Healthcare Transformation

Health Information Technology (HIT) and Digital Health are rapidly transforming healthcare systems spurred by technology innovation, government initiatives, and growing challenges of the 21st century in improving quality, efficiency, and patient experiences. Furthermore, the transformation of the healthcare system through new technological developments is moving into processes, practices and relationships across the ecosystem and is creating new opportunities for the sector and presents the potential to develop new strategies to cope with health risks.

mHealth: A New Path of Transformation for Health through Mobile Technologies

According to the International Telecommunication Union, which is a specialized agency of the United Nations (UN), seven billion people (95% of the global population) live in an area that is covered by a mobile-cellular network. Mobile-broadband networks (3G or above) reach 84% of the global population but only 67% of the rural population. LTE networks have spread quickly over the last three years and reach almost 4 billion people today (53% of the global population), enhancing the quality of Internet use (ICT: Facts and Figures, 2016).
The World Health Organization second global survey on eHealth “mHealth: New horizons for health through mobile technologies” (2011) published new highlights about mHealth that is defined by small-scale pilot projects that address single issues in information sharing and access. This new path of health transformation have the potential to play a key role in healthcare with the support of public-private partnerships to implement large-scale and complex programmes that will become more common as mHealth matures, and the policies and strategies to support its benefits are in place. Governments and private institutions are expressing interest in mHealth as a complementary strategy for strengthening health systems. These initiatives for example act as either stand-alone aids for Veterans with post-traumatic stress disorder (PTSD) or adjuncts to conventional psychotherapy approaches, as well as maternal and child health and evolves into a series of mHealth deployments worldwide that are providing early evidence of the potential for mobile and wireless technologies. These technologies can also aid in reducing the burden of the diseases linked with poverty, including HIV/AIDS, malaria, and tuberculosis (TB) (Ben-Zeev, Dror, 2016).
Many of these diseases, including HIV/AIDS, tuberculosis and malaria, are often considered as “diseases of poverty”; therefore, mortality rates and burden of disease are higher in less developed countries. In addition, malaria and dengue are water-related vector-borne diseases, and global evidence supports a direct and consistent association between access to clean water and poverty levels (UN-Habitat: The Challenge of Slums Global report on Human Settlements, 2006). Consequently, addressing health risks with mobile technologies help to shorten the gap to environmental conditions and poverty, which affect the lives of the poor disproportionately, pose serious health risks and restrain in economic development. Although the world is experiencing health advances in many areas, poor health continues to be a constraint on sustainable development efforts.

Fighting Chronic Disease through Mobile Coaching
Chronic diseases and conditions—such as heart disease, stroke, cancer, type 2 diabetes, obesity, and arthritis—are among the most common, costly, and preventable of all health problems and are also the leading causes of death and disability globally. As health care has become more complex, the burden on most healthcare systems becomes more acute.

An example of the benefits in prevention and early intervention as a big step towards the ultimate goal of making populations healthier through better lifestyles and increased compliance with their suggested care regimens is the impact mobile phone-based coaching and online decision support can have on diabetes patients. Chronic disease management often requires a long-term care plan; hence, chronic disease management is critical to achieving improved health outcomes, quality of life, and cost-effective health care (Hamine S, Gerth-Guyette E, Faulx D, Green BB, Ginsburg AS, 2015). The potential to benefit health care treatment and prevention for mHealth to specially target chronic disease patients, with customized sensors, devices, services and tools to modify behavior in an engaging and sustainable way, is gaining more acceptances. These devices and services permit patients to monitor their health, access health information, and communicate with their health care provider without requiring a wired connection to the Internet and facilitate the self-management and care coordination tool. The former is largely clinical; the latter is contingent on numerous and varying social determinants of health.

WellDoc, a healthcare behavioral science and technology company, developed an application called BlueStar®, the first-of-its-kind Mobile Prescription Therapy cleared by the
FDA and available only by prescription. It provides patients real-time guidance to improve their diabetes self-management, as well as, clinical decision support. The advantages of personalized health care advice take away the health care management from its current reactive and disease-centric system to one that is proactive and focused on wellness, disease prevention, and the precise treatment of disease. These tools help doctors optimize their diabetes treatment plan among other benefits such as obtaining healthcare without the supervision of a licensed healthcare provider. A 2009-2010 US trial of the WellDoc system sought to reduce blood glucose levels in 163 patients suffering from diabetes. (Mobile Coaching and Online Decision Support for Diabetes, 2014; Quinn, C. C., Swasey, K. K., Crabbe, J. C. F., Shardell, M. D., Terrin, M. L., Barr, E. A., & Gruber-Baldini, A. L., 2017).

The trial involved patients receiving a glucose meter and supplies. They also have access to the web-based portal and a mobile phone. Patients entered blood glucose levels and other self-care data into their phones—both ‘feature’ as well as ‘smart’—and receive real-time responses from ‘virtual patient coach’. The assistance come through an expert mobile/web-client and cloud-based software system, providing management conditions, guidance in diets, physical exercise and improvement in the general life-style. Some other benefits of the system includes quality measurement and reporting that produces more accurate and useful information for all health care personnel and evidence-based reports to monitor their conditions more accurately. Figures from the Centers for Disease Control and Prevention (2010) and the American Diabetes Association, (2009) estimates $218 billion is spent annually on diabetes in the US.
The potential for these mobile solutions could enable annual cost savings per patient of as much as US$10,000 in reduced healthcare charges and increased worker productivity (Milliman, 2011; Roebuck MC, et al; Fraze T, et al. 2008; Rockville (MD): Agency for Health Care Policy and Research (US), Aug 2006-2010; Testa MA, et al).

The results of the trial involving patients receiving a glucose meter and supplies have shown:

- A mean decline in A1c (glycated hemoglobin—the gold-standard measure for diabetes control) by 1.9% in the intervention group (against 0.7% in the usual care group) (Sacks DB., 2012).

- A clinically significant change in A1c was seen, regardless of whether patients began the trial with a high or low A1c. By comparison, the US Food and Drug Administration consider a new drug that is able to reduce A1c by 0.5% as clinically significant (Mobile health market, Report 2011-2016).

- WellDoc’s application works on the vast majority of data-enabled mobile phones and can be integrated into the standard software and electronic health records used by doctors (Mobile health market, Report 2011-2016).

- The study also has shown a considerable application potential based on remote coaching for other chronic diseases such as diabetes, obesity and hypertension. The aforementioned chronic diseases potentially have the highest utility for mobile management through smart phones and web-based solutions (Emerging mHealth: Paths for Growth, 2015).
Health Information Technology and Disease Prevention and Control

The rapid growth in health communication strategies and health information technology (HIT) to improve population health outcomes, health care quality and to achieve health equity is helping the health sector to cope with disease prevention and control and disseminate information to educate patients and communities. However, the majority of US hospitals do not yet have HIT fully implemented to support effective communication between nurses, physicians and the general population. Therefore, it is imperative to develop more tools and integrate a variety of electronic methods that are used to manage information about people's health and health care.

The Centers for Disease Control and Prevention (CDC) works to prevent chronic diseases and their risk factors through the following four domains:

- Epidemiology and surveillance refers to systems that are used to track chronic diseases and their risk factors.
- Environmental approaches refer to changes in policies and physical surroundings to make the healthy choice the easy choice.
- Health care system interventions refer to improvements in care that allow doctors to diagnose chronic diseases earlier and to manage them better.
- Community programs linked to clinical services refers to those that help patients prevent and manage their chronic diseases, with guidance from their doctor.

(The Four Domains of Chronic Disease Prevention- Centers for Disease Control and Prevention, 2015).

The use of ICT in epidemiology and surveillance is making a positive impact to support early detection, surveillance and clinical management of diseases. The dengue virus project in
Nicaragua with the involvement of the Sustainable Science Institute (SSI) in collaboration with the MINSA Nicaragua and supported by the Bill & Melinda Gates Foundation and the Fundación Carlos Slim para la Salud involved the utilization of several ICT Tools:

- **DENGUE – ALERT**: An automated early-alert dashboard for enhanced detection and response (by multiple types of users) to dengue outbreaks. This tool COMPLEMENTS existing systems and incorporates information from a wide range of sources not currently incorporated into traditional surveillance systems in an efficient and direct way. Eventually, all priority diseases to be tracked at a national level will be incorporated into the ALERT system.

- **DENGUE – LAB**: An automated laboratory information management system to support sample management tracking and integration of results reporting for a network of national reference laboratories.

- **DENGUE – SPECIALIST**: A mobile clinical decision support tool for doctors and nurses to facilitate hospitalized patient management with dengue. SPECIALIST is designed for use patient-side on tablets, cell phones, laptops, and/or ward-workstation laptops, depending on hardware available. (Sustainable Science Institute, 2014).

Another case study in the use of ICT tools is India. The country has made considerable advancements in technology and keeps making progress in its commitment for establishing and operating a disease surveillance programme responsive to the requirements of the International Health Regulations (IHR[2005]) by the World Health Organization (WHO). India is effectively using ICT for collection, storage, transmission and management of data related to disease surveillance and effective response. Some of these advances are the establishment of terrestrial
and/or satellite based linkages within all states, districts, state-run medical colleges, infectious disease hospitals, and public health laboratories. The benefits of its usage translate into the speedy data transfer, video conferencing, training and e-learning for outbreaks and programme monitoring as well as a media scanning and verification cell functions to receive reports of early warning signals. Moreover, an established call center offers a disease alert service that is open to the public seven days a week. The potential for ICT networks and efficacies was demonstrated in the 2009 H1N1 swine flu strain outbreak. The application of information and communication technologies was in place and part of its Integrated Disease Surveillance Project (IDSP). The utilization of ICTs was to further expansion in hard-to-reach populations, to increase the involvement of the private sector, and to increase the use of other ways to share vital information and communication like e-mail and voicemail (Kant, Lalit, and Sampath K. Krishnan, 2010).

The Risks of Using HIT

It is understandable more information and communication technology (ICT) will be deployed in the next years than ever before, and will carry a variety of benefits, developing new paths for healthcare treatment and management. Nevertheless, these developments do have risks to patients, leading some to call this a “dangerous decade” for health information technology
Some of the risks are poor communication between physicians and nurses, which is well known as one of the most common causes of adverse events for hospitalized patients and a major source for all sentinel events (Gawande AA, Zinner MJ, Studdert DM, Brennan TA Surgery, 2003 and Leape LL, Berwick DM, 2005). The use of ICTs is increasingly changing the way physicians and nurses are communication and exchanging information, there is already evidence that communication technologies can contribute paradoxically to more issues and communication difficulties (Chiasson M, Reddy M, Kaplan B, Davidson E, 2007 and Sutcliffe KM, Lewton E, Rosenthal MM, 2004). It is crucial to understand the use of ICTs and its applications in health care, and how it can be an instrument to eliminating barriers to quality and safety through increased awareness and its advantages to achieve the goals of better communication and safer care (Manojlovich, M., Adler-Milstein, J., Harrod, M., Sales, A., Hofer, T. P., Saint, S., and Krein, S. L., 2015).

Telemedicine, Telehealth and Telecare

The incorporation of new technologies into the fields of health and social care are developing more than in any other field, and in the future it will continue to improve in impressive ways. While we can view these technological advances as promising and sometimes risky and debate the details of future trends in healthcare, we need to be clear about the drivers
so we can align with them and efficiently work to guarantee the best benefits out of these developments in technology and the well-being of society as a whole. The main goal in eHealth is the efficacy, cost-effectiveness of the technology, management ratio and delivery of vital information for the parties involved. Research supporting the usefulness of data collected by lifestyle monitoring systems is required to justify the associated intrusion, particularly in users with cognitive impairment. Studies thus far have focused on patient satisfaction and feasibility rather than the aforementioned benefits. There is an urgent need of research supporting the usefulness of data collected by lifestyle monitoring systems. Therefore, more development improvements of the health system can move further to justify the associated intrusion, particularly in users with cognitive impairment. Wootton (1997) stated that this group may have the most to gain from devices designed to improve safety in the home, allow them to live independently but are at risk of losing their autonomy. Older people are likely to be disproportionately affected by technological change and geriatricians must be aware of the wide-ranging implications for their patients and practice. Hence, these tools, if developed properly accordingly to the needs of patients and ability to deliver an efficient management service, can be a solution to problems of access to health care services and as tools for the management of demand, especially for specialist services. Policy-makers must advocate for the increasing use of ICTs for improvements in the efficiency of health services provision, and which place emphasis on increasing responsibilities for patients to engage in self-care by mobilizing electronic resources (Kendall, 2001; S.Stowe, and S.Harding, 2010 ).
Telemedicine Changing Health Care IT

The improvement and efficient performance of mobile technologies, more mature electronic health records (EHRs) and clinical decision support (CDS) systems are the most significant reasons for the growing interest of the healthcare industry in telemedicine. The applications of telemedicine vary and can be deployed by a variety of medical providers and specialties. For example, some of the benefits are digital imaging and high-bandwidth communication, to remotely view patient medical images--such as photos of skin lesions or CT scans--for diagnosis and treatment recommendations, which are under the dermatology and radiology medical specialties (Clinical Decision Support, 2017).

Another use of telemedicine is for those living in remote areas or has experienced a disaster and does not have access to specialists. Natural and man-made disasters are affecting populations around the world. The Centre for Research on the Epidemiology of Disasters (CRED) works on these four main areas:

- Civil strife and conflict epidemiology
- Database and information support
- Capacity building and training
- Natural disasters and their impacts

CRED report (2017) published the following data:

I. In 2016, 342 disasters triggered by natural hazards were registered.

II. Last year, the number of deaths caused by natural disasters (8,733) was the second
lowest since 2006, largely below the 2006-2015 annual average (69,827).

III. Inversely, the number of people reported affected by natural disasters (564.4 million) was the highest since 2006, amounting to 1.5 times its annual average (224 million).

IV. The estimates of natural disaster economic damages (US$ 154 billion) place last year as the fifth costliest since 2006, 12% above the 2006-2015 annual average. (Guha-Sapir D, Hoyois Ph., Wallemacq P. Below. R., 2016).

Disasters continue to contribute to increased morbidity and mortality with significant economic impacts worldwide. Psychological, physical, and social sequelae persist years after the events (Nicogossian AE., Doarn CR., 2011). Many pre-existing detrimental health and socioeconomic conditions are exacerbated following disasters such as financial losses, misplacement, homelessness, mental health issues, anxiety, and in some cases PTSD (post-traumatic stress disorder). During a disaster, the communication network, roads and access to emergency centers and hospitals may be overwhelmed or even disrupted, exacerbating the hazards and impeding the professional health care team to reach out to the population affected by the impact; therefore, telemedicine can be a tool to use effectively and judiciously in the aftermath of disasters caused by both humans and natural occurring events. The lack of effective communication after a disaster to collect progression and transmit important information is one of the biggest challenges facing the health care team. After a disaster event an effective response is vital for survival and establishing rapid and reliable telecommunications systems specifically directed toward the “disaster medical field” is one of the most important steps to assure a prompt emergency response where mortality rates can be reduced if information exchange is

FIGURE 1.2

The figure above describes the overall system architecture. In each different application the telemedicine unit is located at the patient's site, whereas the base unit (or doctor's unit) is
located at the place where the signals and images of the patient are sent and monitored. The telemedicine device is responsible to collect data (bio-signals and images) from the patient and automatically transmit them to the base unit. The base unit is comprised of a set of user-friendly software modules, which can receive data from the Telemedicine device, transmit information back to it and store important data in a local database. The system has several different applications (with small changes each time), according to the current healthcare provision nature and needs. Before the system's technical implementation, an overview of the current trends and the needs of the aforementioned Telemedicine applications were made, so that the different requirements are taken into account during design and development, thus ensuring maximum applicability and usability of the final system in distinct environments and situations.

As mentioned above, the system consists of two separate modules [Figure 1.1]:
(a) the unit located at the patient's site called “telemedicine unit” and
(b) the unit located at doctor's site called “Base unit”.

The doctor might be using the system either in an emergency case or when monitoring a patient from a remote place. The design and implementation of the system were based on a detailed user requirements analysis, as well as the corresponding system functional specifications (Kyriacou E, Pavlopoulos S, Berler A, Neophytou M, Bourka A, Georgoulas A, Anagnostaki A, Karayiannis D, Schizas C, Pattichis C, Andreou A, Koutsouris D., 2003).

There is several telemedicine technology benefits aligned with sustainable development goals to ensure healthy lives and promote well-being for all at all ages. Therefore, telemedicine
encompass the electronic acquisition, processing, dissemination, storage, retrieval, and exchange of information. SDGs emphasize the promotion of a healthy society, which includes preventing disease, treating the sick, managing chronic illness, rehabilitating the disabled, and protecting public health and safety. Telemedicine strengthen the healthcare system and create partnerships and improve the exchange of communication between different actors such as physician, nurses, medical assistants, health emergency teams and patients. Telemedicine offers an effective connectivity and exchange of information for providers to effectively connect with their patients by phone, email and webcam, providing quickness and convenience on both sides of the health care experience in addition to addressing important issues like inequities in access to care, cost containment, and quality enhancement.

In summary, telemedicine can provide the following benefits:

• Improve access to all levels (primary, secondary, and tertiary) of healthcare for a wide range of conditions—including, but not limited to, heart and cerebrovascular disease, endocrine disorders such as diabetes, cancer, psychiatric disorders, and trauma; as well as services such as radiology, pathology, and rehabilitation.

• Promote patient-centered care at lower cost and in local environments that also contributes to stabilizing local healthcare and economies.

• Enhance efficiency in clinical decision making, prescription ordering, and mentoring.

• Increase effectiveness of chronic disease management in both long-term care facilities and in the home.

• Promote individual adoption of healthy lifestyles and self-care.

(Rashid L. Bashshur and Gary W. Shannon, 2009).
Telehealth, Population aging and Sustainable Development

Population aging is a phenomenon that results from declines in fertility as well as increases in longevity, two trends that are usually associated with social and economic development (Population Ageing and Sustainable Development, 2014).

The increasing prevalence of chronic disease among an ageing population is presenting new challenges in the medical field and society as a whole. The development of new models of health care delivery is foreseeable and the trend is likely to be focused in increasing prominence on patient self-monitoring, health care delivery at patient homes, interdisciplinary treatment plans, a greater percentage of medical care delivered by non-physician health professionals, targeted health educational materials, and greater involvement and training of informal caregivers. The Information Technologies (IT) infrastructure of health systems will need to adapt to this new reality and one of the possible solutions for this adaptation strategy is the use of telehealth as one possible approach to this problem. Telehealth is different from telemedicine because it refers to a broader scope of remote healthcare services.
than telemedicine and involves the remote exchange of data between a patient and healthcare professionals as part of the patient’s diagnosis and healthcare management (Beck, Matthias, and Sara Melo, 2014). Telehealth can be used in reaching patients in their homes through remote monitoring where personal health and medical data is collected from a patient in his home, monitoring blood pressure and blood glucose, and also being touted as a means to improve access to care, while reducing costs of transportation and increasing convenience to patients in obtaining care (Dixon BE, Hook JM, McGowan JJ., 2008). Favorable value propositions in the widespread use of telehealth involves a better understanding of patients health conditions by providing tools for self-monitoring; encourage better self-management of health problems, and alert professional support if devices signal a problem (Telehealth to Digital Medicine, 2014). In its many forms telehealth offers conveniences including increased care accessibility, real-time synchronous audio-video encounters, and it presents the opportunity to reverse the longstanding standard of placing the burden on patients. Furthermore, it provides decreased transportation barriers, and patient empowerment, bringing healthcare directly to the patient (Telehealth to Digital Medicine: How 21st Century Technology Can Benefit Patients, 2014). Steventon, et al (2012) published a comprehensive description on the use of telehealth. “Effect of Telehealth on Use of Secondary Care and Mortality: Findings from the Whole System Demonstrator Cluster Randomised Trial” is a home-based telehealth intervention report on the use of secondary healthcare and mortality and presented the following conclusions:
**Objective:** To assess the effect of home based telehealth interventions on the use of secondary healthcare and mortality.

**Design:** Pragmatic, multisite, cluster randomized trial comparing telehealth with usual care, using data from routine administrative datasets. General practice was the unit of randomisation. We allocated practices using a minimization algorithm, and did analyses by intention to treat.

**Setting:** 179 general practices in three areas in England.

**Participants:** 3230 people with diabetes, chronic obstructive pulmonary disease, or heart failure recruited from practices between May 2008 and November 2009.

**Interventions:** Telehealth involved remote exchange of data between patients and healthcare professionals as part of patients’ diagnosis and management. Usual care reflected the range of services available in the trial sites, excluding telehealth.

**Main outcome measure:** Proportion of patients admitted to hospital during 12 month trial period.

**Results:** Patient characteristics were similar at baseline. Compared with controls, the intervention group had a lower admission proportion within 12 month follow-up (odds ratio 0.82, 95% confidence interval 0.70 to 0.97, P=0.017). Mortality at 12 months was also lower for intervention patients than for controls (4.6% v 8.3%; odds ratio 0.54, 0.39 to 0.75, P<0.001). These differences in admissions and mortality remained significant after adjustment. The mean number of emergency admissions per head also differed between groups (crude rates, intervention 0.54 v control 0.68); these changes were significant in unadjusted comparisons (incidence rate ratio 0.81, 0.65 to 1.00, P=0.046) and after adjusting for a predictive risk score,
but not after adjusting for baseline characteristics. Length of hospital stay was shorter for
intervention patients than for controls (mean bed days per head 4.87 v 5.68; geometric mean
difference −0.64 days, −1.14 to −0.10, P=0.023, which remained significant after adjustment).
Observed differences in other forms of hospital use, including notional costs, were not
significant in general. Differences in emergency admissions were greatest at the beginning of
the trial, during which we observed a particularly large increase for the control group.

**Conclusions:** Telehealth is associated with lower mortality and emergency admission rates. The
reasons for the short term increases in admissions for the control group are not clear, but the
trial recruitment processes could have had an effect (Steventon A, Bardsley M, Doll H, Tuckey

Telecare and its Integration into Traditional Healthcare Services

The health systems still have access barriers to services to the greater population. As society
ages, greater demands for services will put a strain into the healthcare systems and health
professionals. Telecare is able to keep individuals safe and independent, offering remote care for
the elderly and physically less able people. The main goal is for patients to receive the necessary
care and reassurance needed to allow them to remain living in their own homes. Therefore,
telecare applications offer a variety of solutions to many health related issues, particularly for
the aging population. The socioeconomic challenges of an aging population pose significant
challenges to the provision of acute and long-term healthcare and consequently to sustainable
development goals. Just about 28 million persons worldwide suffer from dementia and its financial expenditure is approximately 156 billion dollars in direct care costs per year (Wimo A, Jonsson L, Winblad B., 2006). According to the U.S. Department of Commerce, U.S. Census Report – 2014, between 2012 and 2050, the United States will experience considerable growth in its older population. In 2050, the population aged 65 and over is projected to be 83.7 million, almost double its estimated population of 43.1 million in 2012 (Jennifer M. Ortman, Victoria A. Velkoff, and Howard Hogan, 2014). Elderly people may need different assistant technologies to provide them with independence and quality of life thus monitoring technology around them would provide with the tools to be minimize the risks of safety in their homes. In current situations, the caretaker stays in the home with the elderly for supervision and care. Obviously, this action interferes with their privacy and daily interactions; then, telecare technology can be a solution to this problem.
Figure 4.3 develops the prototyping telecare applications’ implementation to integrate pure-software components and sensors. To make a sensor accessible in the service framework, it is necessary to connect the physical device to a computer and write a wrapper service that communicates with the sensor to obtain the readings. The connection between a sensor and the computer would be wired or wireless, depending on the deployment requirements. Here we assume the connections are wired and it is sufficient for demonstration purpose. In the implementation, we connect the sensors to the Arduino Mega 2560 board. The program uploaded to the Arduino board translates the sensor readings to a value recognized by the
corresponding wrapper service. The wrapper communicates with the Arduino board through the USB (emulated RS232) port. The software services are implemented with the Python SleekXMPP [21] library.

The implemented service components are list below:

• Movement service (wrapper): detects abrupt body movement.
• Image capture service (wrapper): captures an image on-demand.
• Fall image analysis service (pure-software): fetches an image from the image capture service analyze it, and sends a notification if fall is detected.
• Scheduler service (pure-software): sends a message to the registered service at a specific time.
• Reminder service (pure-software): produces beeps on request and sends notification if timeout.
• Button service (wrapper): detects box lid open-close and sends messages to stop the reminder.
• Notification service (pure-software): receives an event and multi-casts it to the subscribers (Chang, Feng-Cheng and Huang, Hsiang-Cheh, 2014).

Telecare technology is here to stay and offer a series of benefits to patients remotely via telecommunications technology, either through synchronous (live video) or asynchronous
means (store-and-forward, remote patient monitoring). However, it should not be seen as a replacement for social support or the guarantee of wider social integration (Alan Roulstone, 2016).

eHealth as a Health Sector Climate Change Mitigation and Adaptation Strategy

The health care industry is an aggregation and integration of sectors within the economic system that provides goods and services to treat patients with curative, preventive, rehabilitative, and palliative care (Healthcare industry, 2015). It is one of the largest and most complex industry systems and in the United States economy has estimated expenditures of US $639 per person-year that corresponds roughly to 8–10% of global gross domestic product (GDP) (Health in the green economy, 2011). The US health care sector is highly interconnected with industrial activities that emit much of the nation’s pollution to air, water, and soils with emissions directly and indirectly referable to the health care sector that poses potential harmful effects on public health. Furthermore, the US health care industry is the second largest energy consumer among all US industrial sectors, and its inpatients facilities are the second most energy-intensive commercial buildings in the country. The National Health Service (NHS), one of the largest European employers, has a carbon footprint of approximately 20 million tonnes of carbon dioxide (CO2) per year (Sustainability in the NHS, Health check, 2012). According to
the UK Department of Energy and Climate Change statistical release (2011) it is equivalent to more than 4% of annual emissions and NHS buildings consume energy worth over £410 million (approximately $556 million US Dollars) annually (Saving Carbon, Improving Health, NHS carbon reduction strategy for England, 2009). Furthermore, while the percentages are expected to be lower in developing countries, in the developed world, the health care sector is estimated to contribute 3–8% of the total emissions. For example, when released as atmospheric gases, inhaled anaesthetics from health care facilities have a much higher global warming potential – hundreds to thousands of times higher – than comparable quantities of carbon dioxide. These gases are emitted into the atmosphere because of poor waste management and lack of recycling strategies (Saving Carbon, Improving Health, NHS carbon reduction strategy for England, 2009; Health in the green economy. co-benefits to health of climate change mitigation, 2011; World Health Organization: Safe health-care waste management, 2004).

As a mobile industry, the consumption of fossil fuels in the health sector (when patients and medical professionals travel to and from appointments, pick up prescriptions, and obtain tests and results) is a serious concern because of the implications of the rapidly increasing risk of adverse effects on health from climate change effects (Holmner, Å., Rocklöv, J., Ng, N., and Nilsson, M., 2012). Considering the increasing detrimental effects of severe weather events, heat waves, exacerbating its effects in poor communities, squatter settlement dwellers, the
homeless, and other susceptible groups that are more vulnerable to climate change, mitigation and adaptation strategies needs to be tailored to the health care sector planning.

Eckelman and Sherman (2018) quantified the increased disease burden caused by US health care sector in their reporting titled: “Estimated Global Disease Burden From US Health Care Sector Greenhouse Gas Emissions”. The study estimated that life cycle GHG emissions associated with US health care activities will cause an additional 123,000 to 381,000 DALYs annually (Figure 6.1) based on 2013 health care sector life cycle emissions. The study used the same proportions of disease contributions to total DALYs for each health damage factor reported in Tang L, Ii R, Tokimatsu K, Itsubo N. Development of human health damage factors related to CO2 emissions (2015) and De Schryver AM, Brakkee KW, Goedkoop MJ, Huijbregts MA. Characterization factors for global warming in life cycle assessment based on damages to humans and ecosystems (2009). In all cases, the largest potential health damages were attributable to malnutrition (49%–63% of the total), which will particularly affect regions with large populations and agricultural areas located on floodplains or lacking irrigation, including much of Africa and parts of South and Southeast Asia. Increased incidence of diarrhea and malaria are the other main contributors to total DALYs, because of lengthening warm seasons and expanding geographic ranges of disease vectors. Adding the average estimate of 209,000 DALYs to the earlier figure reported by Eckelman MJ and Sherman J. Environmental impacts of the US health care system and effects on public health (2016) for non-GHG results increased US
health care–related public health damages to a total of 614,000 DALYs per year for all emission types. Because actual global GHG emissions exceeded those predicted in the SRES scenarios for the early 21st century (Raupach MR, Marland G, Ciais P, et al., 2007) the health damage factors we used may well underestimate actual health damages over the coming decades.
FIGURE 1.4

Note. A1B, A2, B1, and B2 denote the main Special Report Emissions Scenarios (SRES) used by the Intergovernmental Panel on Climate Change (IPCC) used in their Third (2001) and Fourth (2007) Assessment Reports. DALYs from health care sector life cycle emissions of pollution other than GHGs reported by Eckelman and Sherman (2017) are shown for comparison (Eckelman, Matthew J., and Jodi D. Sherman, 2018).

eHealth for a Sustainable World

The health care industry needs to boost sustainability efforts and reduce its environmental impact in order to achieve a greener business operation, minimize its carbon footprint, and achieve some other benefits such as institutional financial gain, improved patient outcomes, better staff health and reduced turnover, and community engagement. Health Information Technology (HIT), also referred as eHealth, can support the sector’ sustainability program and tailored a preexisting strategy. eHealth alone cannot be the solution to a sustainable health sector. It needs to be accompanied by a comprehensive sustainability strategy and risk management framework. Nevertheless, building foundations for eHealth to deliver public health and health services in a more strategic and integrated manner is essential for the effectiveness of national policies, strategies and governance to ensure the progress and long-term sustainability of investments. The term eHealth is broad and includes work within a health care organization
where ICT is the central element and foundation. Electronic medical records, home monitoring of vital parameters using mobile technology, as well as electronic health-surveillance systems, are considered eHealth (Holmner, A., Rocklöv, J., Ng, N., and Nilsson, M., 2012). A strategic framework and policies creating the foundation of an eHealth development plan is fundamental for the implementation of a successful eHealth system. Such e-strategies can help cross implementation barriers and address different views by involving all stakeholders in a common project and focus energy and resources into key development objectives. The proposed initiatives, strategic eHealth planning and policies should be legislated in such a way as to enable eHealth applications and services, accelerate emissions reduction, increase the quality and efficiency of care, reduce erroneous treatments, and improve access to care in remotely populated areas and help addressing the realities of a new healthcare environment.

Climate Change Mitigation and Adaptation Strategy for the Health Sector

The following strategies published in “Climate change and eHealth: a promising strategy for health sector mitigation and adaptation” (2012) represent important steps to consider while developing mitigation and adaptation planning frameworks:

1. Building green, which includes strategies to conserve energy (Houghton, 2011; Younger M, Morrow-Almeida HR, Vindigni SM, Dannenberg AL, 2008).
2. Efficient energy distribution and use of renewable energy sources (Edward Vine, 2012; Omer, 2008).

Other strategies are more specific for the health care sector and include:

2. Increased use of health information technology, such as eHealth (Health in the Green Economy, 2011; Yellowlees PM, Chorba K, Parish MB, Wynn-Jones H, Nafiz N., 2010).

The factors representing the success of eHealth as mitigation strategy is related to the type of service need for investment in new equipment, and lifespan of the technology to efficiently reduce CO2 emissions. The environmental impact and costs of ICT technology such as manufacture, distribution, daily use, and subsequent disposal of waste needs to be assessed. However, a full carbon-cost benefit analysis for these applications can be a challenge since all of the factors contributing to telemedicine's carbon footprint are not adequately studied.

Nevertheless, there are many programmes addressing green and environmental computing or ‘green ICT’ including greener manufacturing of components, increased energy efficiency, and enabling more efficient use of existing technology, leading to the use of eHealth as a strategic tool to the reduction of carbon emissions (WWF Sweden, 2008; Forge, Blackman, Bohlin and Cave, 2009).

Telemedicine has the potential to mitigate carbon emissions and consequently reducing air pollution, known to be adversely associated with disease and deaths by reducing travel and
transportation. Though not all telemedicine applications will reduce travel, the benefits are obvious for home care programmes and outpatient consultations. The telemedicine programme at UC Davis, California is one of the largest telehealth programs in the country, expanding its reach through the Center's internationally recognized and accredited education program, providing leadership in the creation of the California Telehealth Network (CTN). It involved 13,000 outpatient consultations over a period of 5 years, and it has resulted in a savings of 4.7 million miles of travel and a reduction of 1,700 tonnes of CO2 emissions (Yellowlees PM, Chorba K, Parish MB, Wynn-Jones H, Nafiz N., 2010). In Canada, it has been estimated that more than 11 million home visits by nurses could be replaced by telecare, which would result in a reduction of about 120 million km of travel and 33,220 tonnes of associated GHG emissions annually (Scott RE, Perverseff T, Lefebre N., 2010). Therefore, the reduction in carbon emissions, travel time and cost-effective operations show the benefits and potentials of eHealth as a mitigation strategy.

The potential to carbon reduction emissions will be determined by several factors related to the number of users and appointments that can be replaced by virtual visits. The benefits will depend on the distance and type of transportation replaced by technology, related to travels by car, public transportation, or airplane, and the distances between health care professionals and patients involved. The potential net reduction in carbon emission with implementation of
telemedicine services is shown in the following figure (Holmner Å, Rocklöv J, Ng N, Nilsson M., 2012).

![Diagram showing potential net reduction in carbon emission with telemedicine services implementation.](image)

**FIGURE 1.5**

Figure 4.5 shows the schematic illustration of the potential net reduction in carbon emission with implementation of telemedicine services. The reduction potential is dependent on the number of visits as well as the carbon emission caused by each user's travel and visit in a traditional care scenario. The climate impact from travel depends heavily on the type of transportation (e.g. public transportation, car, or airplane) but for simplicity is illustrated as
travel distance only. This simplified model does not take into account that each piece of equipment can only serve a limited number of users and visits (Holmner Å, Rocklöv J, Ng N, Nilsson M., 2012).

eHealth, Public Health and Environmental Impacts

Potential environmental benefits of eHealth are contingent to the health sector infrastructure and local need. Nevertheless, eHealth has an important and relatively unexplored potential as a health-sector mitigation strategy. eHealth full potentials are in the first stage of development and execution. The table below exemplifies existing and potential eHealth methodologies, GHG impacts and potential co-benefits that should be further explored.
<table>
<thead>
<tr>
<th>eHealth methods</th>
<th>Direct &amp; indirect greenhouse gas impact</th>
<th>Potential co-benefits and examples of subsequent implications</th>
</tr>
</thead>
</table>
| Video consultations, e.g. between general practitioner and specialist or specialist and patient | Reduced travel for specialist and/or patient | • Less pollution\(^3\)  
• Positive impact on health economy  
• Long-term benefit: education of the general practitioner  
• Sub-specialist access for out-patient clinics in low-resource settings |
| Telehealthcare, e.g. remote support of self-management in chronic diseases | Reduced travel for patients and specialists | • Less pollution\(^3\)  
• Decrease in hospital admissions for individuals with chronic diseases  
• Positive impact on health economy  
• Increased quality of life for the patient |
| Remote public health or medical education | Reduced travel for teacher, patient, and/or student | • Less pollution\(^3\)  
• Increased medical knowledge, e.g. in poor or remote settings. Positive impact on health economy  
• Large potential for out-patient clinics in remote or low-resource settings |
| Virtual visits | Reduced travel for patients and relatives | • Less pollution\(^3\)  
• Positive impact on long-term hospital admissions since more frequent contact with relatives will be possible  
• Potential to reduce the need for near-hospital parking facilities |
| Remote diagnostics, e.g. teleradiology, remote auscultations | Reduced travel for patient and/or specialist | • Less pollution\(^3\)  
• Positive impact on health economy  
• Large potential for out-patient clinics in remote or low-resource settings |
| Electronic prescriptions | Reduced travel for patient Reduced paperwork\(^b\) | • Less pollution\(^3\)  
• Significant potential to reduce harmful adverse drug interactions |
| Electronic medical records and referrals | Reduction in travel Reduced paperwork\(^b\) | • Less pollution\(^3\)  
• Shared health information leads to safer and more efficient care |
TABLE 1.6
Examples of eHealth methods and their potential impacts and health co-benefits (Holmen Å, Rocklöv J, Ng N, Nilsson M., 2012).

aLess pollution should result in direct benefits of lower rates of diseases such as respiratory diseases and cardiovascular diseases.
bReduced paperwork should result in less deforestation and lowered emission from paper manufacturing, transport and recycling.

List of Terms

Health information technology (HIT): Information technology applied to health and health care. It supports health information management across computerized systems and the secure exchange of health information between consumers, providers, payers, and quality monitors.

Digital health: The convergence of the Digital and Genomic Revolutions with health, healthcare, living, and society. As we are seeing and experiencing, digital health is empowering us to better track, manage, and improve our own and our family's health, live better, more productive lives, and improve society.

mHealth (mobile health): A general term for the use of mobile phones and other wireless technology in medical care. The most common application of mHealth is the use of mobile phones and communication devices to educate consumers about preventive health care services.

Post-traumatic stress disorder (PTSD): A mental health condition that's triggered by a terrifying event — either experiencing it or witnessing it. Symptoms may include flashbacks, nightmares and severe anxiety, as well as uncontrollable thoughts about the event.

Hemoglobin: A conjugated protein, consisting of haem and the protein globin that gives red blood cells their characteristic color. It combines reversibly with oxygen and is thus very important in the transportation of oxygen to tissues.

Glycated hemoglobin: A form of hemoglobin that is measured primarily to identify the three-month average plasma glucose concentration.

Epidemiology: A branch of medical science that deals with the incidence, distribution, and control of disease in a population.
**Telemedicine**: The remote delivery of healthcare services, such as health assessments or consultations, over the telecommunications infrastructure.

**Telehealth**: The collection of means or methods for enhancing health care, public health, and health education delivery and support using telecommunications technologies.

**Telecare**: The term that relates to technology that enables patients to maintain their independence and safety while remaining in their own homes.

**Sequelae**: Pathological conditions resulting from a prior disease, injury, or attack.

**Arduino Mega 2560**: A microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

**Anaesthetic**: A substance that induces insensitivity to pain.

**Disease burden**: The impact of a health problem as measured by financial cost, mortality, morbidity, or other indicators. It is often quantified in terms of quality-adjusted life years (QALYs) or disability-adjusted life years (DALYs), both of which quantify the number of years lost due to disease (YLDs).

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