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LEAPFROGGING TO INDUSTRY 4.0: LESSONS FROM THE HEALTHCARE INDUSTRY

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ABSTRACT

The first three industrial revolutions, namely Industry 1.0 (mechanization), Industry 2.0 (mass production through electrification) and Industry 3.0 (automation), lasted several hundreds of years. Now the era of Industry 4.0 (the fourth industrial revolution) has come. Industry 4.0 encompasses a paradigm shift from automated systems to intelligent systems, with the objective being to optimize and achieve sustainable systems. Industry 4.0 is becoming standard practice in developed countries. In contrast, developing countries still have to catch up with the industrial revolution phases that have played out in developed countries already. This presents a leapfrogging opportunity for developing countries to go straight into Industry 4.0. The impact of this could be far-reaching, as it could enable developing countries to attain the goal of inclusive and sustainable industrial development. The purpose of this article is to critically investigate the opportunities and challenges of Industry 4.0 for developed and developing countries using the private and public health sector as a point of investigation. The article presents a comprehensive literature review on Industry 4.0 focusing on healthcare systems. Applying this to the private and public healthcare sectors could aid the identification of leapfrogging opportunities beyond the healthcare industry.

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1. INTRODUCTION

In the course of history, the world has seen three major industrial revolutions, namely mechanization using water and steam (Industry 1.0), mass production in assembly lines using electric power (Industry 2.0) and automation using electronics and information technology (Industry 3.0) [1-4]. These three industrial revolutions each lasted several years, and now the era of Industry 4.0 (I4.0), the fourth industrial revolution, has come.

Development touches all areas of human existence. As such, the healthcare sector has also evolved, although in its own fashion. One could analogously identify the revolutions in healthcare Health 1.0, Health 2.0 and Health 3.0, with Health 4.0 just having been introduced.

I4.0 comprises a paradigm shift from automated systems to intelligent systems, with the objective being to promote sustainable production and agile supply chains [3]. I4.0 is becoming standard practice in developed countries. Major strides in advocating and promoting I4.0 has been witnessed in countries such as Germany, the United States, Japan and Korea [3].

United Nations Sustainable Development Goal number nine promotes inclusive and sustainable industrialization [5]. However, there is a noticeable industrialization gap between developed and developing countries. The current status shows that developing countries have to catch up with phases of industrial revolution that have been surpassed in the developed world. This presents leapfrogging opportunities for developing countries to go straight to Industry 4.0 to achieve the goal of inclusive and sustainable industrialization.

The principles of I4.0 are equally applicable to the healthcare systems [2]. The South African healthcare sector comprises of private healthcare, which is well resourced and advanced, and public healthcare, which has noticeable shortages of resources and is under-developed [6-8]. In this study, the private and the public health sectors are used to represent the developed and developing countries respectively.

The purpose of this paper is to critically investigate the opportunities and challenges of I4.0 for both developed and developing countries. A strengths, opportunities, aspirations and results (SOAR) analysis is applied to identify possible leapfrogging opportunities.

The paper is organized as follows: first, Section 2 presents a comprehensive literature review on I4.0 and the healthcare system. Section 3 discusses the South African healthcare system. The application of the SOAR analysis to identify the leapfrogging opportunities and challenges that Industry 4.0 presents is performed in Section 4. Section 5 examines I4.0 opportunities and challenges for developing and developed countries. Section 6 presents a discussion on leapfrogging opportunities to I4.0 in developing countries and Section 7 presents the conclusion and suggestions for further work.

2. INDUSTRY 4.0 AND THE HEALTHCARE SYSTEM

Industry 4.0 design principles are focused on interoperability, virtualization, decentralization, real-time capability, service orientation and modularity [9]. This section presents the overview of I4.0 in Section 2.1 and Health 4.0 in Section 2.2. The application of I4.0 in healthcare system (Section 2.3) is presented last.

2.1 Overview of Industry 4.

Figure I shows the phases of the industrial revolution, including the recently advocated I4.0. The ideas at the base of I4.0 emerged in Germany as a high-tech strategy to promote digitization of its manufacturing industry with the goal to remain competitive [10, 11]. The 2013 Hannover industry fair resulted in the coining of the term I4.0, now widely used in European countries and accepted in some Asian countries such as China [1, 11]. In other countries, such as the United States, the term Internet of Things (IoT), Internet of Everything (IoE) or Industrial Internet is used instead [1, 11].

McKinsey [12] defines I4.0 as “digitisation of the manufacturing sector, with embedded sensors in virtually all product components and manufacturing equipment, ubiquitous cyber physical systems, and analysis of all relevant data.”

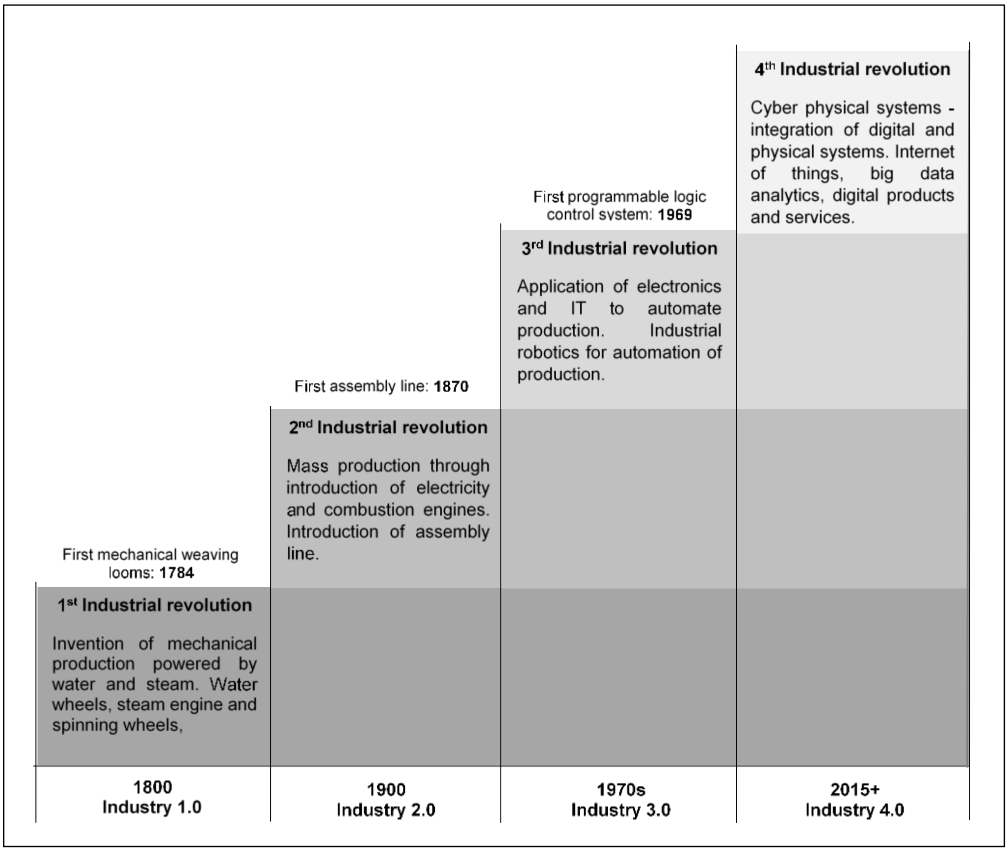

Figure I: Phases of Industrialization [10, 11, 13]

I4.0 in essence entails integrating a set of technologies to permit ecosystems of intelligent, autonomous and decentralized factories and integrated products and services [2]. I4.0 is driven by technologies such as cyber-physical systems (CPS), IoT, 3D-printing, big data analytics (BDA), autonomous systems, cloud computing and mobile solutions [2, 14, 15].

For the purposes of this discussion, the terms I4.0 and digitization are used interchangeably, while CPS is interchanged with digitization of production. Embedded software is used to allow communication between all production components to produce smart products. These components know how they are made and what they will be used for. A digital factory is characterized by CPS, smart robots and machines; a new quality of connectivity; big data; energy efficiency; decentralization and virtual industrialization [15].

I4.0 can be understood as the application of the generic concept of CPS to the interaction between humans, machines and products during production processes enabled by cyber-physical production systems (CPPS) [16]. Thoben simplifies I4.0 by stating that it is a paradigm shift from automated systems to intelligent systems [3].

MacDougall clearly points out that the term smart industry can be used interchangeably with I4.0. I4.0 can be described as the technological evolution from embedded systems to CPS, and this will radically transform industry and the production value chain and business model. I4.0 drives a shift from centralized to decentralized production, which constitutes a reversal of convectional production process logic [17].

I4.0 strategies seek to shift industries from being manufacturers to service providers that permit individualization and personalization for consumers [9]. The influence of I4.0 on individualization and virtualization stretches across different industrial fields [9].

According to Rüßmann et al., I4.0 is powered by nine technological advances, namely autonomous robots, simulation, horizontal and vertical system integration, the industrial IoT, cybersecurity, the cloud, additive manufacturing, augmented reality and big data and analytics [4]. Thuemmler and Bai further state that the primary elements of Industry 4.0 are CPS, IoT, Internet of Services (IoS) and smart factories [9].

Interoperability, virtualization, decentralization, real-time capability, service orientation and modularity are the design principles of I4.0. Thuemmler and Bai note that I4.0 design principles are highly applicable in the healthcare industry [9].

2.2 Health 4.0

The healthcare system has transformed from Health 1.0 through to Health 4.0 in a manner that is similar to industry, but not identical. Industry 1.0, Industry 2.0 and Industry 3.0 derived technologies do not directly correlate with Health 1.0, Health 2.0 and Health 3.0 respectively. However, there is direct core relationship between Health 4.0 and I4.0 with Health 4.0 being an I4.0 strategic concept applied to the healthcare systems domain. Figure II shows the paradigm shift in the healthcare system over the years.

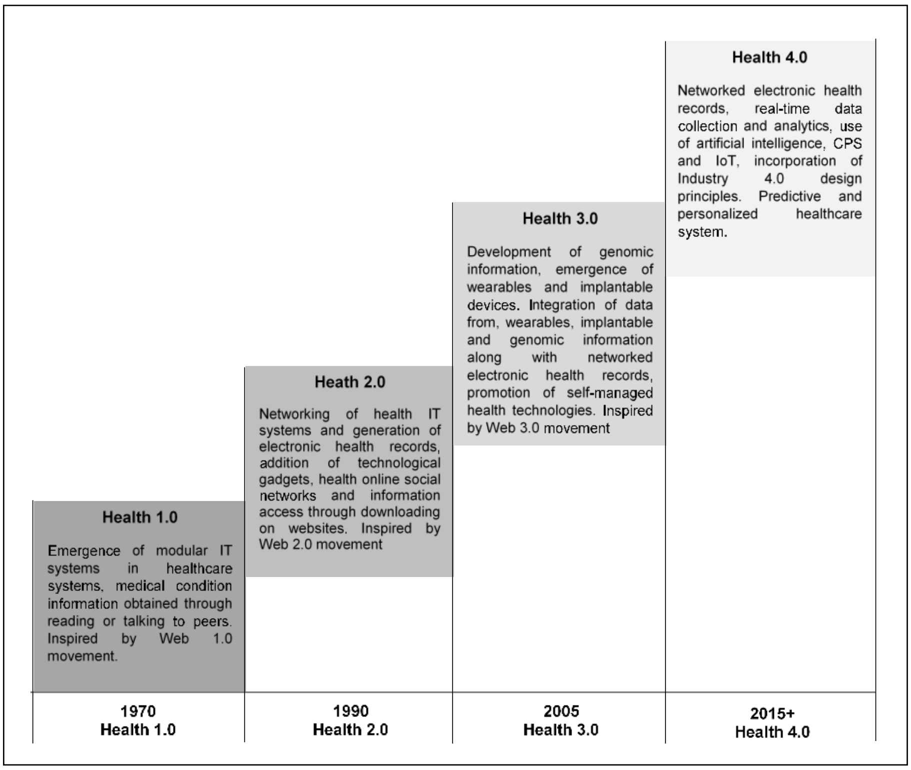

Figure II: Healthcare system paradigm shifts (Adopted from [9, 18-22])

Health 1.0 to Health 3.0 were inspired by Web 1.0 to Web 3.0 respectively [19]. Health 1.0 is the era of the introduction of modular IT systems in the healthcare industry [22]. Knowledge about medical conditions came from reading or talking to family and friends and the medical provider was the final reference [18, 19].

Health 2.0 allowed people to access information to discuss with their caregivers by means of websites [18]. Technological gadgets such as wristbands, back bands and sleep monitors were added to ensure monitoring and quantifying of and reporting on health matters [20]. Patients gained the privilege of reading online social network sites and getting input on how their peers have managed their sickness [21].

Health 3.0 concentrates on the consumer patient model [19]. Health 3.0 focuses on ensuring a better quality of life and promoted networking between people with related health matters using internet platforms [19]. People are empowered to take responsibility for their health and health treatments with the availability of secured technologies and support groups [21]. Health 3.0 sought to destroy patient dependency syndrome, promote patient independence and make the patient part of the medical team [21]. Health 3.0 promoted communication and self-managed health technologies [21].

The concept of Health 4.0 is derived from I4.0 as a strategic concept for the healthcare systems domain. Progressive virtualization to enable the automation and personalization of health care in next to real time for patients, professionals and formal and informal carers is attainable through Health 4.0 [9, 23]. The use of CPS, IoT, IoS, IoP, cloud computing and the development of 5G mobile communication networks will enable the personalization of healthcare [9]. Further to this, Industry 4.0 design principles stand to be the main goal of Health 4.0 [23].

Health 4.0 facilitates a digitally connected healthcare system that provides efficient healthcare services and produces sustainable improvements in medical care for patients and increased profitability for care providers [24].

Health 4.0 is driven by electronic health records, artificial intelligence (AI), real-time data from wearable devices and data analytics [22]. A predictive and personalized healthcare system can be accomplished through emphasis on collaboration, coherence and convergence [22]. The availability of real-time data and data analytics permits timely and innovative diagnoses and medical response [22]. Health 4.0 aims to shift the entire healthcare system to a value-based system with measurable outcomes and provides proactive prevention[22].

2.3 Application of Industry 4.0 in the healthcare systems

CPS is at the core of I4.0 and enables the linkage between the physical world and the virtual world to create the IoT [9]. Medical CPS is an approach that is positioned to permit smart healthcare systems to monitor, process and make independent decisions in the absence of a healthcare provider [23]. An example of the application of CPS in the health domain is "the connection of body area networks and sensors in smart pharmaceuticals to disease management platforms with either autoregulatory feedback loops or feedback via accessories such as smart phones" [9].

IoT, cloud computing and BDA are key I4.0 technologies that can universally facilitate efficient and enhancing sustainable healthcare systems through the personalization of healthcare and improved basic nursing care [25-28].

IoT is the connection of unlimited, smart, physical and virtual objects with distinct identities with internet to generate an infinite CPS framework [25, 29-31]. IoT solutions involve capturing, monitoring and transmitting data to a public or private cloud to facilitate accessible and efficient automation [29].

Diverse medical sensors, advanced devices such as heart pressure watches, smartphones, imaging devices, personal digital assistants and electronic health records (EHR) are integral elements of the healthcare IoT system [29, 30]. Healthcare providers can noticeably improve the quality of care and health outcomes by using health data monitored and collected by these devices [29, 31].

Figure III shows a typical healthcare IoT for a hospital. A patient can access their EHR and medical histories stored securely in a cloud by scanning their identity card. At the other end, healthcare professionals can access similar records on their mobile medical devices [31]. This will facilitate efficiency and effectiveness in the healthcare sector.

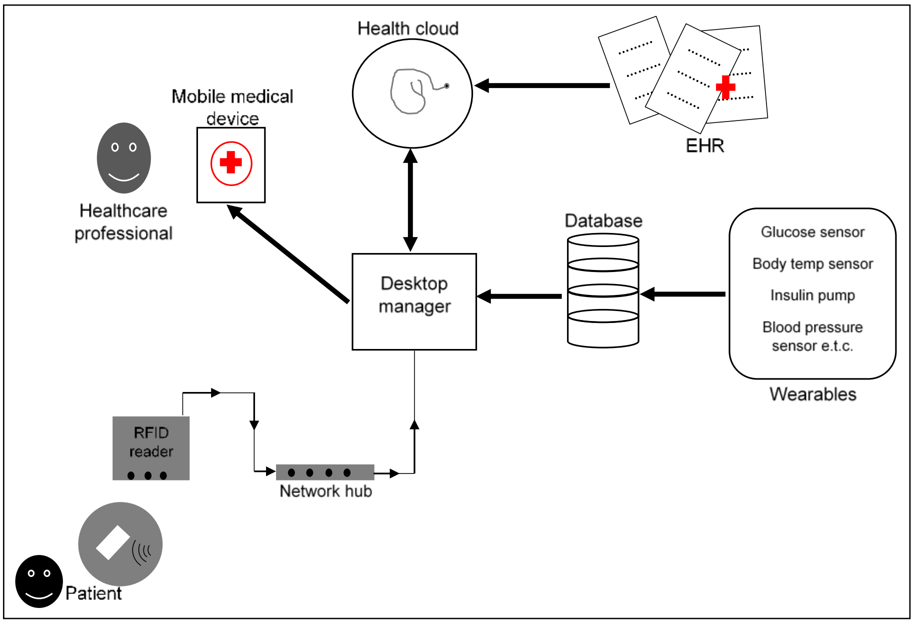

Figure III: Schematic diagram for a typical IoT healthcare system [31]

IoT and cloud computing application in the healthcare systems leads to significant improvements in the provision of patient-centric healthcare and reduces healthcare cost, leading to a sustainable healthcare industry [25, 30]. Medical IoT can noticeably assist in improving agility in remote health deliverables [29].

IoT promotes remote health monitoring, remote diagnostics, chronic diseases management and independent care for the elderly [29, 31]. The challenge of patients not complying with medication and treatment by healthcare providers can potentially be addressed by the application of IoT. Further to this, IoT will significantly add value and change the landscape in aspects of authenticating medicine, monitoring drug supplies and providing efficient scheduling of available resources to ensure best use for more patients [29].

Challenges associated with medical IoT include the need to detect and manage mobile medical sensors at any time and maintaining robust protection and security of patients' information [30, 32]. Other issues to be considered in healthcare IoT is reliability and quality of care [30]. Medical IoT faces the challenge of non-existent standardization of proprietary protocols to facilitate communication between sensors from different manufactures [31].

The emergence of wearable medical devices with sensors resulted in the generation of large volumes of medical data on human physical and mental health [26, 29, 30, 32]. Further to this, digital devices such as smartphones and electronic health records (EHR) add to the available medical data [27, 31]. The large volumes of medical data of high velocity, intricacy and of a wide variety requiring advance techniques and technologies to analyse can be referred to as big data [27, 30, 32].

The big data explosion in the healthcare sector provides an opportunity for BDA, an I4.0 concept [3, 27, 31]. BDA provides noticeable possibilities to improve healthcare, save lives and minimize costs by evaluating medical data to attain an in-depth understanding of different views on human life [27].

The application of BDA in healthcare can result in providing vital support for creating individually customized healthcare where an individual receives the right health intervention and the health problem can be identified in an evidence-based manner [27, 29]. BDA promotes evidence-based decisions, thorough and perceptive diagnoses and treatments leading to improved quality of healthcare [27].

BDA has assisted healthcare players with tracking adherence to treatments and monitoring trends that promote wellness in individuals and populations [27, 29]. Further to this, BDA can facilitate identifying diseases at an early stage and exposing healthcare fraud effectively and efficiently [27].

The implementation of BDA has been noticeably slow in the healthcare industry due to diverse and interlinked technological, legal and ethical problems associated with the industry [29, 31]. Data assurance, known as veracity, is potentially a problematic factor in healthcare BDA. The quality of BDA and its outcomes are major concerns in healthcare since life or death decisions are made [3, 27]

Patients' lack of trust in sharing personal data stands to be one of the obstacles to implementing BDA. Latif et al. [29] suggest a patient-centric big data-enabled healthcare system, shown in Figure IV, which will give patients control over their personal information [29]. The suggested patient-centric model can promote information sharing in the healthcare system, thus enabling the BDA.

Healthcare BDA is faced with the challenge of implementing real-time analysis, which is an essential aspect in this sector. The gap that exists between data collection and data analysis has to be addressed [27].

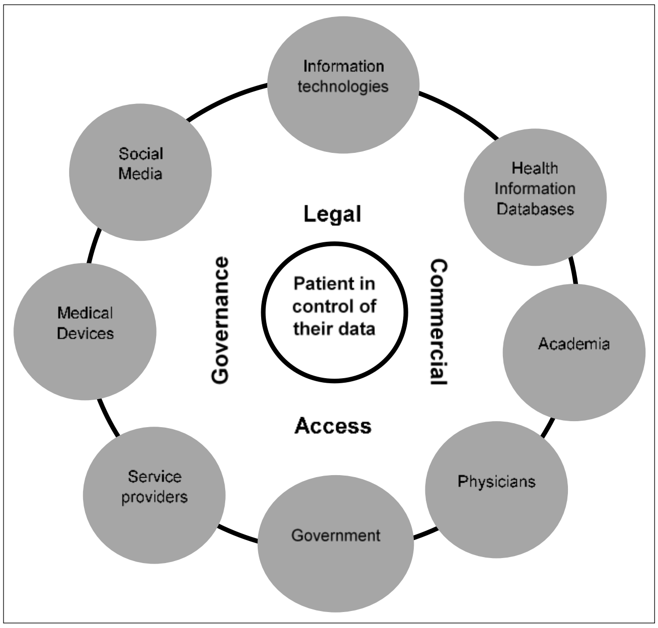

Figure IV: Patient-centred big data-enabled healthcare ecosystem [29]

Inadequate knowledge of patients' historical health and personal preferences result in the medical practitioners offering inferior healthcare services. Artificial intelligence (AI) and machine learning (ML) are the cornerstones of systems that are driven by scientific and statistically driven data that will result in optimal healthcare outcomes [2, 29]. Predictive AI algorithms can be used to analyse data obtained from patients' records, thus minimizing re-admission rates [31]. AI and automated systems in healthcare systems could provide vital assistance to doctors and this would significantly complement and augment their expertise [2, 29]. In this way accuracy, effectiveness and efficiency in the healthcare system can significantly improve as a nurse or physician would be able to perform at a level of a specialist [29]. AI will positively influence disease control and medicine by permitting early detection [2].

The use of mobile apps in healthcare is on the rise and they are helping patients to manage their health outcomes, to find healthcare providers and to improve the health of their lifestyle [27, 31]. Mobile devices and advanced wireless technologies can stimulate various healthcare solutions for personalized care. Information provided by the mobile devices provide data to be used in big data analytics and AI to ensure smart healthcare solutions. Further to this, smartphones and tablets can be used as IoT terminals that monitor healthcare data in real time and communicate with physical sensors in the medical IoT network [29].

The integration of IoT, cloud computing, BDA, mobile solutions and wireless devices will significantly contribute in mitigating problems of uneven distribution of healthcare resources, healthcare disparities, and the growing number of patients with chronic diseases and increasing medical expenses.

3. THE SOUTH AFRICAN HEALTHCARE SYSTEM

The South African healthcare system divides into a private and public healthcare sector. A significant equality gap exists between the private and public healthcare sectors in terms of resources [6, 7]. Private healthcare is perceived to be over-serviced while covering a minority population, while the public healthcare is under-serviced with majority coverage [8].

The private healthcare sector is driven by profit-making [6, 7]. Practitioners and institutions charge noticeably more than the public sector for the same medical procedures and medication [8, 33]. Private healthcare is furthermore characterized by considerable resources and mainly accommodates the affluent population who can afford the services [6, 7, 34, 35]. The private healthcare sector is perceived to provide good quality of care due to good financial accessibility and human resources [6, 7]. It is approximated that 80% of South Africa's health specialists are in the private healthcare sector [35].

In contrast, the public health sector is under-resourced with old facilities and infrastructure and financial problems. This sector serves the majority of South Africans [6, 7, 34]. Inadequate quality of service and a shortage of qualified human resources stands out in the public healthcare sector [7, 8].

Users of public healthcare sector are reported to have noticeable challenges with drug availability, incorrect diagnoses, the cleanliness of facilities, rude staff, long waiting times and rushed appointments [6, 7]. In contrast, the private healthcare sector is characterized by short waiting times, thorough consultation and proper disease control and prevention [6, 7].

The South African healthcare sector spends 3.5% more of its GDP than the recommended World Health Organization (WHO) threshold [33, 36]. Figure V shows how the South African healthcare GDP expenditure compares to the WHO recommended threshold.

Figure VI further compares the private and the public healthcare sector GDP expenditure to the population serviced. Note that the private healthcare sector spends 4.4% of the GDP and services 16% of the population. The public healthcare sector spends 4.1% of the GDP and services 84% of the population [33, 36]. This points to a gross inequality in how resources are shared between the private and public healthcare sectors.

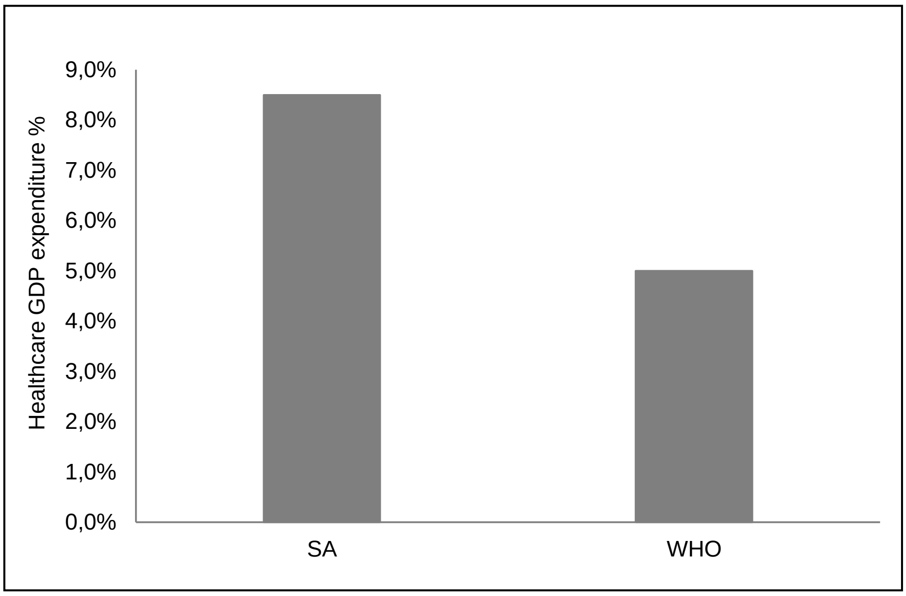

Figure V: GDP expenditure comparison (Adopted from [36])

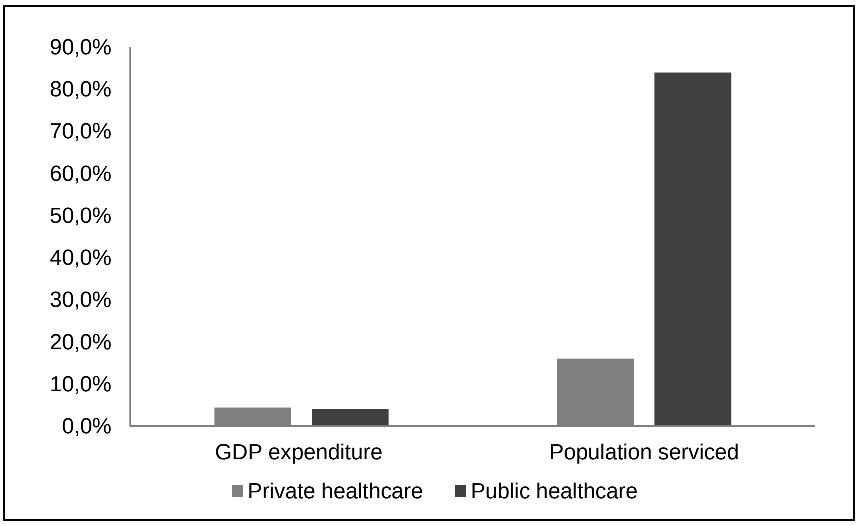

Figure VI: Comparison of private and public healthcare sectors (Adopted from [36])

In a move to transform the healthcare sector in South Africa, the government announced in 2011 that they intend to introduce National Health Insurance (NHI). A policy that introduces NHI could revolutionize healthcare delivery in South Africa by ensuring universal health coverage [37]. The envisioned policy to provide NHI is currently in the drafting phase, with several draft policies and pilot projects currently on the table. Although the policy would affect medical aids, the government insists that the introduction of NHI is not intended to destroy the private healthcare sector, but to ensure quality healthcare for the majority [35].

A key component of the NHI implementation plan is to strengthen the public health sector in South Africa [37]. The government is aiming to create an integrated healthcare system that is affordable and reachable to the majority of South Africans, thus addressing the existing inequalities [7].

A partnership between the private and public healthcare sectors is inevitable if we want to address the challenges encountered in the healthcare sector [34]. The resources of the private and public healthcare sectors would have to be combined to achieve the goal of equal access to quality healthcare in South Africa [34, 36]. The move will result in a leap to digitization of the healthcare sector in South Africa, thus addressing the current quality of service in the public health sector.

4. LEAPFROGGING TO INDUSTRY 4.0: OPPORTUNITIES AND CHALLENGES

4.1 Overview of the leapfrogging concept

The concept of technological leapfrogging entails that developing countries skip investment in obsolete technologies and investing in future technologies [38]. Perkins states that “leapfrogging implies a development strategy for industrialising countries to bypass the dirty stages of economic growth through the use of modern technologies that use fewer resources and/or generate less pollution” [39]. It can be argued that leapfrogging is an advancement strategy for developing countries skip certain phases of industrial revolutions jump to I4.0.

Technological leapfrogging can also mean skipping ahead to become a forerunner rather than just skipping over generations of technology [38]. The problems and challenges developing countries face present innovation opportunities to address the challenges [40]. Sarabhai further argues that the available knowledge presents leapfrogging opportunities for developing countries [41]. The country’s capacity to technologically leapfrog is significantly influenced by human capital and economic status. Skills development is therefore a vital component in facilitating technological diffusion [38].

The strategic thinking process that involves SOAR analysis focuses on creating future aspirations and desired results, thus it can be applied in analysing technological leapfrogging opportunities. In this study, the SOAR analysis model was applied to analyse the opportunities and challenges of leapfrogging to Industry 4.0 using the South African healthcare system as a point of reference.

4.2 Strengths, opportunities, aspirations and results (SOAR) analysis

SOAR analysis is a dynamic strategic thinking tool used by organizations to identify their strengths and opportunities when they plan for the future [42-44]. The SOAR analysis uses an appreciative inquiry approach to concentrate on what works [42-46]. This model is driven by the desire to remain focused on the targeted positive outcomes by translating challenges into opportunities [43, 44].

The SOAR analysis can be used as an alternative to the strength, weakness, opportunities and threats (SWOT) analysis [45]. In contrast to a SWOT analysis, a SOAR analysis focuses on co-producing the desired future by means of a process of inquiry, imagination, innovation and aspiration [42, 43, 47]. SOAR remodels the SWOT analysis into a progressive framework and creates a transformational strategic thinking process [45].

The SOAR analysis model can be used to investigate initiatives, develop strategic plans and to focus and redirect efforts and resources [42, 45]. It does not entirely leave out dealing with challenges, but rather reframes the negative issues as opportunities [45].

The SOAR analysis has significant capacity to create and manage change and map organizational strategic planning [45]. This model can be applied to all industries and has been used by corporations, municipal governments and the healthcare sectors [42, 45].

Table 1 shows a graphical presentation of the SOAR analysis model. The process of SOAR analysis begins by understanding strengths and formulating a conception of the potential opportunities, followed by rising innovation in the future by aspirations and finally thinking inspiration to realize results [45, 48].

Table 1: Graphical presentations of SOAR analysis [42, 44-46]

Strategic inquiry	**STRENGTHS** What the organization does best, key assets, resources, capabilities and accomplishments.	**OPPORTUNITIES** Conditions that can be used to influence success. These include partnerships that can lead to success, threats that can be reframed as opportunities.
Appreciative intent	**ASPIRATIONS** Preferred future - build on the current strengths and challenge the current situation.	**RESULTS** Measurable outcomes that prove that goals and aspirations have been achieved.

4.3 SOAR analysis of the South African healthcare system

Digital transformation trends are becoming global and universal and cannot be overlooked if organizations and companies have to match the rest [11]. This presents the need for developing countries to formulate technological leapfrogging strategies.

This section applies the principles of a SOAR analysis in evaluating the opportunities and challenges of leapfrogging to I4.0 using the South African healthcare system as a point of reference. The strength and opportunities were derived from the private and public healthcare sectors, which represents developed and developing countries respectively. Table 2 gives an overview of the SOAR for the South African healthcare system.

Table 2: Overview of the South African healthcare system SOAR analysis

STRATEGIC INQUIRY	
Strengths • A well-resourced private healthcare sector [7, 33-35]. • Provision of good quality of care due to good financial accessibility in South African private health sector [7, 33]. • Innovations such as an electronic bed management system for the public hospitals in the Gauteng province [49]. • Introduction of the NHI in South Africa [7, 33, 36, 37]. • Significant GDP expenditure in healthcare systems higher than the WHO threshold [33, 36]. • Positive response from consumers to digital services as demonstrated by tendency to access services through mobile devices [50]. • Wide use of mobile technology [2].	**Opportunities** • Inadequate quality of service and shortage of qualified human resources in the public healthcare sector [7, 8]. • Noticeable challenges with drug availability, incorrect diagnoses, cleanliness of facilities, rude staff, long waiting times and rushed appointments [6, 7]. • Old facilities and infrastructure in public healthcare sector coupled with serving the majority of South Africans [6, 7, 34]. • Availability of standalone mobile health with the growing use of smartphones among clinicians and patients [50]. In South Africa use of mobile messaging platforms such as MomConnect has seen significant adoption by users [50]. • Potentially disruptive technologies and apps are available in standalone bases and are not connected to medical practitioners, resulting in technological progression occurring in fragmentation and silos [50].
APPRECIATIVE INTENT	
Aspirations • Ensuring healthy lives and promoting well-being for every person of every age [5]. • Universal and quality healthcare coverage for every individual [35, 37]. • Reduction of the inequality of resource sharing in the private and public healthcare sectors[7]. • Achieving a patient-centric healthcare system. • Agile remote healthcare deliverables.	**Results** • Partnership between the private and public health care sector [34, 36, 50]. • Complete integration of fragmented apps and technologies [50]. • Monitored healthcare in the homes of patients through personalized healthcare system [50]. • Affordable healthcare for every person. • Universal access to healthcare by all people [5]. • Integrated EHR.

5. THE OPPORTUNITIES AND CHALLENGES THAT INDUSTRY 4.0 HOLDS FOR DEVELOPED AND DEVELOPING COUNTRIES

I4.0 presents significant opportunities for both developed and developing countries. However, I4.0 could pose significantly more challenges in developing countries than in developed countries [2]. Table 3 compares the generic opportunities and challenges for both developed and developing countries.

Table 3: I4.0 opportunities and challenges

Industry 4.0 in developed countries	
Opportunities • The implementation of I4.0 can help to offset excessive production costs and solve the issue of an ageing population [2]. • I4.0 enables interconnected, flexible and efficient supply chain processes [2]. • I4.0 offers more extensive and intelligent solutions to the global demand mass customization in a bid to increase quality and efficiency [1, 2] • The use of BDA results in identifying faults and shortcomings leading to systems and process	**Challenges** • Data security and privacy concerns arising from the need for data sharing and smooth connectivity in creating a digital ecosystem [1-3, 10, 27, 53]. • Problems of I4.0 standardization to permit communication and seamless data sharing in the IoT system [1, 2, 31]. • Need for intense workforce transformation to meet the I4.0 skills level requirements due to significant penetration of digital labour such as intelligent machines and advanced robots [1, 53].

optimization. This results in efficient use of resources [1]. • I4.0 facilitates moving production plants offshore and manufacturing goods locally due to advanced automation technologies results [51]. • I4.0 facilitates sustainable economic, social and environmental industrial value creation [52].	• Awareness and readiness challenges due to uncertainty issues. Business assumptions should be challenged and tested [53].
Industry 4.0 in developing countries	
Opportunities • I4.0 will result in sustainable manufacturing and consumption trends in developing countries [2]. • Independent industry due to reduction in the delocalization pattern of manufacturing companies by developed countries [51]. • Minimum resistance to disruptive technology due to the absence of infrastructure legacy [51]. This presents an opportunity to introduce I4.0 ready infrastructure [11]. • Unique opportunity for technological leapfrogging like for example the adoption of mobile phones in Africa [2, 51]. • Rising need of alternative sources of electrical power can result in leapfrogging the production of clean energy [51]. • Exposure to cutting-edge innovations generates an opportunity for skills and knowledge transfer [41, 51]. • Industry and government has an opportunity to participate in training and developing the digital workforce of the future [11].	**Challenges** • Shortage of professionals with required set skills for I4.0 [2, 11]. I4.0 requires skillsets such as robotic programming and big data analytics. These are available in pouches in developing countries [53]. • The current economic challenges that developing countries in Africa face divert attention from innovation and focus on cost saving [2, 11]. • Noticeable problems of monetary funding and business management buy-in which are fundamental to sign up to I4.0 roadmaps [53]. • Significant challenges related to connectivity and accessibility due to old and disparate IT infrastructure, mainly in Africa [2, 11]. • Unreliable and unstable electricity network impairs implementation of I4.0 strategies [2]. • Absence of regulatory framework that facilitate implementation of I4.0 [2]. • Job security and inequality due to advancement in artificial intelligence and advanced robotics [2]. Adoption of I4.0 will require a fundamental change of employment and skills. • A lack of awareness of products and how they function contribute to public resistance to the adoption of new technologies [38].

Successful implementation of I4.0 can fast-track the attainment of inclusive and sustainable industrialization and embrace innovation in developed and developing countries [2]. Collaboration between all stakeholders and joint action between developed and developing countries will lead to successful and inclusive implementation of I4.0.

6. DISCUSSION: DEVELOPING COUNTRIES LEAPFROGGING OPPORTUNITIES TO INDUSTRY 4.0

The opportunities, aspirations and results cited in Table 2 present the need to leapfrog to I4.0. Translating the public healthcare challenges into opportunities and viewing the aspirations and results desired in the healthcare would provoke innovation in the direction of achieving Health 4.0, an I4.0 health domain.

I4.0 technologies such as IoT, BDA and AI are ideal for addressing the opportunities and achieving the aspirations and results presented in Table 2. Combining resources in the private and public healthcare sector offers the main opportunity with respect to achieving a technological leap in healthcare. This will drive the country towards achieving the sustainable development goal in the healthcare industry.

Technological leapfrogging in healthcare systems requires private sector, public sector and all other stakeholder collaboration and broader acceptance of new technologies [50]. Complete integration of fragmented apps and technologies will result in a leap towards digital health, which will significantly improve healthcare systems and affordable access to healthcare by the majority [50].

Over the past years, technological advancement has been witnessed in African countries. The increasing use of the cloud, telemedicine and virtual reality in healthcare systems shows the potential for technological leapfrogging. Further to this, there have been pockets of IoT applications on the African continent, showing the continent's ability to attain technological advancement.

Perceiving challenges as opportunities can be a tool to inspire innovation, thus achieving technological leapfrogging that can be applied beyond the healthcare systems. For example, the challenge of old infrastructure can be viewed as an opportunity as it means that healthcare is not burdened by infrastructure legacy issues, this in turn leading to minimum resistance to embracing change [11]. The challenges that developing countries face in relation to implementing I4.0 presented in Table 3 can be translated into opportunities that can drive leapfrogging to I4.0.

Collaboration between government, industries and research institutions provides significant potential to directly implement specific I4.0 applications and to build distinctive local digital products and services that will surpass global competitors in the future [11].

7. CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

The purpose of this paper was to investigate the opportunities developing countries have to leapfrog to I4.0 using healthcare system as a point of reference. The article presented a comprehensive literature review on I4.0 focusing on the healthcare systems. Thereafter a SOAR analysis was performed on the South Africa health system. This leads to the conclusion that the challenges in the healthcare system and other sectors can be translated into opportunities that drive innovation towards I4.0 in developing countries. I4.0 technologies have significant potential to drive sustainable healthcare systems and to be applicable to other domains.

Further recommended work includes evaluating the awareness of I4.0 in healthcare systems in developing countries using South Africa as point of reference and developing an I4.0 leapfrogging maturity model for the South African healthcare system.

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