access to government services by citizens. Further, while the IT and telecommunications sectors were initially governed by two different agencies, each under the purview of two different ministries, the convergence of the IT and telecommunications markets resulted in the establishment of the IDA in 1999 as a combination of the NCS and the Telecommunications Authority of Singapore (TAS). (Chua 2012)

These concerted investments have grown ICT's prominence in Singapore. In 2013, the infocomm industry made up 4.0% of the nation's GDP, employed 146,700 people, and accounted for S\$148 billion (US\$185 billion) in revenue, the last of which represented a 14.8% growth from 2008 (IDA 2014). Smartphone and tablet penetration in Singapore are also the highest globally at 89% and 85% globally (Deloitte 2014).

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<sup>6</sup> See overview of Singapore's ICT master plans in Appendix A.

### 3.1.3 Innovation Capacity

The National Science and Technology Board (NSTB) launched Singapore's first formal science and technology (S&T) plan in 1991 (NatureJobs 2011). Initially focused on Singapore's traditional strengths in the physical science and engineering sectors, seven research institutes in that area were established. NSTB's successor the Agency for Science, Technology and Research (A\*STAR) broadened that remit by making significant infrastructure and manpower investments in the biomedical sciences starting in 2000, creating the "Biopolis", a campus for public and private biomedical R&D activities. This put Singapore on the global biomedical map with the establishment of more than five new biomedical research institutes over the course of the next ten years. Around the same time, Singapore universities underwent restructuring in the 1990s to intensify their focus on research and develop into world-class institutions of higher education (M. H. Lee and Gopinathan 2008). Combined, this precipitated a significant increase in R&D spending and R&D manpower: between 2003 and 2013, compound annual growth rate (CAGR) of Gross Expenditure on R&D (GERD) was 8.2%<sup>7</sup>, and that of number of researchers was 5.9%<sup>8</sup> (A\*STAR 2014).

This intense focus on R&D has borne fruit. Between 2009 to 2011, Singapore was ranked 4<sup>th</sup> for mean citation rate among the 39 countries with at least 4,000 publications a year, indicating a high quality of papers produced. The same report

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<sup>7</sup> In 2003, GERD was S\$3.4 billion and GDP stood at S\$169.0 billion. In 2013, GERD was S\$7.6 billion and GDP was S\$372.8 billion.

<sup>8</sup> Number of researchers grew from 19,448 in 2003 to 34,373 in 2013.

showed that among the countries studied, Singapore’s trend of mean citation rate showed the steepest growth during the period of analysis (1990 and 2011), further validating the government’s deep investment in R&D. (Karlsson and Persson 2012)

Patent filings have also seen an increase. In 2013, the number of primary patent applications as a result of R&D conducted in Singapore was 2,144. This was a growth of 24.5% from patents filed in 2012, and a cumulative average growth rate of 7.9% from patents filed in 2003. (A\*STAR 2014)

### 3.1.4 Entrepreneurial Capacity

The entrepreneurial capacity of Singapore appears low given its high innovation capacity. Table 2 illustrates that Singapore lags its competitors in terms of entrepreneurial activity and ambition (Singer, Amorós, and Moska 2015).

**Table 2. Selected 2014 indicators from the Global Entrepreneurship Monitor. (Singer, Amorós, and Moska 2015)**

<b>Indicator</b>	<b>Singapore</b>	<b>United States</b>
Established Business Ownership Rate	2.9	7.0
Total early-stage Entrepreneurial Activity	11.0	13.8
Nascent Entrepreneurship Rate	6.4	9.7
Entrepreneurial Intention	9.4	12.1

This disparity between innovation and entrepreneurial capacity can be seen the results from the Global Innovation Index . Despite ranking 7<sup>th</sup> overall and 1<sup>st</sup> overall for the Innovation Input Sub-Index, the nation ranks only 25<sup>th</sup> in the Output Sub-Index of the Global Innovation Index 2014, due largely to comparatively low

scores in knowledge and technology outputs and creative outputs (Scott and Vincent-Lancrin 2014). Further, while the Global Entrepreneurship Index (GEI) 2015 ranked Singapore as 10<sup>th</sup> country globally with regards to entrepreneurial capacity, Singapore has lower than world average performance on startup skills and networking (Ács, Szerb, and Autio 2014).

Studies indicate that Singaporean entrepreneurs tend to be less risk-taking and uncertainty-bearing (Ho and Koh 1992; W. C. Tan and Tay 1995; Teoh and Foo 1997). This could be due to “the stringent control and omnipresence of the government in most businesses” (W. C. Tan and Tay 1995) as well as the “dominance of MNCs in key industries, and the dominance of government-linked businesses in various services” (Boey and Chiam-Lee 1994).

Despite the lack of intentional focus, IDEs have found their way into the Singapore ecosystem, with founders attracted due to the ease of business environment, access to Asian markets, and living standards of the island-nation. Action has not been initiated as centrally coordinated policies from the larger players in the government (e.g. the cabinet, or the ministries), but rather in limited term funding programs from disparate government agencies (e.g. NRF, SPRING, IDA) and universities responding, in part, to this increased activity and energy from entrepreneurial technology and start-up companies in the ICT space – such as Google, Rocket, Uber – locating in Singapore.

A key initiative has been the recent rise of Block 71 (commonly referred to as “Blk 71”) as the epicenter for ICT startup activity with more than 100 startups, venture-capital firms and tech incubators (Chng 2014). Blk 71 was established in 2011 in what was once a former factory building slated for demolition. This piece of real estate was re-envisioned as a cluster for interactive digital media and other ICT start-ups by a coalition consisting of NUS Enterprise, the Media Development Authority and SingTel’s venture capital fund Innov8. (Anthony 2015)

That initiative has shown sufficient success that an expansion to two more buildings has been planned to accommodate further growth. However, some venture capital firms still question the level of creativity and innovativeness that Singapore start-ups bring to the table (Lucas 2015).

### ***Over-reliance on MNCs?***

The aggressive focus on MNCs to fuel export-focused industrialization and growth has transformed Singapore to become a competitive and compelling location for MNCs’ increasingly sophisticated operations. However, the same cannot be said of the environment for local entrepreneurs. Besides the creation of government linked companies such as Singtel and Singapore Airlines, prominent business people and politicians have expressed concern about the lack of large successful domestic enterprises: 99% of Singaporean business are still considered small and medium enterprises (SMEs) with either annual revenue of less than S\$100 million or having less than 200 workers employed (Vietor and White 2014). MNCs’ operations outside



their home countries are naturally less rooted and more susceptible to structural changes in response to the business environment. Without local businesses successful on a regional or global scale, it is challenging to ensure that companies remain “stickier” to Singapore’s shores despite global upheavals.

Singapore’s industrial policies have been almost exclusively focused on job-creation and economic growth. With MNCs appearing to have a greater economic impact on a per project basis than local companies (at least initially), this focus is unsurprising. Unlike the service given to MNCs by EDB as a “one-stop-shop”, SMEs have no central point of contact or advocate within the government<sup>9</sup>. It is only recently, especially with the new productivity drive established in 2010<sup>10</sup> and the “watershed” 2011 elections where the popular vote for the PAP was at historic lows<sup>11</sup>, that there has been a new focus on “sustainable” jobs for Singaporeans, and an increased pride in and affinity for local companies. Still, there remains a strong preference by Singaporeans to work for MNCs if possible (Vietor and White 2014).

Despite the positive business environment, it could be argued that the government hinders entrepreneurial behavior in citizens in two ways: firstly by performing many services internally in the name of efficiency (e.g. F1 race coordination, port services, R&D services, etc.), and by absorbing much of the best talent through its scholarship programs. If anything, much of the entrepreneurial

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<sup>9</sup> Local companies tend to have to deal variously with SPRING for start-up grants, IE Singapore for grants to expand overseas, A\*STAR for R&D grants, and IDA for productivity grants.

<sup>10</sup> Coordinated by the National Productivity and Continuing Education Council (NPCEC).

<sup>11</sup> 60.5%, down 6.5% from the previous election.

energy in Singapore could be argued to have (at least in the past) been concentrated within the government: enabling it to move quickly, pivot, and be successful in the dynamic global environment.

### **3.1.5 Singapore's Economy Today**

This state-driven development model has been successful in delivering high GDP growth and low unemployment for over four decades. Besides ranking as one of the world's richest nations by per capita income<sup>12</sup>, Singapore also ranks highly on many global indices, including investment potential<sup>13</sup>, foreign trade and investment<sup>14</sup>, ease of doing business<sup>15</sup>, competitiveness<sup>16</sup>, network-readiness<sup>17</sup>, and IP protection<sup>18</sup>, among others.

However, GDP growth since 2012 has slowed significantly (see Table 3). This is in part due to the global economic weakness since 2008, the high cost of business and manufacturing operations in Singapore, as well as the tightening in foreign worker quotas. In particular, the manufacturing sector, which still accounts for

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<sup>12</sup> Ranked 5<sup>th</sup> globally based on information from the World Bank.

<sup>13</sup> In its BERI Report 2014-I (April 2014), US-based research institute Business Environment Risk Intelligence (BERI) ranked Singapore first.

<sup>14</sup> According to the Globalisation Index 2012, Singapore came in after Hong Kong as the country preferred for foreign trade and investment.

<sup>15</sup> According to the Doing Business 2014 Report by the World Bank, Singapore is the easiest place in the world to conduct business

<sup>16</sup> According to the Global Competitiveness Report 2014 – 2015 by the World Economic Forum, Singapore is the 2<sup>nd</sup> most competitive country in the world.

<sup>17</sup> Based on the The Global Information Technology Report 2014 as conducted by the World Economic Forum, Singapore has the 2<sup>nd</sup> best network-ready environment in the world.

<sup>18</sup> In its Global Competitiveness Report 2013 – 2014, the World Economic Forum ranked Singapore as having the second best IP protection in the world.

18.4% of Singapore’s economy, has been hard hit by declines in output due to all three reasons previously outlined<sup>19</sup>.

**Table 3. Singapore’s GDP growth rate from 2010 to 2015.**

<b>Year</b>	<b>GDP growth rate per year</b>
2010	15.2%
2011	7.4%
2012	4.6%
2013	4.4%
2014	3.1%
2015	2-2.5% <i>est.</i> <sup>20</sup>

### ***Challenges to Sustainable Growth***

Singapore was the first Asian country to enter recession after the great recession hit Asia in 2008, due largely to its continued high dependency on MNC-led export driven sales (Porter, Neo, and Ketels 2009). As such, PM Lee Hsien Loong convened the Economic Strategies Committee (ESC) in May 2009 to provide recommendations on ensuring and sustaining Singapore’s future economic growth. In particular, the challenge to increase productivity while moderating future growth of the foreign workforce was tasked to the Committee.

In January 2010, the ESC provided a report detailing three main recommendations:

1. “Boost skills in every job” to allow all workers to acquire “greater proficiency, knowledge and expertise”.

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<sup>19</sup> Source: Ministry of Trade and Industry, March 2015.

<sup>20</sup> Estimated for 2015 given by the Ministry of Trade and Industry on 11Aug 2015.

2. “Deepen capabilities among Singapore companies” to grow into industry leaders within Asia as a complement to the MNC strategy.
3. Grow Singapore into a “distinctive global city” by attracting and nurturing “highly capable and entrepreneurial people”. The ESC also noted a “new normal” for Singapore’s annual GDP growth of 3-5% given the country’s developed status. (ESC 2010)

Relying less on labor force expansion for GDP growth implies a shift to greater reliance in productivity improvements. Singapore’s low relative productivity has long been a concern. For example, Singapore’s productivity in manufacturing and services are 55% to 65% of those in the United States and Japan respectively (ESC 2010). The ESC set a target of 2% to 3% productivity growth per annum. However, between 2009 and 2014 and excluding the strong rebound in 2010 following the global financial crisis, the Ministry of Trade and Industry announced that productivity growth has been a lackluster 0.3% on a cumulative annual growth rate basis (T. W. Goh and Fan 2015).

### **3.2 Singapore’s Healthcare System**

At Singapore’s founding, Yong Nyuk Lin, then Minister for Health, stated bluntly that “health would rank, at the most, fifth in order of priority” for public funds. In the eyes of the then fledgling cabinet, ahead of health were national security, job creation, housing, and education. (Yong 1967) However, good fundamentals in public health were seen as crucial for the economic well-being of the nation, hence

early initiatives included providing clean water, developing a vaccination program, and guaranteeing access to basic medications and clean food (Haseltine 2013).

This balance between a conservative approach to healthcare spending and the investment in population health fundamentals (and not necessarily the skill of healthcare providers) continues in Singapore's healthcare system today. In the 1993 white paper on Affordable Health Care, the Ministry of Health (MOH) put forward the government's five objectives for healthcare:

- "a. To nurture a healthy nation by promoting good health;*
- b. To promote personal responsibility for one's health and avoid over-reliance on state welfare or medical insurance;*
- c. To provide good and affordable basic medical services to all Singaporeans;*
- d. To rely on competition and market forces to improve service and raise efficiency; and*
- e. To intervene directly in the health care sector, when necessary, where the market fails to keep health care costs down."*

(MOH 1993)

In his comprehensive account of the Singapore healthcare system, Dr. Jeremy Lim further articulates the policy principles for healthcare as three-fold: "(1) the need for co-payments to mitigate moral hazard, (2) the potentially ruinous nature of subsidies, (3) a fundamental belief in economic theory and the power of markets to

drive efficiency and deliver the greatest value to society.” He goes on to add two more ideologies as also key: “(4) ‘productivist welfare capitalism’<sup>21</sup> and (5) the primacy of the state.” (J. Lim 2013 p.16)

This set of five ideologies have led to the central features of Singapore’s healthcare system that distinguish it from other prominent healthcare systems of developed nations. Ranked 6<sup>th</sup> overall by the World Health Organization (WHO) in 2000 (WHO 2000) and 1<sup>st</sup> in efficiency by Bloomberg in 2015 (Bloomberg 2015), Singapore’s system is known for its positive health outcomes despite overall low spending for a developed nation.

Singapore spends only 4.6% of its GDP on healthcare, as compared to the United States’ 17.1% (see Table 4), yet has a healthier population (see Table 5). However, what stands out is Singapore’s out-of-pocket health expenditure as a percentage of private expenditure on health, which is very high among developed nations (see Table 4).

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<sup>21</sup> Described as a regime where “(s)ocial policy is strictly subordinate to the overriding policy objective of economic growth.” (Holliday 2000)

**Table 4. 2013 Indicators of Healthcare Spending in Singapore and Selected Developed Nations (WHO 2015)**

Country	Health expenditure, total (% of GDP)	Health expenditure per capita (current US\$)	Health expenditure, public (% of total health expenditure)	Out-of-pocket health expenditure (% of private expenditure on health)
Singapore	4.6	2,507	77.5	94.3
United States	17.1	9,146	82.1	22.3
France	11.7	4,864	83.5	32.9
Japan	10.3	3,966	66.3	80.2
United Kingdom	9.1	3,598	55.0	56.4

**Table 5. 2013 Indicators of Quality of Health in Singapore and Selected Developed Nations (WHO 2015)**

Country	Life expectancy at birth, total (years)	Mortality rate, under-5 (per 1,000 live births)
Singapore	82.3	2.8
United States	78.8	6.9
France	82.0	4.2
Japan	83.3	2.9
United Kingdom	81.0	4.6

### 3.2.1 Paying for Healthcare

These characteristics have been attributed to Singapore's unique healthcare payment structure that places heavy emphasis on individuals to take responsibility for their own health and health spending, as previously discussed in the five ideologies of Singapore's healthcare system. Table 6 illustrates the different forms of healthcare financing in Singapore. While the government administers three of the

major payment programs used in the healthcare system, only Medifund is government funded. The two other programs are funded from the mandatory Government pension scheme (the Central Provident Fund, CPF). For the CPF, a total of up to 37% of wages<sup>22</sup> is contributed to individual accounts to fund retirement and health related expenditure (CPF 2015).

**Table 6. Healthcare Financing in Singapore. (Tucci 2009)**

<b>Scheme</b>	<b>Payor</b>	<b>Description</b>
Government Subsidies	Government	The Government directly subsidises healthcare using tax revenue, providing funds for public hospitals and health promotion.
Medifund	Government	A means-tested scheme intended to assist those in financial hardship to fund their medical needs.
Medisave	Individual (CPF) <i>(Administered by the government)</i>	A compulsory medical savings scheme with funds to meet a portion of personal or immediate family's health services (hospitalisation, day surgery and certain outpatient expenses) or certain health insurance plans.
Medishield	Individual (CPF) <i>(Administered by the government)</i>	A national insurance scheme for catastrophic illness.
Eldershield	Individual (CPF) <i>(Administered by the government)</i>	A private insurance scheme for the elderly that aims to help fund future medical expenses incurred in the event of severe disability.
Private Insurance	Individual/ Employer	A significant portion of workers and their dependents are covered by private health insurance not covered by the above schemes, e.g. deductibles for inpatient treatment, pregnancy, treatment for early stages of cancer, general health screenings, etc.
Direct Payment	Individual	Typically, individuals will still have to pay for at least part of their medical treatment directly. For example, outpatient treatment at a General Practitioner is often paid this way.

### 3.2.2 Healthcare Delivery

In line with the philosophy that people must take responsibility for their own health, primary care is largely issued by private providers, and typically paid out-of-pocket. There are 2,000 general practitioners in Singapore who delivery 80% of primary

<sup>22</sup> This comprises employee contributions of up to 20% and employer contributions of up to 13%.



care. The remaining 20% of primary care is provided through 18 government run “polyclinics”, which provide highly subsidized services. While these polyclinics accept walk-ins, they usually have longer waiting times for appointments, and may be further away from patients than the many general practitioners clinics. (Haseltine 2013)

For inpatient and specialist treatment, private and public providers both exist in the marketplace. However, inpatient care is directed towards public entities due to the availability of patient incentives and subsidies: 80% of it is provided by the public sector and 20% by the private sector (Haseltine 2013). Public hospitals provide a tiered system of “wards” that are differentially priced, to allow individuals to select their level of comfort and expenditure while undergoing inpatient treatment. The different classes of wards also allow for different levels of means-tested government subsidies.

### **3.2.3 Structure of Public Hospitals**

Today, all public hospitals, along with public specialist centers, are government-owned corporations belonging to one of six healthcare groups. These healthcare groups are still owned by the MOH through a holding company called MOH Holdings Private Limited (MOHH). Restructuring was first undertaken between 1985 to the 1990s, and then again in 2000. The aim was to allow “public/restructured” hospitals to compete against one another in both pricing and management, so as to give patients greater choice as well as to manage rising costs. (Haseltine 2013) MOHH’s

role is to “enhance public healthcare sector performance by unlocking synergies and economies of scale” (MOHH 2015), and to ensure that deep government influence in healthcare is maintained to provide counterbalance when market mechanisms do not maintain low cost care.

### **3.2.4 Digital Health in Hospitals**

The use of digital health technologies to solve capacity constraints and cost increases, as well as enhance patient care, has been a top priority for the Singapore government; one of MOHH’s strategies is to “[develop] a national IT framework that facilitates seamless delivery of care to our patients”. Chief amongst the government’s concerns is the impending “Silver Tsunami”: by 2030 one in five Singaporeans will be over 65, and by 2050 Singapore’s median age will be 54, marking it among the world’s oldest demographics (National Population and Talent Division 2015).

Integrated Health Information Systems (IHIS) was established in 2008 as a private entity wholly owned by MOHH, and seeded with staff from IT departments of all public hospitals. IHIS acts as the de-facto Chief Information Officer and shared IT department for all the healthcare groups, with the aim to “drive greater synergies and high performing systems”. The agency has been key in driving the implementation and rollout of the National Electronic Health Record (NEHR) system across all healthcare groups, and is active in using tele-health and mobile technologies to extend the hospitals’ reach. (IHIS 2012) Deployed in 2011, the NEHR

aims to allow providers secure real-time access to patients' records in order to allow patients to receive coordinated patient-centric care at the most appropriate healthcare setting (Muttitt, McKinnon, and Rainey 2012).

Besides the NEHR, another area of focus for MOH is telemedicine. While the focus for telemedicine in other countries may be in healthcare delivery to rural areas, Singapore sees this innovation as an opportunity to increase access to the growing elderly population for whom mobility and transportation is an issue. Another topic of interest is the ability to better monitor chronic disease in patients, using the technology to allow for more timely intervention and reduce doctors' visits. (IDA 2013) To facilitate further innovation and regulate usage, MOH released the National Telemedicine Guidelines in early 2015 (National Telemedicine Advisory Committee et al. 2015).

### **3.3 Opportunities in Digital Health Entrepreneurship**

The Singapore government recently announced the Smart Nation Program in November 2014. This program intends to leverage the nation's ICT infrastructure and capabilities for three aims: support better living, create more opportunities, and support stronger communities. (H. L. Lee 2014) As a result, the recently released Infocomm Media Masterplan has tailored its recommendations to build this "Smart Nation". Notably, one of the plan's three recommendations explicitly mentions the development of "Singapore-made content, products, and services" through the

enhanced support of infocomm media start-ups (Infocomm Media Masterplan Steering Committee 2015).

The triple convergence of the nation's focus in ICT, availability of a digital platform in healthcare, along with the acknowledgment of the increasingly important role IDEs should play in the economy, make digital health entrepreneurship an opportunity for further emphasis. On one hand, this sector plays to Singapore's strengths in ICT and healthcare delivery, while building off the recent entrepreneurial energy in internet start-ups. On the other hand, solutions in this space can also ameliorate the capacity, cost, and patient care challenges faced by the Singapore health system.

Domestically, Singapore's healthcare spending is predicted to grow strongly over the next decade – from S\$18 billion (US\$14 billion) in 2014 to S\$39 billion (US\$32 billion) by 2024, representing a 10 year CAGR of 8.1% in local currency terms<sup>23</sup> – to address the growing economy and increasingly ageing population (BMI Research 2015). These challenges could also provide opportunities for digital health entrepreneurs to help the government more efficiently build capacity and produce cost savings.

Further, successfully providing digital health solutions is also a business opportunity on a regional and global scale. In the Asia Pacific, many countries are

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<sup>23</sup> CAGR of 8.6% in US dollar terms.

still struggling to improve basic health outcomes and cannot afford to stop investing in healthcare. Coupled with its high population base and relatively nascent stage of IT adoption, digital health has immense potential for growth: global spending on healthcare is expected by the International Data Corporation to grow at a CAGR of 8% between 2013 to 2018 (Burghard et al. 2014).

However, Singapore-based entrepreneurs have not yet seized on many of these opportunities. While Singapore has been touted as the “Boston of Asia” by dint of its highly developed healthcare infrastructure (Min 2014), digital health entrepreneurial activities are nowhere near as close. In 2014, healthcare start-ups accounted for 27% of venture capital funding in Boston (Harris 2015), but healthcare was less than 0.5% of the same in Singapore (Z. Tan 2015a; Z. Tan 2015b).

## **Chapter 4. Case Study: Comparing Hospitals in Singapore and Boston**

Compared to Singapore's fledgling digital health IDE ecosystem, Boston's ecosystem is much more matured and developed, with a plethora of digital health startups, accelerators, access to funding, and related innovation initiatives at private enterprises and hospitals. An indicator of depth of the IDE ecosystem in Boston is the success of its startups in raising money. Digital health startups based in the city raised the third highest amount of venture capital in the United States in the first quarter of 2015 (nine deals raising a total of US\$113 million). This lagged behind only San Francisco (25 deals raising \$390 million) and San Diego (four deals raising \$127 million) (Bartlett 2015).

With hospitals playing such a significant role in the digital health IDE ecosystem (Rowe et al. 2004; Nathanson and Morlock 1980; Wood, Bhuian, and Kiecker 2000), they can reasonably be used as a representative microcosm. Hence, this case study compares similar hospitals – one each from Singapore and Boston – to contextualize the strengths and weaknesses of the Singapore ecosystem and give insights on potential improvements.

The KK Women's and Children's Hospital (KKH) from Singapore and the Boston Children's Hospital (BCH) were studied and compared for this case study. These two hospitals were chosen because they had a similar narrowed scope of clinical practice (i.e. pediatrics) as compared to general hospitals, were both leading

pediatric hospitals in their respective regions for clinical practice and research, and both had top pediatric specialist medical training programs for their regions. While KKH has a significant women's health practice that is absent in BCH, the "critical mass" of pediatric cases seen at each hospital provides a more similar basis for comparison than between general hospitals of both cities, where the strengths between individual specialties may differ greatly.

This case study will first compare indicators of innovation capacity between BCH and KKH, including human capital, publications, and patents. Subsequently, indicators of entrepreneurial capacity will be compared between the two hospitals, including depth of stakeholder networks and research diversity. The chapter will then progress to a comparison of internal policies, resources, cultures, and attitudes gleaned from interview data. Finally, a series of recommendations for Singapore hospitals to improve the digital health IDE ecosystem will end the chapter.

## **4.1 Case Study**

### **4.1.1 Overview of KKH<sup>24</sup>**

KKH is the largest hospital specializing in the healthcare of women and children in Singapore. The hospital was established in 1858 as the Fifth General Hospital, and in the 1920s became the Free Maternity Hospital of Kandang Kerbau. In 1990, the hospital adopted its contemporary name, KK Women's and Children's Hospital

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<sup>24</sup> Source: KKH website, <http://www.kkh.com.sg/AboutUs/>

(KKH), when it expanded its clinical offerings to include pediatric care. Today, KKH is a 830-bed public/restructured hospital under the SingHealth group, with over 600 doctors and more than 1,800 nurses on its staff. It is host to SingHealth's pediatrics residency program and is considered a regional leader within Southeast Asia in obstetrics, gynaecology, pediatrics and neonatology. The hospital also houses the largest neonatal intensive care unit (NICU) in Southeast Asia with 32 beds.

#### **4.1.2 Overview of BCH<sup>25</sup>**

BCH is a not-for-profit children's general facility located in Boston, MA, and ranked nationally in 10 pediatric specialties. Established in 1869 as a 20-bed facility, the hospital today has 395 beds, and is the largest training program for pediatricians and pediatric subspecialists in the United States. The hospital also houses a 24-bed NICU. BCH counts more than 1,700 physicians and 1,500 nurses on its staff.

#### **4.2 Indicators of Innovation Capacity: Analysis of human capital, publications, and patents**

Educational qualifications of staff, number of publications, and number of patents filed are common indicators of innovation capacity. This section will compare these indicators between KKH and BCH, and discuss potential rationale for the findings.

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<sup>25</sup> Source, BCH website, <http://www.childrenshospital.org/about-us/>



#### **4.2.1 Methodology**

Publicly available data was obtained to provide insights into the innovation capacity of both hospitals.

The qualifications of researchers were used as an indicator of quality of human capital. Both hospitals listed researcher names and qualifications on their website, and a manual count was done to ascertain the number of researchers who were qualified as physicians (MD or MBBS), with PhDs, or both.

Publications by each hospital from the three years between 2011 to 2013 was obtained from Elsevier's Scopus — an abstract and citation database of peer-reviewed literature<sup>26</sup>.

The number of patents filed in each hospital's home country over three years from 2011 to 2013 was used. For BCH, its Technology and Innovation Development Office (TIDO) provides an annual report listing the number of patents filed in the United States.

KKH files its patents through its parent group, SingHealth. All patents filed by SingHealth in Singapore from 2011 to 2013 were obtained using the Intellectual Property Office of Singapore's (IPOS) e-services portal<sup>27</sup>. This selection process yielded 96 patents. To determine the number of KKH patents, the affiliation of all

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<sup>26</sup> Source: Scopus website, <http://www.scopus.com/>

<sup>27</sup> From 2011 and 2013, no patents with KKH listed as applicant were found.

listed inventors was ascertained by their listed address. If the address was inconclusive, an online search was manually done to determine their affiliation. It should be noted that in the selected patents, there was no instance where a patent had both a KKH inventor and an inventor from another SingHealth-affiliated healthcare unit. Hence, a patent filed by SingHealth with a KKH-affiliated inventor was counted as a patent filed by KKH. It should also be noted that 49 (51%) of the patents had no named inventors. The application status of all such patents was “Abandoned”, indicating that while an initial filing was made, the progress was ceased quickly enough that inventor information was not submitted.

#### **4.2.2 Researcher Qualifications and Publications**

BCH is home to the world’s largest research enterprise at a pediatric center, and has more than 600 faculty researchers listed on its website. In comparison, KKH lists 37 researchers on its website. In comparing the proportions of the different types of qualifications of research staff as illustrated in Table 7, KKH has a slightly lower proportion of MD/MBBS researchers. Also, KKH’s proportion of physician researchers with PhDs is about half that of BCH’s. While more than a quarter of physicians are listed as researchers in BCH, the same proportion at KKH is less than 4%.

**Table 7. Qualifications of researchers at each hospital.**

Qualifications	BCH <sup>28</sup>		KKH <sup>29</sup>	
	Number	% of total researchers	Number	% of total researchers
MD or MBBS <sup>30</sup> (A)	470	69.2%	24	64.9%
MD PhD or MBBS PhD	81	11.9%	2	5.4%
PhD Only (B)	181	26.7%	5	13.5%
All PhD	262	38.6%	7	18.9%
Total PhD and MD or MBBS (A+B)	651	95.9%	29	78.4%
<b>Total number of researchers</b>	<b>679</b>	-	<b>37</b>	-
Total number of physicians	1,700	-	636 <sup>31</sup>	-
MD or MBBS researchers as a % of all physicians	27.6%	-	3.8%	-

It should be noted that physicians not listed as researchers may also undertake research work and submit articles. However, the large difference between BCH and KKH in the proportion of named researchers to the total physician population is likely to be a main cause for the difference in the number of peer reviewed papers authored by each hospital, both in terms of sheer volume as well as papers per physician (see Table 8).

<sup>28</sup> Number and qualifications of BCH researchers obtained from BCH website (BCH 2015)

<sup>29</sup> Number and qualifications of KKH researchers obtained from KKH website (KKH 2015b)

<sup>30</sup> MD, or Doctor of Medicine, is the qualification required in the United States to practice as a physician. MBBS, or Bachelor of Medicine Bachelor of Surgery, is the qualification required in Singapore to do the same.

<sup>31</sup> Number of KKH doctors at the end of the 2013 fiscal year (SingHealth 2014)

**Table 8. Number of papers authored by each hospital from 2011 - 2013, taken from Scopus.**

Hospital	Year			Total, 2011 - 2013	Ave. paper/physician/year <sup>32</sup>
	2011	2012 <i>Y-o-Y % change</i>	2013 <i>Y-o-Y % change</i>		
BCH	2,168	2,279 +5%	2,143 -6%	8,569	1.68
KKH	88	133 +51%	161 +21%	576	0.30

Nevertheless, the number of papers from KKH has been increasing. While there has been some growth in physician staffing (see Table 9), this is not sufficient to explain the much larger percentage increase in publications. Instead, the increase in research output could be due to KKH's increased focus on research, with a prime example being the recent launch of the Academic Medicine Research Institute (AMRI@KKH) in 2012<sup>33</sup>. AMRI is a joint initiative between KKH, the Duke-NUS Graduate Medical School of Singapore (Duke-NUS), and the SingHealth Group. Duke-NUS was established to meet the need for US-style medical education in Singapore and to "produce the highly trained medical leaders needed to support the Biomedical Sciences Initiative"<sup>34</sup>. It also provides Singapore's only MD/PhD program, with the first students from this program starting their research attachment in 2007 and graduating around 2012. With the AMRI initiative, KKH has begun building a cadre of clinician scientists. Interested students typically take up MD PhD programs to undertake research-oriented clinical careers, which also better equips these graduates to contribute towards the translational research that links

<sup>32</sup> Using the figure for number of physicians obtained for the year 2014.

<sup>33</sup> Source: KKH website (KKH 2015a)

<sup>34</sup> Source: Duke-NUS website, <https://www.duke-nus.edu.sg/about/duke-nus-story>

basic research with clinical research, hence potentially enhancing both innovation and entrepreneurial capacity. While it is probably too early to see the effects of the initiative on the numbers of patents, AMRI provides the opportunity and resources for KKH to strengthen its capabilities in translational research.

**Table 9. Physician staffing and growth at KKH from 2011 to 2013.**

	<b>2011</b>	<b>2012</b>	<b>2013</b>
Physicians	519	598	636
Y-o-Y growth	-	15.2%	6.4%

#### 4.2.3 Patents Filed in Home Country

Table 10 shows the numbers of patents filed by BCH and KKH, while Table 11 illustrates that the number patents filed by BCH is consistently an order of magnitude above that of KKH. Normalizing the number of patents filed by the total number of physicians, the disparity narrows somewhat: on average, patent productivity at BCH is more than 9 times greater than at KKH.

**Table 10. Number of patents filed by BCH and KKH in their home countries from 2011 - 2013.**

Year	BCH			KKH		
	Patents filed in the United States ( $F_{BCH}$ )	Y-o-Y % increase	Patents per Physician ( $P_{BCH}$ )	Patents filed in Singapore ( $F_{KKH}$ )	Y-o-Y % increase	Patents per Physician ( $P_{KKH}$ )
2011	52	-	0.031	1	-	0.002
2012	59	13%	0.035	4	300%	0.006
2013	62	5%	0.036	2	-50%	0.003
<b>Total</b>	<b>173</b>	-	<b>0.102</b>	<b>7</b>	-	<b>0.011</b>

**Table 11. Patent filing ratio and productivity ratio of BCH to KKH.**

<b>Year</b>	<b>F<sub>BCH</sub> / F<sub>KKH</sub></b>	<b>P<sub>BCH</sub>/P<sub>KKH</sub></b>
2011	52.00	19.45
2012	14.75	5.52
2013	31.00	11.60
<b>Total</b>	<b>24.71</b>	<b>9.25</b>

KKH's lower patent filing numbers are not surprising. A high correlation between research output and patent filing has been shown to exist both at universities (Agrawal and Henderson 2002; Geuna and Nesta 2006) and at companies (JAFFE 1986). However, while the number of papers published has increased, patents filed by KKH have not. In fact, named inventors of patents from KKH seem highly concentrated, and Table 12 illustrates that only five KKH staff (less than 1% of KKH physicians) comprise the inventors for the patents filed between 2011 and 2013. This may indicate that commercialization at KKH is more a function of the physician's/inventor's individual proclivity rather than organizational factors.

**Table 12. KKH Inventors of patents filed from 2011 to 2013.**

<b>Inventor Initials</b>	<b>Number of Patents</b>
A.S.	3
K.H.T.	2
G.Y.	1
H.Y.L and I.N.	1
<b>Total</b>	<b>7</b>

#### **4.2.4 Caseloads: a Limiting Factor in I-Cap**

As the primary mission at any hospital is patient care, there may be a more fundamental explanation for the gap in innovation output: a disparity in caseloads.

The yearly admission and operations rates at each hospital, as well as the normalized rates per physician, bear out this difference (see Table 13).

**Table 13. Number of admissions and operations per year.**

	BCH		KKH	
	Number	Admissions/ operations per physician	Number <sup>35</sup>	Admissions/ operations per physician
Total patient admissions per year	25,000 <sup>36</sup>	14.7	68,229	107.3
Total operations per year	26,500 <sup>36</sup>	15.6	35,098	55.2

KKH’s higher caseloads are indicative of the wider landscape in Singapore. The Singapore healthcare system has significantly lower ratios of both doctors and nurses to patients as compared to other developed countries like the United States, UK, and Australia (see Table 14). Further, KKH has reached its prominence in Singapore and the region due to the “critical mass” of cases it sees in both its women’s and children’s wing. As an example, between the 1950s to the 1970s, KKH was entered in the *Guinness Book of Records* as the world’s busiest maternity hospital for many consecutive years (Cheong 2008). Similarly, KKH’s Children’s wing also sees high caseloads of pediatric procedures. This is due to the hospital handling a high proportion of Singapore’s pediatric specialty cases as well as pediatric patients referred to Singapore from Southeast Asia – e.g. for pediatric oncology cases, the figure is 70% of all local cases and 50% of patients referred from the region (Cheong 2008).

<sup>35</sup> Figures at the end of the 2013 fiscal year (SingHealth 2014)  
<sup>36</sup> Source, BCH website, <http://www.childrenshospital.org/about-us/>

**Table 14. Health Workforce Density per 1,000 population**

*Figures from 2013 unless otherwise indicated*

Country	Physicians	Nursing and midwife personnel
Singapore	1.95	5.76
United States	2.452 <sup>37</sup>	9.815 <sup>38</sup>
UK	2.809	8.801
Australia	3.273 <sup>37</sup>	10.648 <sup>37</sup>

*Source: (WHO 2015)*

### **4.3 Indicators of Entrepreneurial Capacity: Analysis of Stakeholders Strength and Research Diversity**

As KKH does not track number of businesses spun out, other indicators of entrepreneurial capacity had to be analyzed. Depth of stakeholder networks and competency in many disciplines have been shown to be indicators of successful entrepreneurs. Using bibliographic analysis, this section proposes that affiliations of co-authors and diversity of research discipline are appropriate proxies for depth of stakeholder network and competency in many disciplines, respectively. By comparing these indicators between KKH and BCH, the discrepancy in entrepreneurial capacities between the two hospitals will be discussed.

#### **4.3.1 Methodology: Bibliographic analysis**

Articles authored by researchers from each hospital during the period between 2011-2013, inclusive, were obtained from Scopus. This selection process yielded the

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<sup>37</sup> 2011 figure, latest available.

<sup>38</sup> 2005 figure, latest available.



number of articles as shown in Table 15, and these articles were used in both the stakeholder network and research diversity analyses.

**Table 15. Number of articles obtained via selection process.**

Hospital	Year			2011 - 2013
	2011	2012	2013	
BCH	2,168	2,279	2,143	8,569
KKH	88	133	161	576

### ***Depth of Stakeholder Network***

As noted in Chapter 2, the depth and strength of stakeholder networks is crucial for the health of an IDE cluster (Nieto and Santamaría 2007; Butler and Hansen 1991; Shapero 1975). Bibliographic studies of article affiliations have previously been used to show extent of social networks, collaboration, and linkages (Newman 2001; Hesford et al. 2006; Yan and Ding 2012). Here, a simplified form of the technique is used to illustrate the extent to which a hospital has linkages with the actors identified in the “Digital Health REAP stakeholder model”, namely: (other) hospitals, academic institutions, government, established enterprises, and risk capital. It should be noted that none of the papers obtained via the selection process had affiliations from the risk capital category.

For the selected articles, a list of related co-author affiliations and the number of papers associated with that affiliation was obtained using Scopus. Each affiliation was manually put into one of seven categories: hospitals (and other organizations where providing healthcare is the main mission), medical schools, universities (and other educational institutions), research institutes, government,

companies, and risk capital. Where possible, medical schools were separated from universities to account for medical schools' primary capabilities as healthcare providers and healthcare-related training, likening them more closely with hospitals rather than the broader educational institutions in which they tend to reside.

To ensure that the results were not skewed by one-off collaborations, only affiliations that appeared in at least two papers within that year were considered (i.e. "qualifying entities"). The total number of papers from qualifying entities in each category per year was normalized against the sum of all papers from qualifying entities (the stakeholder proportion). A two-tailed t-test was undertaken to determine if there were significant differences between the respective stakeholder proportions of papers from KKH and BCH. Specifically, as BCH resides in an ecosystem with higher entrepreneurial capacity, the hypothesis was that BCH would have a higher proportion of papers with university and research institute affiliates and a higher proportion of papers with stakeholders outside of healthcare (i.e. KKH would have a higher proportion of papers with healthcare stakeholders). More details of the data used can be found in Appendix B.

### ***Diversity of Research Disciplines***

Lazear suggested that entrepreneurs must be "jack of all trades" who are competent in many skills and disciplines (Lazear 2005). This characterization has been shown to hold in many studies (Lazear 2005; Oberschachtsiek 2008; Wagner 2006). This is especially so as digital healthcare is inherently an inter-disciplinary pursuit. Thus,

diverse subjects of research are taken as a precursor for entrepreneurial potential. Hence, the type and diversity of subjects of articles was used to indicate the propensity of the author hospital to engage in research within particular disciplines. As there appears to be more digital health activity at BCH, the hypothesis was that BCH would have a higher proportion of articles related to engineering and/or computer science. Further, as BCH has a higher innovation capacity, it was hypothesized that BCH would have a higher proportion of articles that were multidisciplinary, as well as related to subjects outside of medicine and medicine-related fields.

For the selected articles, subjects were extracted from Scopus. For each hospital in each of the years, the number of papers under each subject was normalized against the total number of papers. Once again, a two-tailed t-test was used to determine if there were significant differences between the respective subject ratios of papers from KKH and BCH. More details of the data used can be found in Appendix C.

#### **4.3.2 Depth of Stakeholder Networks**

As illustrated in Table 16, the hypothesis that BCH would have a higher proportion of papers with university and research institute affiliates and a higher proportion of papers with stakeholders outside of healthcare appears to be true for 2011. However, by 2013, there appears to be no significant difference at the 10% level in the proportions of co-author affiliation categories between the two hospitals.

**Table 16. Difference in proportions of BCH and KKH papers co-authored with different categories of affiliates.**

Affiliates/Stakeholders	$\pi(\text{BCH papers with } x \text{ stakeholder as affiliates}) - \pi(\text{KKH papers with } x \text{ stakeholder as affiliates})$		
	2011	2012	2013
Hospital (A)	-14.0%	2.2%	0.2%
Medical School (B)	-0.7%	-5.0%	-1.5%
University (C)	5.2%	-0.9%	0.3%
Research Institute (D)	9.9%	4.8%	0.8%
Government/NFP <sup>39</sup> /NGO <sup>40</sup> (E)	-1.6%	-2.2%	0.4%
Company (F)	1.1%	1.2%	-0.2%
<b>SUBTOTAL: Healthcare Providers (A+B)</b>	<b>-14.6%</b>	<b>-2.8%</b>	<b>-1.3%</b>
<b>SUBTOTAL: Innovation stakeholders with missions outside of healthcare (C+D)</b>	<b>15.1%</b>	<b>3.9%</b>	<b>1.1%</b>

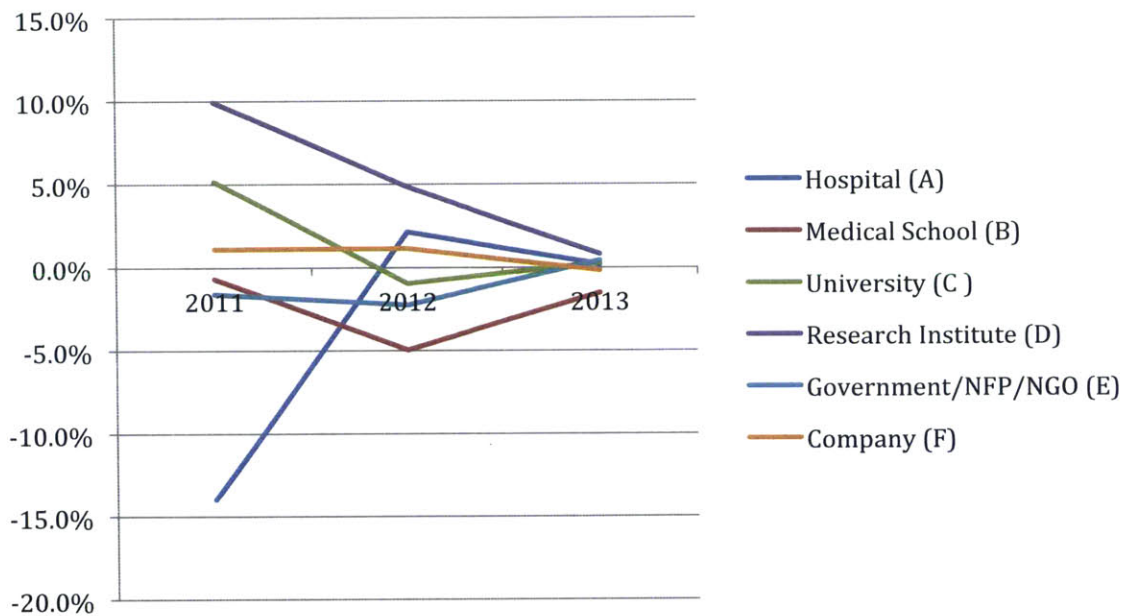
*Green indicates that the difference between the two proportions is statistically significant at the 10% level using a two-tailed t-test*

Figure 1 more clearly shows this decrease in disparity between BCH and KKH between 2011 and 2013. Hence, this implies that any disparity in entrepreneurial capacities between KKH and BCH may have been previously due to insufficient links with non-healthcare stakeholders, which cannot be said for the situation today.

<sup>39</sup> Non for profit organization.

<sup>40</sup> Non-governmental organization.

**Figure 1. Difference in proportions of BCH and KKH papers co-authored with different categories of affiliates.**



#### 4.3.3 Diversity of Research Disciplines

Surprisingly, Table 17 shows no statistical significance between KKH and BCH in the proportion of papers related to either engineering or computer science. In fact, KKH produced a greater proportion of papers related to engineer in 2012 and 2013. This may indicate that cutting-edge capabilities and research into engineering and computer science are not necessary for digital health innovation. Instead, physicians at BCH may simply be more comfortable with, or have more support with, using digital health tools for research.

On the other hand, BCH has a higher proportion of articles that were multidisciplinary than KKH, as well as a higher proportion of articles related to

subjects outside of medicine and medicine-related fields. This heterogeneity research may point to BCH's higher entrepreneurial capacity.

**Table 17. Difference in proportions of BCH and KKH papers written on particular subjects.**

Subject	$\pi(\text{BCH papers with } x \text{ subject}) - \pi(\text{KKH papers with } x \text{ subject})$			
	2011	2012	2013	2011 - 2013
Medicine	-5.9%	-7.4%	0.5%	-4.0%
Engineering	2.7%	-0.6%	-2.0%	-0.3%
Computer Science	1.1%	0.4%	0.9%	0.8%
Multidisciplinary	3.4%	2.8%	3.5%	3.2%
All subjects excluding Medicine and Medicine related subjects	13.5%	7.3%	9.9%	9.7%

*Green indicates that the difference between the two proportions is statistically significant at the 10% level using a two-tailed t-test*

#### **4.4 Comparison of Internal Policies, Resources, Cultures and Attitudes**

##### **4.4.1 Methodology: Interviews**

In order to capture the tacit knowledge about the policies, resources, culture and attitudes surrounding digital health, a series of interviews with personnel from both hospitals was conducted.

A total of seven people were interviewed, four from KKH and three from BCH. The number of interviewees represented the medical, (IT) operations, and digital health leadership, as well as the end-users of digital health initiatives (i.e. physicians) from both hospitals. Although the interview sample size was not large

enough for a valid statistical data population, this does not detract from the qualitative value of the knowledge obtained.

### ***Interview Methodology and Process***

Interviewees were selected from several sources, including the author's personal network, recommendations from MIT Hacking Medicine members, and recommendations from the interviewees themselves. These sessions typically lasted 45 minutes to one and a half hours, and were either conducted in-person, or via telephone/Skype.

The interview process was structured as follows:

1. Prior to the interview, a consent form (see Appendix D) was emailed to the interviewees. The consent form informed the interviewee about the motivation and objectives for this research, as well as the levels of consent that could be given for the release of interview information.
2. During the interview, interviewees were verbally given an overview of the motivation and objectives for this research, and walked through the consent form. Thereafter, interviewees were given time to indicate their consent and the level of anonymity required from this author in reproducing the conversation.
3. Interviewees introduced their background and experiences with regards to their respective hospitals and to research topic.

4. Based on their introduction, questions around digital health – focused on their background and experiences – were posed to the interviewees. Interviewees were provided sufficient time to respond, and encouraged to ask follow-up questions for elaboration.
5. After the questions were covered, interviewees were provided a period of open dialog to elaborate further on any topic previously discussed and offer additional insights not included in the questionnaire.

The following questions were posed to all interviewees:

1. What does digital health and/or healthcare IT mean for you?
2. Describe your experience with at least one implementation of digital health and/or healthcare IT within your hospital.
  - a. Please highlight your perceived rationale/motivation for the new system to be implemented.
  - b. Please explain the challenges in implementation.
  - c. Please highlight the perceived outcome and benefits (if applicable) of the digital health solution.
3. How is the hospital obtaining the IT and other non-medical expertise/resources for digital health/healthcare IT implementation and innovation?
4. If applicable, describe any initiatives/policies that are in place to encourage digital health/healthcare IT innovation and entrepreneurship at the hospital.



5. What are the future challenges and opportunities for digital health/healthcare IT at the hospital?

For interviewees with leadership roles in IT and operations, one further question was posed:

6. Describe the relationship with digital healthcare/healthcare IT solutions providers.

### ***Data Collection and Analysis***

Upon completion of the interview process, the information on each hospital's approach towards digital health was captured and consolidated. The latter half of this chapter will analyze these responses, drawing from common themes by categorizing similar responses from different interviewees. Insights on KKH's and BCH's policies, resources, trends, and attitudes to digital health innovation and entrepreneurship will be discussed.

#### **4.4.2 Findings**

##### ***Theme #1: Leadership as digital health innovation "champions"***

Two of the interviewees from BCH were hospital leaders with digital health innovation promotion under their purview<sup>41</sup>: Dr. Daniel Nigrin, Senior Vice

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<sup>41</sup> Another such BCH leader is Ms. Jean Mixer, Vice President of Strategy and Digital Health; however, she was not interviewed.

President for Information Services and Chief Information Officer; and Dr. John Brownstein, Chief Innovation Officer. Besides ensuring the success of new digital health tools being rolled out, both stated that a top priority was to facilitate hospital staff to innovate using digital health technologies (Nigrin 2015; Brownstein 2015). Also, both of these leaders were themselves early adopters and innovators in digital health: Nigrin took on the role of BCH's first Director of Clinical Computing in the 2000s (Nigrin 2015), and Brownstein was formerly the director of BCH's computational epidemiology group and considered a "global leader" in healthcare IT for his research and commercialization of public health informatics innovation (BCH 2015a).

The KKH interviewees acknowledged the importance of digital health in the hospital. Alson Goh, Chief Operating Officer, and Dr. Alex Sia highlighted that all public/restructured hospitals were mandated by MOH to appoint a chief medical information officer, who was also a practicing doctor, to oversee digital health initiatives (A. Goh 2015; Sia 2015). Dr. Joseph Gomez, Director of Medical Informatics, shared that he was deeply involved in both the roll-out of new digital health systems as well as the establishment of internal digital health interest groups at KKH to build familiarity and capability among the early adopter staff (Gomez 2015).

The presence of innovators and early adopters as prominent hospital leaders and innovation "champions" helps facilitate a positive innovation culture (Lee 2004;

Rogers 2010) and provides senior doctors with opinion leaders and positive examples to emulate (Berwick DM 2003; Lindquist et al. 2008). While BCH has a longer history of engaging in digital health research, KKH appears to be on the right path with leadership acknowledging the importance of this area. As the KKH's experience with digital health matures, the hospital could potentially identify additional innovators and early adopters for future digital health leadership positions.

***Theme #2: Dedicated in-house resources for digital health commercialization***

Nigrin and Alan Yen, Licensing Manager at TIDO, shared the availability of the FastTrack Innovation in Technology (FIT) Award to provide BCH innovators who have clinical software ideas with “dedicated, skilled software development support, business analysis and deployment expertise” (Nigrin 2015; Yen 2015; BCH 2015b). Yen noted that this gave physicians access to IT and other business resources that would otherwise be focused on hospital operations, and allowed innovators to build subalpha prototypes. Yen also noted that BCH had a team of informatics researchers that physicians could tap on for informatics-related research.

Being part of the SingHealth group, KKH's commercialization resources reside centrally with their organizational parent. In terms of IT resources, Gomez and Sia shared that IHIS provided the hospital with technical managers, some who sit within KKH. Based on the discussions by a new internal core group for data analytics formed earlier in 2015, KKH was also considering bringing in new staff

with statistics and engineering background to assist in digital health development. (Gomez 2015; Sia 2015)

The availability of resources for commercialization helps build the important “market-oriented business culture” that is key for innovators to understand customer needs (Deshpande and Webster Jr 1989; Slater, Mohr, and Sengupta 1995). This provides physicians with the confidence that their digital health ideas could have clinical impact even if they themselves do not possess the engineering capabilities to build them. This “market-oriented business culture” at BCH was also evident in Brownstein’s comment that BCH leaders were showing interest and investment in digital health as they viewed this area as both a competitive threat and a business opportunity (Brownstein 2015). Further, these resources act as physical manifestations of a hospital’s openness to develop and adopt innovative ideas (Thakur, Hsu, and Fontenot 2012).

Once again, KKH appears to be much earlier in its digital health journey than BCH. KKH’s approach to build interest internally and plans for future dedicated resources are steps in the right direction. However, as the interest in digital health matures, KKH could also consider bringing more downstream capabilities onboard, e.g. business analysis and deployment, or partner more closely with SingHealth to make technology transfer resources more accessible.

### ***Theme #3: Consultative process for new systems roll-out***

When asked to recount how a new healthcare IT system was rolled out, Nigrin cited a new automated error-checking system for drug prescription that began piloting at BCH in the early 2000s. He described a long consultative process with healthcare staff at all levels that allowed for feedback, buy-in and resultant system iteration and improvement. The initial stages of consultation engaged with staff across the hospital, including management, doctors, nurses, pharmacists, and IT personnel. In total the new system took around four years to implement. Nigrin also highlighted that in his experience, off-the-shelf technology was rarely a perfect match for the hospital's needs, and emphasized the importance of having strategic partnerships with vendors. (Nigrin 2015)

Interviewees from KKH also described a similar Closed Loop Medication Management System (CLMM), which was rolled out by IHiS between 2009 to 2011 (IHiS 2012). Gomez described that the decision for equipment and vendor selection was based on views "IT-savvy senior clinicians. To facilitate the new system roll-out, user-champions were identified from every department. With training materials created in-house, the vendor was tasked with training staff. (Gomez 2015)

A 4th-year obstetrics and gynecology (OB/GYN) resident at KKH recounted that the CLMM roll-out was communicated to most doctors by email, and that due to time constraints, only the most salient features of the new system were taught to junior doctors. As junior doctors tended to be the heaviest users of the system, this

initial training appeared to be insufficient, and they recalled having to teach themselves the remaining parts of the system through trial and error. Furthermore, they shared that “among clinicians, digital health is seen as infrastructure, something that the hospital deals with,” and observed that it appeared only the administration had access to funding and resources to undertake digital health innovation. (4th-year KKH OB/GYN resident 2015)

When describing best practices for roll out of new healthcare IT systems at KKH in general, Goh iterated the importance of having both healthcare professional user champions and patient focus groups to provide in-depth feedback. Additionally, he emphasized the importance of being responsive to feedback from users in order to continuously refine the system. (Goh 2015)

Studies show that commitment from both the ICT vendor team and acceptance by key user groups is important to ensure the successful implementation of a new system (Constantinides and Barrett 2006). Especially when it comes to business process redesign, empowering all the representatives enhances the innovation process, encourages continuous improvement, and strengthens the collective commitment to the innovation (Smith and Fingar 2003; Thakur, Hsu, and Fontenot 2012). Although user-champions were identified at KKH, the process of roll out still appeared very top-down and did not seem to have strong involvement from junior staff. While this allows a new system to be implemented more quickly, it may limit the impact of the new system because of insufficient understanding and

buy-in from staff. Additionally, the potential for a negative experience provoked by a new system may alienate healthcare professionals from perceiving digital health as a tool to solve their research and clinical challenges.

#### **4.5 Discussion and Recommendations**

The capacity of Singapore healthcare professionals in general, let alone for innovation, appears to be a longstanding issue. While Singapore is looking into ways to ameliorate the situation, progress is likely to take place slowly over the long term. Besides this, while KKH is newer to digital health, it appears to be on the right path in engaging a wide spectrum of stakeholders, undertaking a variety of research, and getting leadership to champion digital health initiatives.

##### **4.5.1 Recommendation #1. More Inclusive Input for New Digital Health Systems**

One area of improvement is KKH's inclusiveness of staff outside senior doctors and leadership into the roll-out of new digital health systems. While a more top-down approach increases the speed of buy-in, a greater focus on bottom-up engagement could increase buy-in from the more junior staff who are likely to be the heaviest users of the new system. Further, positive experiences with new systems is more likely to predispose healthcare professionals to view digital health as a potential tool for innovation, rather than just "infrastructure" that they are merely users of.

#### **4.5.2 Recommendation #2: Identify and Celebrate Innovators and Early Adopters**

The effort to seed a digital health community at KKH, i.e. the big data core group, allows likeminded individuals to further their interest in digital health within a culture more amenable to innovation. In order for this culture to more quickly spread throughout the organization, innovators and early adopters in digital health can be identified and celebrated. Doctors who are involved in digital health research or patents should be encouraged to share their experience. This will create increased awareness among healthcare professionals that digital health can be applied to clinically important challenges.

#### **4.5.3 Recommendation #3: Partner to Build Digital Health Innovation and Entrepreneurial Capacity**

As previously mentioned, the capacity to engage in innovation and entrepreneurship is not one that can be solved internally. Further, KKH's structure dictates that much of its IT and technology transfer capabilities must lie outside the hospital. In particular, KKH does not seem to have ready access resources for commercialization of the new technologies that might arise from increased digital health innovation. One way to address these issues is to partner with other organizations - e.g. Singhealth, universities, research institutes, companies, etc. - to leverage their capacity and capabilities, yet still have a close relationship with the patient environment to enable greater impact. However, any such partnership will still require motivated KKH champions to anchor each collaboration, hence the



importance of recommendation #2 to be implemented first in order to build up a critical mass of clinicians with familiarity and interest in this space.

## Chapter 5. Hackathons as a Program to Enhance the Digital Health IDE Ecosystem in Singapore?

Hackathons in Singapore are not new. UP Singapore, the main organizer of hackathons in the country, organized its first hackathon in 2012 and has since organized 27 hackathons focused on a variety of socio-economic and environmental challenges<sup>42</sup>. While the organization states that they “welcome people with different backgrounds and skills, so [participants] don’t necessarily need to have coding skills”<sup>42</sup>, UP Singapore events tend to focus around data sets and application programming interfaces (APIs) provided by public and private partners. Anecdotally, hackathons in Singapore seem to have retained their traditional computer science and developer focus, typically attracting participation mainly from developers and data scientists.

“MIT Hacking Medicine @ SG50”<sup>43</sup> was a healthcare hackathon organized around the theme “Aging in place”<sup>44</sup>. As the first healthcare hackathon in Singapore using the “Hacking Medicine process”(DePasse et al. 2014), the event targeted participation from four main skillsets: healthcare professionals, designers, business professionals/entrepreneurs, in addition to the traditional developer/engineer population. As indicated from the case study in Chapter 5, greater multi-disciplinary interaction and partnership with external organisations could help Singapore-based doctors engage more fully in Digital Health innovation and entrepreneurship. Hence

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<sup>42</sup> Source: UP Singapore website, <http://www.upsingapore.com/about/>

<sup>43</sup> Where “SG” is the 2-letter code for Singapore as supplied by the International Organization for Standardization (ISO). “SG50” is the moniker given to the events surrounding the celebration of Singapore’s 50<sup>th</sup> year of independence, which took place in 2015.

<sup>44</sup> Source: event website, <https://ideas.ecitizen.gov.sg/a/pages/hackathon-at-sg-2015-hackmed>

an analysis of this hackathon for its effectiveness in creating a stronger network among IDE ecosystem stakeholders and a greater awareness of the opportunities in digital health is of considerable interest. Thus, a special effort was made by the hackathon organizers to reach out to healthcare professionals and healthcare business people, to ensure they were a significant population of participants at the event.

A unique challenge of this healthcare hackathon, compared to the traditional hackathon, was that in addition to the traditional prototype, participants were asked to create a business plan for a technology-driven innovation that improved healthcare and wellness for Singaporean seniors. An online survey was distributed near the end of the event to evaluate this hackathon's effectiveness in creating the networks and culture to advance Digital Health innovation and entrepreneurship in Singapore.

## **5.1 Overview of the Event**

### **5.1.1 Organizers and Roles**

The hackathon was the result of a collaboration between the four main organizers: MIT Hacking Medicine (MIT HM), Hacking Medicine Institute (HMI), the Singapore-MIT Alliance for Research and Technology (SMART), and the Infocomm Development Agency of Singapore (IDA). (It should be noted that this author was a member of the organising team under MIT HM.)

**Table 18. Description of the four main organizers**

Organisation	Description
MIT Hacking Medicine (MIT HM)	MIT Hacking Medicine is a MIT student group that aims to energize the health ecosystem to solve some of healthcare’s biggest challenges by connecting the best and most diverse minds. Since holding the first ever health hackathon in 2010, the group has organized over 40 health hackathons with more than 30 national and international organizations. More than 10 healthcare start-ups have emerged from MIT HM’s health hackathons. <sup>45</sup>
Hacking Medicine Institute (HMI)	Hacking Medicine Institute is a non-profit educational institute spun out of MIT’s Hacking Medicine Initiative in 2015 to teach how digital health and technology are enabling the global transformation of healthcare across the triple aims of increased access, better outcomes and lower costs. HMI convenes summits of health leaders across the range of stakeholders to identify opportunities for collaboration and active data generation around tech-enabled scaling of medicine and health. <sup>46</sup>
Singapore-MIT Alliance for Research and Technology (SMART)	Established in 2007, the SMART Center is MIT’s first, and to-date only, research centre outside the United States. MIT faculty members have laboratories at SMART, mentor postdoctoral associates and graduate students, and collaborate with researchers from universities, research institutes and industries in Singapore and Asia. <sup>47</sup>
Infocomm Development Agency of Singapore (IDA)	The Infocomm Development Authority of Singapore’s mission is to develop information technology and telecommunications within Singapore with a view to serve citizens of all ages and companies of all sizes. IDA does this by actively supporting the growth of innovative technology companies and start-ups in Singapore, working with leading global IT companies as well as developing excellent information technology and telecommunications infrastructure, policies and capabilities for Singapore. <sup>48</sup>

The idea for such an event and collaboration came from SMART, who also took on the roles of outreach to participants and mentors, and sourcing for partners. Building on their experience organising health hackathons, MIT HM and HMI were brought in to serve as “lead designers” and facilitators for the event, with a team of 11 from Cambridge, MA traveling to Singapore for the weekend. IDA’s roles were as

<sup>45</sup> Source: MIT HM website, <http://hackingmedicine.mit.edu/>

<sup>46</sup> Source: Mr. Zen Chu, President of HMI

<sup>47</sup> Source: SMART website, <http://smart.mit.edu/>

<sup>48</sup> Source: IDA website, <http://www.ida.gov.sg/About-Us/What-We-Do>

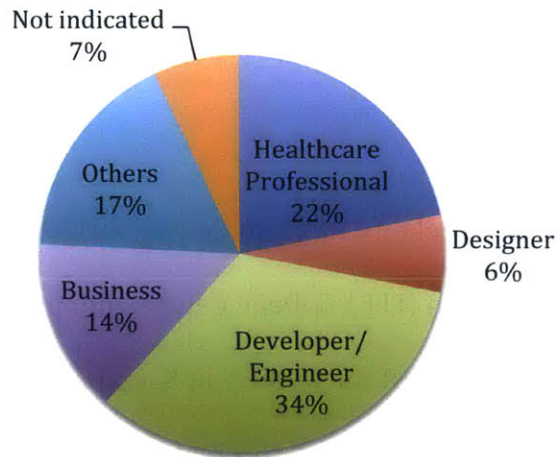
the main sponsor, logistical lead, and event marketer, leveraging their lead role in the larger Hackathon @ SG50 event.

### **5.1.2 Event Details**

The event took place over the weekend of 25 to 26 July 2015, and was co-located at the Institute of Technical Education (ITE) College Central alongside IDA's "Hackathon @ SG50" event, touted as the "largest hackathon in Singapore" with more than 400 registrants. IDA's aim for both events was to create excitement and buzz for the "Smart Nation" Programme announced by Singapore Prime Minister Lee Hsien Loong in the previous year (H. L. Lee 2014).

128 participants registered at the event, and their indicated professions are shown in Figure 2. 44 mentors were on hand during the event to provide feedback to teams as they refined their solutions. The mentors' professional backgrounds were from various parts of the digital healthcare ecosystem – including doctors, occupational therapists, entrepreneurs, entrepreneurial educators, venture capitalists, policy makers, engineers, and medical technology designers.

**Figure 2. Professions of the 128 participants**



### **5.1.3 Event Proceedings**

The hackathon followed the “MIT Hacking Medicine process” described by DePasse *et al*(DePasse et al. 2014). A detailed schedule of the two days can be found in Appendix E.

#### ***Pitching and Team Formation***

The first half of day one was devoted to problem pitching and team formation. Individuals had the opportunity to give a one-minute pitch on a problem they were passionate about solving over the weekend. A total of 62 pitches were given. Team formation took place immediately afterwards, allowing teams to form along similar interests and encouraging diversity in skill sets within the teams.

### ***“Hacking” and Mentoring***

Teams had the remainder of the day one and up to 2pm on the day two to define their problem, propose a solution, iterate and refine that solution, as well as to build and test a prototype. A combination of verbal briefing, educational materials, and coaching from mentors guided teams “to use design thinking techniques while rapidly iterating upon developing solutions” (DePasse et al. 2014).

Two “pitch practice” sessions were held. The first occurred on Saturday evening, where teams were given feedback from a panel of mentors on their problem definition and proposed solution. The first practice pitch session was intentionally informal, ensuring teams had made progress and were on a reasonable pace toward suggested milestones. It also benefited the mentor group by demonstrating which teams needed additional support. The second session was on Sunday morning, where teams obtained feedback on the delivery of their final presentation from another panel of mentors.

### ***Final Presentation and Judging***

Starting at 2pm on the second day, 24 teams gave a final presentation of their problem, solution, prototype, and business model. Each team had three minutes to present, followed by a two minute question and answer session with the judges. A panel of six judges – representing expertise from healthcare delivery, product design, entrepreneurship, and government – decided on winners for the 10 prizes

totalling S\$25,000. See Appendix F for the list of judges and judging criteria, and Appendix G for details on the 10 prizes and prizewinners.

## **5.2 Survey Methodology**

HMI designed and administered an anonymous online survey to all participants. The aim was to gain insights into the participants' demography, the event's effectiveness in promoting digital health innovation and entrepreneurship, as well as to obtain general feedback on the overall organisation of the event. Participants were given the link to the survey after the final presentations, while the judges were deliberating the final outcome. A copy of the survey questions can be found in Appendix H.

With HMI's permission, data from this survey was analyzed to evaluate the following:

- Whether the hackathon increased awareness of the opportunities in Digital Health solutions for the elderly (one scaled item<sup>49</sup>);
- Whether the participants felt more able and willing to innovate Digital Health solutions for the elderly after the hackathon (two scaled items);
- The value and breadth of networks that participants formed during the hackathon (two scaled items<sup>50</sup> and two multiple choice questions allowing more than one option); and

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<sup>49</sup> Measured on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

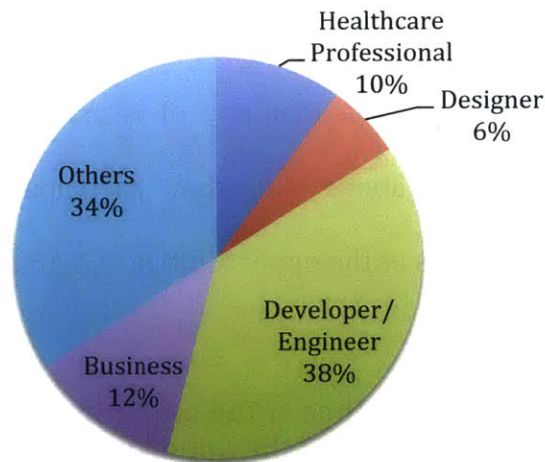


- Participants' perceived value of the hackathon (two scaled items<sup>49</sup>).

### 5.3 Data and Analysis

A total of 50 participants responded to the survey corresponding to 39.1% of all registered participants. Hence, unless otherwise indicated, N=50 for all the responses analyzed. A breakdown of respondents by profession is shown below.

**Figure 3. Professions of the 50 survey respondents.**



The hypothesis that healthcare professionals and business people would not have typically attended hackathons is borne out in the responses to the question “How many hackathons have you previously attended” (see Table 19). None of the respondents from these two professions had previously attended a hackathon. In fact, two-thirds of respondents indicated that this was their first time at any

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<sup>50</sup> Measured on a 5-point Likert scale, with one set of responses ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), and the other set of responses ranging from 1 (*extremely poor*) to 5 (*excellent*).

hackathon. Also as hypothesized from anecdotal evidence, a majority of respondents who had previously attended hackathons identified themselves as developers/engineers (14 out of 17 or 82.4% of these respondents).

**Table 19. Response to “How many hackathons have you previously attended?”**

Profession	Indicated "0"	Total number of respondents	% of all respondents
Healthcare Professional	5	5	100.0%
Designer	2	3	66.7%
Developer/Engineer	5	19	26.3%
Business	6	6	100.0%
Others	15	17	88.2%
<b>Total</b>	<b>33</b>	<b>50</b>	<b>66.0%</b>

As Table 20 illustrates, the majority of respondents agree, with sample weighted average response above 4.0, that participating in the Hackathon contributed to their awareness of the opportunities in digital health for the elderly.

**Table 20. Participants’ perceptions of the hackathon’s contribution towards awareness of the opportunities.**

Statement	Sample weighted average response	Sample SD
I have a clearer understanding of the problems faced by the elderly, their families, and their caretakers after the hackathon.*	4.14	0.84
*Responses on a scale from 1 to 5 (1 = <i>strongly disagree</i> and 5 = <i>strongly agree</i> )		

As seen in Table 21, agreement with the statement “I am more confident in my ability to contribute to the problems faced by the elderly and their caretakers after the hackathon” has a sample weighted average response of 4.0, while the same value for the statement “I plan to continue pursuing the idea/business that my team

developed this weekend” is slightly less than 4.0. This may indicate that while participating in the Hackathon contributed towards respondents’ perception of their ability to innovate for digital health, it did not necessarily contribute towards their willingness to do so outside the event. As a program, hackathons’ success in directly creating impact (i.e. innovations and new enterprises) outside the event is debateable. As an example, despite the over 40 hackathons that MIT HM has organized and the undoubtedly hundreds of teams that have experienced these healthcare hackathons, the group only counts 12 businesses as having had their origins at a MIT HM event<sup>51</sup>. Besides the high failure rate of startups in general, this could also be the nature of a healthcare hackathon: as teams are usually formed in an *ad hoc* manner, the decision to embark on a new enterprise with a team of almost-strangers is understandably not immediately attractive.

**Table 21. Participants’ perceptions of the hackathon’s contribution towards ability and willingness to innovate.**

Statement	Sample weighted average response	Sample SD
I am more confident in my ability to contribute to the problems faced by the elderly and their caretakers after the hackathon.*	4.00	0.70
I plan to continue pursuing the idea/business that my team developed this weekend.*	3.88	1.05
*Responses on a scale from 1 to 5 (1 = <i>strongly disagree</i> and 5 = <i>strongly agree</i> )		

The breadth of team members’ professions is borne out by the response to the statement “The people in my team are outside my discipline/profession”, with a mean response above 4.0, as well as by the average number of professions and

<sup>51</sup> Source: MIT HM website, <http://hackingmedicine.mit.edu/>

organizations represented by respondents' teammates reported as more than 3.0 (see Tables 22 and 23). However, the diversity of networks available was not uniformly perceived as being valuable to respondents, with mean agreement to the statement "I networked and made valuable contacts at this hackathon" being slightly below 4.0.

**Table 22. Participants' perceptions of the value and breadth of networks formed.**

Statement	Sample weighted average response	Sample SD
I networked and made valuable contacts at this hackathon.*	3.82	0.69
The people in my team are outside my discipline/profession.*	4.29	0.81
*Responses on a scale from 1 to 5 (1 = <i>strongly disagree</i> and 5 = <i>strongly agree</i> )		

**Table 23. Participants' self reporting on the breadth of professions and organizations of their team mates**

Statement	Average number represented by team members	Sample SD
As best as you can, indicate all the professions of your team members (more than 1 choice acceptable). Please exclude yourself.	3.26 different categories of professions	1.14
As best as you can, indicate all the places of work of your team members (more than 1 choice acceptable). Please exclude yourself.	3.08 different categories of organizations	1.19

**Table 24. Respondents who indicated that they had the following professions represented on their team.**

	Business development/sales	Health-care professional	Designer	Developer	Engineer	Entrepreneur	Civil/public servant	Others
Number	23	27	28	35	25	13	6	4
% of total	46%	54%	56%	70%	50%	26%	12%	8%

**Table 25. Respondents who indicated that they had the following organizations represented on their team.**

←Potential source of innovation for IDEs→

←Potential source of business for IDEs→

	Government	University	Research Institute	Hospital	Large private business <sup>52</sup>	Small and medium enterprise <sup>53</sup>	Start-up <sup>54</sup>	Bank/Risk Capital
Number	21	25	17	18	11	18	19	5
% of total	42%	50%	34%	36%	22%	36%	38%	10%

In addition, as seen in Table 26, mean agreement with the statements “How does the healthcare hackathon fair in comparison to other ideation and networking events you’ve attended” and “I would recommend a healthcare hackathon to my friends and/or colleagues” were at least 4.0. This indicates that overall, respondents found value in the event, and that future healthcare hackathons might be expected to enjoy similar or greater participation across the relevant professions and stakeholders.

**Table 26. Participants’ perceptions of the Hackathon’s value.**

Statement	Sample weighted average response	Sample SD
How does the healthcare hackathon fair in comparison to other ideation and networking events you’ve attended? <sup>§</sup> <i>(Note: For this question, N=31, as respondents were given the option of answering “NA” to take into account those who had not previously attended ideation and networking events.)</i>	4.00	0.88
I would recommend a healthcare hackathon to my friends and/or colleagues.*	4.33	0.62
<sup>§</sup> Responses on a scale from 1 to 5 (1 = <i>extremely poor</i> and 5 = <i>excellent</i> ) <sup>*</sup> Responses on a scale from 1 to 5 (1 = <i>strongly disagree</i> and 5 = <i>strongly agree</i> )		

<sup>52</sup> Defined as having more than 200 employees.

<sup>53</sup> Defined as having less than 200 employees and more than 5 years in business.

<sup>54</sup> Defined as having less than 5 years in business.

The survey also included two open-ended questions that prompted the respondents to give feedback on the multidisciplinary and business plan-focused nature of the healthcare hackathon (as compared to regular coding-centric hackathons), as well as comments and suggestions for the event in general. Responses were mixed. Positive responses showed appreciation for four main themes: the breadth of participants; the help availed by mentors; structure of the event; and insights into digital healthcare business formation. Negative responses – aside from those concerning the logistics of the event – noted a frustration with three main themes: an over-emphasis on business; an insufficient focus on coding; and some teams having an insufficient breadth of skillsets. These themes, along with examples of illustrative verbatim comments, are displayed in Table 27.

**Table 27. Respondents’ open-ended evaluation of the Hackathon**

<b>Positive themes</b>	<b>Example verbatim comments</b>
Breadth of participants	“It was great that I met so many different professionals from different disciplines.” “Great for networking.”
Help availed by mentors	“Great mentorship and great building of enthusiasm.” “We get much more help from mentor and expert.”
Structure of event	“The practise sessions aid in identifying key areas for the participants to focus on and certainly brings desired direction to the final presentation.” “Management was great.”
Insights into digital healthcare business formation	“Good insights into business development, and exploring opportunities in healthcare.” “I found the Hackathon to be a very friendly event for an industry that is monolithic and intimidating, and for a theme that can go in very depressing directions.”
<b>Negative themes</b>	
Over-emphasis on business	“Having focus on the business model is distracting.”
Insufficient focus on coding	“Should have been more about coding.” “Barely any focus on the tech and data.”
Teams not having a breadth of skillsets	“Organizers need to take a more active role linking up tech people with healthcare people. Many teams were visibly imbalanced.”

## **5.4 Discussion and Recommendations**

The results from the survey broadly indicate that a “MIT HM process” healthcare hackathon are a credible programmatic intervention to enhance the knowhow, networks, and attitudes surrounding digital health innovation and entrepreneurship in Singapore. These events could also be a catalyst for change in hospitals when healthcare professionals bring their newfound networks and understanding of digital health opportunities into their workplaces. Additionally, these attendees could be identified by hospitals as digital health innovators and early adopters. However, in light of some of the constructive feedback from the survey, a few changes are recommended to better tailor the event for the Singaporean context.

### **5.4.1 Recommendation 1: Hackathon Organizers to be More Hands-On With Team Formation**

The Singapore community is relatively new to the interdisciplinary collaboration necessary for digital health. Hence, healthcare hackathon organizers could provide more structure to better ensure that teams have the diverse skillsets necessary, as well as provide more encouragement for team diversity. Sharing success stories of diverse hackathon teams that have started companies could help address the latter. The former could be achieved by being stricter on the ratio of skillsets admitted to a hackathon, as well as prescribing that teams require multiple skillsets to be eligible to win a prize. Less rigidly, conducting talks and networking opportunities prior to the hackathon would allow hackathon organisers to be more familiar with participants’ skillsets, as well as help participants get to know each other. This

would allow hackathon organisers to directly assist in matchmaking teams during the team formation phase.

#### **5.4.2 Recommendation 2: More Education Around Healthcare Design Thinking and Business Models**

While a common criticism was that the event was overly-focused on business to the detriment of “coding”, the aim of this event was for teams to create *both* prototypes and a business plan, in order for the solutions developed to have the potential to create impact in healthcare. Unlike “hacking” for other challenges, design and business planning for healthcare innovations are inherently complicated due to the multi-faceted interactions between patient, physician, provider, and payor. Hence, it is not surprising that teams, largely consisting of first-time participants, spent much of the time refining their problem definition and business model, which was a necessary to inform the design and subsequent prototype.

In the future, participant’s abilities in healthcare design thinking and business models should be increased for teams to progress further with meaningful prototyping. Of course, entrepreneurial education is one of the aims of the event. However, healthcare hackathons could hold pre-event workshops covering these topics. More broadly, if schools seek to enable students in digital healthcare innovation and entrepreneurship, healthcare classes with a dual design and business focus can be taught. Examples of such classes taught at American



Universities include Healthcare Ventures at MIT<sup>55</sup>; Engineering Health at the MIT Media Lab<sup>56</sup>; New Ventures in Healthcare and the Life Sciences at Yale University<sup>57</sup>; and Innovating in Healthcare at the Harvard Business School (HBS)<sup>58</sup>.

### **5.4.3 Recommendation 3: Create Continuity and Sustainability**

While not the result of direct feedback from participants, an inherent weakness of the hackathon is its one-off nature. There are typically no follow-on actions to reinforce the boost in knowhow, networks, and attitudes that participants experience. As the time invested by participants in a hackathon is significant, this shortcoming cannot be sustainably ameliorated by increasing the frequency of events.

One way MIT HM is attempting to address this in its home base of Boston is to offer a prize to the team that undergoes the greatest progress a month after the hackathon. While no data has yet been collected on this, anecdotally, the prospect of a prize seems to give some teams the additional incentive to keep working on their idea after the event.

As one of the foremost benefits of the event is the increased network, another way to preserve this over a longer period of time is to create a community

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<sup>55</sup> More information on the MIT Martin Trust Centre for Entrepreneurship website, <https://entrepreneurship.mit.edu/academics#f-15367>

<sup>56</sup> More information on the MIT Media Lab website, <http://cameraculture.media.mit.edu/enghealth/>

<sup>57</sup> More information on the Yale School of Management website, <http://som.yale.edu/faculty-research/our-centers-initiatives/program-entrepreneurship/curriculum>

<sup>58</sup> More information on the HBS website, <http://www.hbs.edu/coursecatalog/2180.html>

around the hackathon participants through shared information and events. Some examples of this include a mailing list, networking events, visits to healthcare facilities, and talks.

Also, as Boston hospitals have been regular partners with MIT HM over the last five years, these organizations have taken the hackathon ethos in-house and established their own digital health pilot initiatives backed by substantial resources over an extended period of time. Examples include the Co.Create program at the Massachusetts General Hospital (MGH) launched in 2015, which provides funding, mentorship, and a pilot opportunity to students with successful digital health proposals<sup>59</sup>; and the Pilot Shark Tank Challenge at Brigham and Women's Hospital (BWH) launched in 2014, which connects health tech entrepreneurs and hackers with clinical partners at BWH, as well as providing a pilot opportunity to successful applicants<sup>60</sup>.

It should be noted that Singapore hospitals may not be the best home for such initiatives at this time due to higher order priorities and limited resources in staffing and patient care. Nevertheless, other organisations like public research agencies, university technology transfer offices, healthcare companies, startup accelerators and government agencies with a mission to promote IDEs could be potential leads. For the innovations to be piloted in a real-world setting, healthcare providers would likely be required as close partners. However, such an initiative is

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<sup>59</sup> Source: MGH Co.Create website, <http://sandeep-burugupalli-ccl.squarespace.com/#newapproach>

<sup>60</sup> Source: BWH Innovation Hub website, <http://disruptingmedicine.org/for-external-innovators/>

probably more appropriate in the medium term, when the community reaches critical mass, and the knowhow, networks, and culture of “digital healthcare hacking” have gained more acceptance and legitimacy within the ecosystem.

## **Chapter 6. Conclusion**

This study shows that while Singapore has the necessary ingredients for success in digital health, more could be done to generate awareness for the opportunities in this space, as well as to nurture healthcare professionals with stronger affinities for digital health innovation. Collaboration and community are key ingredients to enable the digital health sector in Singapore to thrive. Growing those networks in an environment where key human resources are limited by capacity issues will be challenging. However, as attendance by healthcare professionals at the hackathon showed, the challenge is not insurmountable. Appropriate organization of hackathons and other ideation/networking events could have a catalytic effect on the ecosystem. This is especially so given that so many in the potential participant pool have not previously attended similar events.

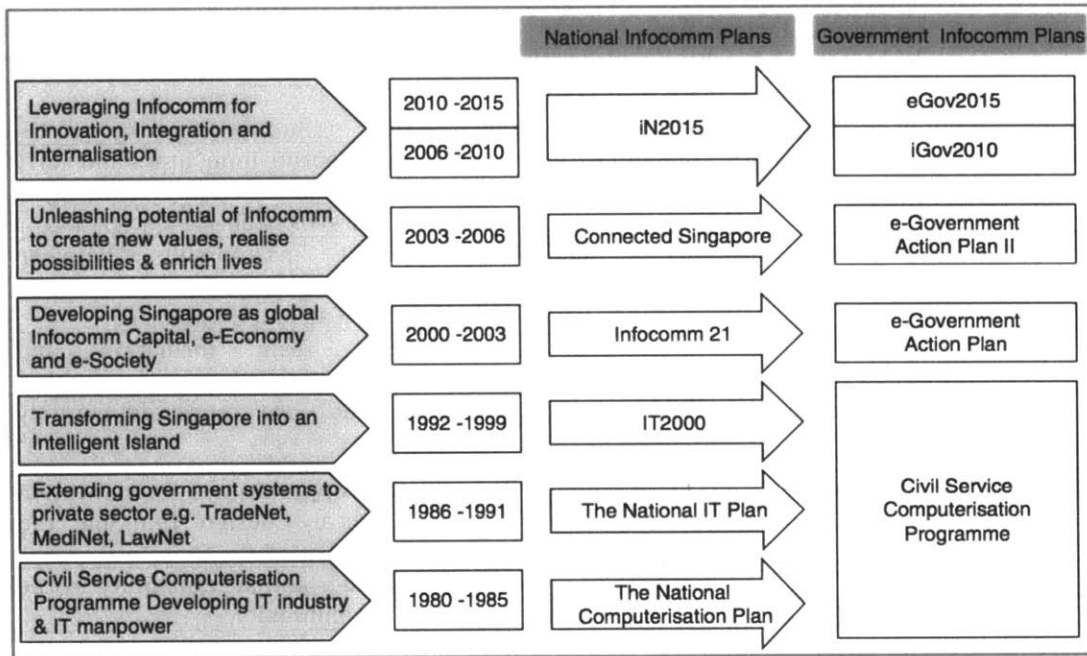
While not comprehensive, the recommendations in this work provide direction at the micro-level for hospital leadership looking to enhance clinicians' use of digital health tools, and also at the macro-level for ecosystem builders seeking to make the broader environment more conducive for the formation of digital health IDEs. These are summarized in the below table.

**Table 28. Summary of Recommendations.**

<b>Section</b>	<b>Recommendations for Hospital Leadership</b>	<b>Recommendations for Ecosystem Builders</b>
4.5.1	Seek more inclusive input across all staff for roll-out of new digital health systems.	-
4.5.2	Identify and celebrate innovators and early adopters of digital health technologies from hospital ranks.	Identify and celebrate innovators and early adopters of digital health technologies throughout the ecosystem
4.5.3	Partner strategic organizations to build digital health I-Cap and E-Cap.	Facilitate the partnership between hospitals and other organizations to build digital health I-Cap and E-Cap.
5.4.1	-	Ensure that team formation and networking at hackathons (and other ideation events) are more deliberately considered for diversity.
5.4.2	Encourage hospital staff to learn about healthcare design thinking and business models.	Provide more opportunities for education around healthcare design thinking and business models.
5.4.3	-	Create continuity and sustainability in the digital health community.

A hackathon only delineates the potential beginning of a start-up’s journey. Related future studies could build on these findings by analyzing what digital health start-ups in Singapore require from other stakeholders – i.e. risk capital, government, academic entities, and corporate entities – in order to be globally competitive. These studies would help ecosystem builders understand how to best support the IDE activities once a sustainable community is formed.

# Appendix A: Overview of Singapore's ICT master plans



Source: (Chua 2012 p.44)

## Appendix B: Data for Stakeholder Network Depth

	Number of BCH papers in the year			Number of KKH papers in the year		
	2011	2012	2013	2011	2012	2013
Hospital	1359	1576	1476	34	53	56
Medical School	1087	1229	1234	19	54	50
University	1589	1799	1794	23	67	68
Institute	456	559	459	0	11	16
Government/NFP/NGO	45	47	21	2	6	0
Company	51	61	44	0	0	2
<b>Total, N</b>	<b>4587</b>	<b>5271</b>	<b>5028</b>	<b>78</b>	<b>191</b>	<b>192</b>

	$\pi$ (BCH papers with x Stakeholder as affiliates)			$\pi$ (KKH papers with x Stakeholder as affiliates)		
	2011	2012	2013	2011	2012	2013
Hospital	29.6%	29.9%	29.4%	43.6%	27.7%	29.2%
Medical School	23.7%	23.3%	24.5%	24.4%	28.3%	26.0%
University	34.6%	34.1%	35.7%	29.5%	35.1%	35.4%
Institute	9.9%	10.6%	9.1%	0.0%	5.8%	8.3%
Government/NFP/NGO	1.0%	0.9%	0.4%	2.6%	3.1%	0.0%
Company	1.1%	1.2%	0.9%	0.0%	0.0%	1.0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

## Appendix C: Data for Diversity of Research Disciplines

Subject	Number of papers from BCH				Number of papers from KKH			
	2011	2012	2013	SUM	2011	2012	2013	SUM
Medicine	1844	1922	1887	5653	80	122	141	343
Multidisciplinary	74	80	74	228	0	1		1
Engineering	83	73	63	219	1	5	8	14
Computer Science	48	43	32	123	1	2	1	4
Business, Management and Accounting and Decision Sciences	3	1	2	6	0	0	0	0
All subjects excluding Medicine and Medicine related subjects	415	475	439	1329	5	18	17	40
<b>TOTAL PAPERS, N</b>	<b>2168</b>	<b>2279</b>	<b>2143</b>	<b>8569</b>	<b>88</b>	<b>133</b>	<b>161</b>	<b>576</b>

Subject	Proportion of papers with that subject from BCH in that year				Proportion of papers with that subject from KKH in that year			
	2011	2012	2013	SUM	2011	2012	2013	SUM
Medicine	85.1%	84.3%	88.1%	66.0%	90.9%	91.7%	87.6%	59.5%
Multidisciplinary	3.4%	3.5%	3.5%	2.7%	0.0%	0.8%	0.0%	0.2%
Engineering	3.8%	3.2%	2.9%	2.6%	1.1%	3.8%	5.0%	2.4%
Computer Science	2.2%	1.9%	1.5%	1.4%	1.1%	1.5%	0.6%	0.7%
Business, Management and Accounting and Decision Sciences	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
All subjects excluding Medicine and Medicine related subjects	19.1%	20.8%	20.5%	15.5%	5.7%	13.5%	10.6%	6.9%



# Appendix D: Interview Consent Form

## CONSENT TO PARTICIPATE IN INTERVIEW

Digital Healthcare Innovation and Entrepreneurship

You have been asked to participate in a research study conducted by Shirlene Liew from Engineering Systems Division (ESD) at the Massachusetts Institute of Technology (M.I.T.). The purpose of the study is to understand hospitals' experiences incorporating digital healthcare innovation and entrepreneurship into their operations, workflow, and culture; with the specific goal of comparing Boston's ecosystem and Singapore's. The results of this study will be included in Shirlene Liew's Masters thesis. You were selected as a possible participant in this study because you are a healthcare professional, manager, researcher, and/or administrator at a hospital. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

- This interview is voluntary. You have the right not to answer any question, and to stop the interview at any time or for any reason. I expect that the interview will take about 45 minutes.
- You will not be compensated for this interview.
- Unless you give us permission to use your name, title, and / or quote you in any publications that may result from this research, the information you tell us will be confidential.
- I would like to record this interview so that I can use it for reference while proceeding with this study. I will not record this interview without your permission. If you do grant permission for this conversation to be recorded, you have the right to revoke recording permission and/or end the interview at any time.

This project will be completed by August 30, 2015. All interview recordings will be stored in a secure work space until 2 years after that date. The recordings will then be destroyed.

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

*(Please check all that apply)*

I give permission for this interview to be recorded.

I give permission for the following information to be included in publications resulting from this study:

my name    my title    direct quotes from this interview

Name of Subject \_\_\_\_\_

Signature of Subject \_\_\_\_\_ Date \_\_\_\_\_

Signature of Investigator \_\_\_\_\_ Date \_\_\_\_\_

Please contact Shirlene Liew (617-949-9284 or shirlene@mit.edu) with any questions or concerns.

## Appendix E: Hackathon Schedule

<b>Time</b>	<b>DAY 1, 25 July 2015</b>
8:30am	Registration, Breakfast
9:30am	Kick-off, welcome
9:40am	Problem statements from partners
10:15am	Hack 101, How to pitch
10:30am	Problem pitch
11:45am	Social mingling
12:30pm	Overview of the rest of the day
12:45pm	Lunch served, Hack!
1:00pm	Mentors available
3:00pm	Deadline for team sign up, tea
6:00pm	Dinner served, keep hacking
	<b>DAY 2, 26 July 2015</b>
8:30-9:30 am	Breakfast
10:00am-1:00pm	Pitch practice sessions with mentors
12:00pm	Lunch served
2:00pm	Final presentations
4:00pm	Judges deliberate
4:30pm	Prize winners can be announced
5:00pm	Refreshments, networking

## Appendix F: List of Judges and Judging Criteria

### List of Judges

Name	Title, Organisation
Karen Koh	Partner, Myanmar Investment Group
Bruce Liang	Chief Information Office, Ministry of Health (MOH) Chief Information Officer, MOH Holdings
Low Cheaw Hwei	VP, Global Head of Product and Service Design, Philips Head of Design, Philips Asia
Dr. Snehal Patel	Co-Founder, MyDoc Managing Director, Saena Partners
Teoh Tsin Woon	Deputy Secretary (Development), Ministry of Health
Zee Yong Kang	Chief Executive Officer, Health Promotion Board

### Judging Criteria

#### HEALTH/WELLNESS IMPACT

1      2      3      4      5

Does the solution have the potential for widespread health/wellness impact in Singapore, and/or internationally? Does it address an important challenge identified in elder care, geriatrics, senior's caretakers, and/or any other clear need for seniors? Did the solution designed resolve the health and/or accessibility problems identified? How intuitive and user-friendly is the solution for users?

#### INNOVATION

1      2      3      4      5

How technologically innovative and creative/original is the solution ('better/faster/cheaper')? Does the team provide a convincing rationale for why their solution may work, and do they address significant technical issues relevant for the elderly and the people who care for them? Did the solution successfully combine design with technology seamlessly?

#### BUSINESS MODEL

1      2      3      4      5

Does the project have a sustainable business model? Did the team demonstrate plan to work in the field and continually incorporate end-user feedback? Did the team consider the experience, user interface or service design elements of the business model?

#### PRESENTATION

1      2      3      4      5

How effective was the presentation? Does this team have what it takes to carry on the project and implement it (e.g. cross-disciplinary expertise in technology development, clinical medicine, experience in elder care, and business/implementation)? Is the design concept clearly and convincingly visualised/presented?

TOTAL SCORE: \_\_\_\_\_

## **Appendix G: Prizes and Prizewinners**

### **First Prize: Caregiver (\$9,000)**

An app that facilitates communication between physicians and caregivers, where physicians can create and push monitoring questions to a caregiver's phone to solicit information for timely diagnosis and decisions.

### **Second - Foodnut (\$6,000)**

A simple drag-and-drop platform that provides diabetic patients access to a healthy and tasty diet.

### **Third Prize - Jaga.me (\$3,000)**

The 'Uber' of home care - the platform to efficiently match certified care aides/nurses and homebound patient.

### **Best Design - Mobile Wound Doctor (\$1,000)**

An app that analyses and monitors diabetic foot ulcers using machine learning algorithms, completing and facilitating clinician's care.

### **Best Business Plan - FoodNut (\$1,000)**

A simple drag-and-drop platform for selection and provision of a healthy and tasty diet to diabetic patients.

### **People's choice Prize - eMPower (\$1,000)**

An "active ageing" e-platform to constructively Employ, Engage, Entertain, Exercise and promote Companionship.

### **Best addresses "Ageing-in-Place" theme (\$1,000 each)**

#### **1. Caregiver**

An app that facilitates communication between physicians and caregivers, where physicians can create and push monitoring questions to a caregiver's phone to solicit information for timely diagnosis and decisions.

#### **2. Grandma, it's me!**

An app for families and communities to remind the elderly taking medicines on-time through voice messaging.

**Best Use of Technology to Promote Healthy Lifestyle for Seniors – Funhap (\$1,000)**

A fun, engaging and interactive game that brings rehab therapy to the homes of the elderly.

**Best Use of Technology to Navigate Singapore’s Healthcare System – Homage (\$1,000)**

An online senior in-homecare service that screens and links qualified care professionals with seniors.

## Appendix H: Post-hackathon participants' survey

Administered by HMI.

All multiple choice questions are single choice unless otherwise stated.

### Demographics

1. Age group
  - a. Below 16
  - b. 16-20
  - c. 21-25
  - d. 26-30
  - e. 31-40
  - f. 41-50
  - g. 51-60
  - h. >60
  
2. Role in Organization
  - a. Healthcare professional
  - b. Developer/Engineer
  - c. Designer
  - d. Business
  - e. Other (please indicate)
  
3. Country of residence
  - a. Singapore
  - b. South East Asia
  - c. Other (please indicate)
  
4. Place of work
  - a. Government
  - b. Hospital
  - c. VWO/NGO
  - d. University
  - e. Research Institute
  - f. Finance/Bank
  - g. Large private business (>200 employees)
  - h. Small and Medium Enterprise (SME) (<200 employees, >5 years in business)
  - i. Startup (<5 years in business)
  - j. Other (please indicate)
  
5. How many hackathons have you previously attended?
  - a. 0
  - b. 1
  - c. 2-4

- d. 5 or more
6. How did you hear about this event?
- a. Friend, colleague, word-of-mouth
  - b. Email blast
  - c. News article (Asian Scientist, etc.)
  - d. Social media (Facebook, Twitter, etc.)
  - e. Online search
  - f. Other (please indicate)

Please indicate how strongly you agree with statements 7 to 11.

7. I have a clearer understanding of the problems faced by the elderly and their caretakers after the hackathon.
- 1. Strongly disagree
  - 2. Disagree
  - 3. Neutral
  - 4. Agree
  - 5. Strongly agree
8. I am more confident in my ability to contribute to the problems faced by the elderly and their caretakers after the hackathon.
- 1. Strongly disagree
  - 2. Disagree
  - 3. Neutral
  - 4. Agree
  - 5. Strongly agree
9. I plan to continue pursuing the idea/business that my team developed this weekend
- 1. Strongly disagree
  - 2. Disagree
  - 3. Neutral
  - 4. Agree
  - 5. Strongly agree
10. I networked and made valuable contacts at this hackathon.
- 1. Strongly disagree
  - 2. Disagree
  - 3. Neutral
  - 4. Agree
  - 5. Strongly agree
11. The people in my team are outside my discipline/profession.
- 1. Strongly disagree

2. Disagree
3. Neutral
4. Agree
5. Strongly agree

12. As best as you can, indicate all the professions of your team members (more than 1 choice acceptable). Please exclude yourself.

- a. Healthcare professional
- b. Developer
- c. Engineer
- d. Designer
- e. Entrepreneur (company is <5 years in business)
- f. Others (please indicate)

13. As best as you can, indicate all the places of work of your team members (more than 1 choice acceptable). Please exclude yourself.

- a. Government
- b. Hospital
- c. VWO/NGO
- d. University
- e. Research Institute
- f. Finance
- g. Large business (>200 employees)
- h. SME (<200 employees, >5 years in business)
- i. Startup (<5 years in business)
- j. Others, please indicate

14. If you've previously attended hackathons in Singapore before, how does the healthcare hackathon fair in comparison to the previous hackathons you've attended?

1. Extremely Poor
2. Below Average
3. Average
4. Above Average
5. Excellent

15. In hackathons in Singapore, there is typically a pre-defined problem statement, teams are formed before the event, and no pitch practice session prior to the final presentation. This is a non-exhaustive list of where typical hackathons differ from this healthcare hackathon. We would appreciate your comments on whether you found these differences useful/not useful, and why.

*[Free text response]*



16. What other activities do you take part in to work on new ideas and expand your network? (Choose all that apply)

- a. Conferences
- b. Professional societies
- c. Interest groups
- d. Alumni organisations
- e. Others (please indicate)

17. How does the healthcare hackathon fair in comparison to other ideation and networking events you've attended (as indicated in question 16)?

- 1. Extremely Poor
- 2. Below Average
- 3. Average
- 4. Above Average
- 5. Excellent

Please indicate how strongly you agree with statement 18.

18. I would recommend a healthcare hackathon to my friends and/or colleagues

- 1. Strongly disagree
- 2. Disagree
- 3. Neutral
- 4. Agree
- 5. Strongly agree

19. Finally, we would appreciate any comments and suggestions you may have.

*[Free text response]*

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