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***The role and the impact of Artificial  
Intelligence in the domain of healthcare***

*A business opportunity*

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## **INTRODUCTION AND SYNTHESIS**

According to an analysis carried out by Tractica in the first quarter of 2019, the forecasted revenues from the Artificial Intelligence market worldwide for the next six years are extremely high. If the last year (2018) the revenues from the digital intelligence market were only approximately 9.5 billion U.S. dollars, the profits for the 2025 are expected to be 118.6 billion U.S. dollars.

Even the number of sectors that are currently investing in this field is systematically increasing; according to a study conducted by IDC in 2018, the area that is now investing more in this technology is the banking and finance, with an average of \$3.3 billion; at the second position there is the retail sector, which will probably replace the first place because \$3.4 billion are expected to be invested in this field in 2019. In the IDC ranking the third place is occupied by the Manufactory industries with \$2.2 billion of AI investments. Health care is at the fourth spot with \$1.7 billion of investments followed by Energy, Logistic and Transport, Education and Tourism industries.

It is evident that the Artificial Intelligent is making its entrance in every sector on the market and wherever it goes it brings huge possibilities both in terms of profitability and efficiency. The purpose of this thesis can be found on this point. Great changes are happening and there is a need to better understand them. Because this topic is very broad this very study will not analyse every sector, but it will concentrate its attention on the healthcare. The health system has in fact experienced a huge growth in the past years but with the growth an enormous amount of money waste has risen. Due to the relevance of the sector and the necessity to find a solution to those problems, the first chapter will pay attention to explain and understand the healthcare, by going through its main determinants and the possible way to reshape the sector, suggesting, at the end, a digitalization of the sector as likely way to rethink of it.

Following this proposal, the second chapter will try to understand the world of Artificial Intelligence while trying to answer one of the questions of this thesis: “what is the role of AI in the healthcare?”. To do so I will go through the literature that has treated this field in the past five years. The literature in fact, undoubtedly represents all the applications of AI that can nowadays be found in the healthcare, this means it can be safely used as a

benchmark to summarise all the possible applications. Due to the relevance of the literature for this work the selection of the paper has been well structured: I have used the online database Scopus and, in date 23/01/19, I have followed these searching's steps with the following results:

*Table 1.1, Scopus research scheme 23/01/2019*

<b>Keywords</b>			
<b>Artificial Intelligence</b>		<b>Health Care</b>	
	Machine intelligence	Primary care	
or	Machine learning	Health system	or
or	Thinking machine	Wellness program	or
or	Digital Intelligence	Preventive medicine	or
Search 1: "artificial intelligence": 305,899 Documents		Search 2: "health care": 1,550,425 Documents	
Search 3: Search 1 AND Search 2: 3,639 Documents			
Limit to: 2014, 2015, 2016, 2017 and 2018 Papers: 1,822 Documents			
Limit to: Article, Article in Press, Review Papers; Journal; English Language; Business, Management and Accounting: 24 Documents			
Limit to Documents with DOI: 23 Documents			

The final chapter of this work will take care of using all the knowledge acquired during the process and make some proposals from an economical point. Starting from a hypothesis analysis to test the actual size of AI's impacts, the third chapter will develop a market analysis with the purpose of determine which countries are more likely to accept an investment on machine learning in their health systems. The final natural step of this process will consist in a brainstorm of possible business ideas that could be applied in the markets that have been detected in the previous section. Business ideas that will be deduced from the work done during the analysis of the literature.



# **1. CHAPTER -**

## ***HEALTHCARE SYSTEM: OVERVIEW AND DETERMINANTS***

### **1.1 Introduction**

In 2017, in the countries of the Organisation for Economic Co-operation and Development, the 20% of the total spending on the healthcare system was wasted or ineffective. On this matter the report “Tackling Wasteful Spending on Health”, from the OECD was very clear: even if the growth of the health system, both in term of longevity and quality, was improved compared to the previous years, the waste was still too high and it was not planning to stop.

Two years from that report the situation has not changed. According to the WHO, the world nations are still spending huge quantitative of money on the healthcare, accounting, on average, for 10% of the GDP, number that is expected to significantly increase in the next years.

From a certain point of view a government that increases its investment on the healthcare could be considered as good sign for a country as it is spending more money on the wellness of its citizens. The WHO, however, is clear on this point: with the growth of spending there is a growth in terms of waste which is greater, in percentage than the overall spending growth.

In a situation like the one described, there is the necessity of redesigning the way the healthcare is provided. On this matter, the next paragraphs will try to describe the health system and provide ideas to improve the current status quo and increase its efficiency.

In particular, the chapter will be organised as follow: at the first the attention will be on the main policies that could be used in order to reorganize the healthcare and solve the issue of overspending, starting from the more traditional approaches, like a regulatory review, and moving to a new way of thinking the matter, like digitalization.

The second paragraph, however, will focus its attention on the main determinants of the healthcare with the purpose of analysing which are the main variables that should be considered in order to explore some business opportunities in the sector.

## **1.2 Healthcare policies**

According to the World Health Organization, healthcare or health system “consists of all organizations, people and actions whose primary intent is to promote, restore or maintain health. [...] A health system is therefore more than the pyramid of publicly owned facilities that deliver personal health services. It includes, for example, a mother caring for a sick child at home; private providers; behaviour change programmes; vector-control campaigns; health insurance organizations; occupational health and safety legislation [...]”.

The definition from the WHO reveals how this system is rooted and built deep into the society and states how redesigning the healthcare will mean completely transform the way people think of the primary care and the way it is delivered. However, a change is necessary due to the rapidly increase of the health spending and the huge wastes that are daily occurring.

Nowadays there can be identified 4 macro areas of healthcare policies that would help in the process of reshaping the health system.

### ***Regulatory review***

The first way to tackle the issue of expenses and waste in the healthcare is by reviewing and change the list of norms that regulate this specific system. The typical system where this policy is applied is where most of the share of the health system is in government’s hands. This is because it would be much faster to implement new regulations and it would be easier to get the new norms approved if there is no pressure from the privates.

In a situation where the private has the major, or at least a good part of the share of the market, the government would have much more trouble trying to apply new norms to the private sector and it would become hard to make a drastic change.

If a regulatory review of the healthcare will be proved to be successful in increasing the overall efficiency of the sector and decrease the costs, the country will significantly improve its economic situation.

### ***Health Insurance***

It is a contract stipulated between an individual and an insurance company or the government. The health insurance grants coverage to the individual for medical expenses in exchange for regular payments to the company. The amount of money coverage

depends on the agreement that has been stipulated. Usually the more you pay the more coverage you get.

The main drawback of this contract is that the level of coverage is directly related to the wealth of a person, which means that some people, if they cannot afford an insurance, could be unable to reach a minimum medical coverage. On the other hand, the health insurance system can grant huge benefits to those people who can afford high level coverages plans.

### ***Hybrid Healthcare system***

Another way of redesigning the healthcare is moving to a hybrid healthcare system. The term hybrid means that the system is financed partially by the government and partially by the private sector. This system has proved to be effective in several national markets, on top of them France where the life expectancy has surpassed 80 years.

Adopting this system brings the good traits of both a public healthcare and of a private one, which can be summed in few, but relevant characteristics.

From the public point of view: equality, as everyone has access to the primary care; positive externalities, healthy population increase the productivity of a country.

From the private point of view: efficiency of the private sector and unlimited budget.

The process of improving the efficiency of the healthcare with this policy will happen through two different practices: for what concerns the governments, through a regulatory review, and for the private sector, efficiency improvement is a natural part of a business growth

### ***Digital Transformation***

Digital transformation is the process of converting a business model thanks to new technologies. In the past few years, this trend has granted several companies the chance to make their stand in their markets while increasing productivity, efficiency and reducing the costs. This new way of reshaping the healthcare has the potential to become the solution the problems that are attacking the sector, because it grants all the advantages of the conventional policies with less expenses and time consuming.

According to Forbes, there are 5 main trends that are currently shaking the health system.

- Telemedicine is the first of the several applications of new technologies in the healthcare. Telemedicine breaks the rule of visiting the doctor face to face during

sickness. Nowadays in fact, patients can easily get in touch with their physicians and get a diagnosis just by connecting digitally with them.

- **Blockchain.** This technology is a step forward to destroy the tedious process of processing and dealing with medical records. Blockchain can grant doctors easy access to any medical records in no time, avoiding the patient to take care of looking for specific documents, while treated, and then send them to the physicians.
- **AR and VR.** Augmented reality is truly a breakthrough in the sector. Thanks to this technology in fact, doctors can practice on difficult medical procedures in completely safety, efficiency and no waste of money. AR and VR have proved to be useful also for patients' treatments. An example is how Alzheimer's' patients can be helped to retrieve their memories by showing them images from the past thanks to VR technologies.
- **Digital Twin** connects digital and physical world. This technology grants physicians to create "a safe environment where providers and manufacturers can test the impact of potential change on the performance of a healthcare procedure by experimenting on a virtual version of the system". Digital twin permits physicians a safe trial before making the final choice.
- **Artificial Intelligence** is the last one of these new trends, but it is very likely to become the leading innovation that will completely change the way we think of the health system. From detecting diseases faster than a doctor to predict the outcome of treatments combination, AI can significantly increase the efficiency of the sector while reducing the costs.

### **1.3 Healthcare System's Determinants**

The healthcare systems can be defined and analysed from several aspects and in different ways. This paragraph, however, will try to understand it only from a digitalization point of view as this trend is expected to become the leading one. Besides the fact that plenty of studies have already been performed on the conventional policies.

In the specific, AI will be the main aspect of digitalization that will be considered, as it is several steps ahead of the other trends. With the final purpose of solving the problem of efficiency and money waste, two main indicators can be identified that could help to solve

the issue. These are: Bloomberg's health efficiency score and health spending data from OECD.

- **Efficiency Score:** The health efficiency score is an index, developed by Bloomberg, which ranks country based on the level of their healthcare. For a country to be enlisted in this ranking it needs to have a lifespan of at least 70 years, a GDP per capita that exceeds \$5,000 and a minimum population of 5 million. Then a score will be assigned, and the nation will be put inside the ranking. Currently the lowest score is held by Bulgaria, with 29.4 and the highest by Hong Kong, with 87.3.
- **Health Spending:** This value is calculated by the OECD and it consist in: "the final consumption of health care goods and services including personal health care and collective services" (calculated on the GDP). These data are filtered only for the Government and compulsory expenditures, because they show a broader view of the system than the voluntary spending.

Moving to a more in-depth analysis of the market, that could help in a situation of investment decision, 5 more variables could be used to describe the system.

### ***Education level***

These data can be drawn from the 2016 Human Development Report. This indicator is helpful as it shows how likely is a country to accept a digitalization of the healthcare. It is proven in fact, that a well-educated country is more likely to accept new form of technology, which is a relevant factor for a mind changing technology like AI, if we consider that the scientific world is fighting on the decision to adopt/invest or not on this technology.

### ***Number of medical graduates***

This indicator is relevant to describe the health system of a country in two distinctive ways. At first it gives an idea of evolution of the market. A significant number of medical graduates can be easily associated with a significant quantity of doctors available in the system in a next future, which can be interpreted as a good sign of wellness of the system. Secondly, from a healthcare investor point of view, a good graduates' coverage can be associated with a good workforce presence in that specific national market, vital for a business. A good benchmark can be deducted from the OECD indicator that provides the

number of medical graduates as an average of the amount of graduates every 100,000 inhabitants (the highest the number the better).

### ***Percentage of engineer graduates***

Like the data for the number of medical graduates, also the percentage of engineer graduates can be obtained from an OECD database. Unlike the previous variable, which can explain the healthcare in different way, this one is useful only in a situation of investment analysis. The reason is that this indicator is only helpful for those companies or governments that want to invest on digitalization, and for this reason they are in need for engineers. So, this index is more effective in illustrating the feasibility of this kind of project rather than describing the health system. The percentage of engineer graduates is calculated out of the total amount of graduates per year (the highest the percentage the better).

### ***Received FDI***

These data can be extracted from the World Bank Database, where the FDI are calculated as percentage on the country's GDP. This variable shows how much a country is open to foreign investments. If there are in fact, too many foreign direct investments in that specific country, it could mean that the market is already full and there are not anymore investment opportunities. At the same time if the level of FDI in a country is low it is very likely that this country will accept external investments and, to foster this process, it could provide help for the investors.

### ***Voluntary health spending***

These data are from the OECD database of the first steps and the spending is calculated on the GDP. The purpose of using this variable is to understand which countries are investing on improving the quality of the healthcare and which relies more on the private sector. In fact, if there is a huge amount of voluntary expenses, it means that the people are forced to pay for their own cure instead of relying on the government.

## **1.4 Conclusion**

To provide their citizens the best health services possible, world governments need to solve the problem of increasing growth of money waste in the healthcare sector. On this

matter, the policies that can be adopted are several, from a regulatory review to a public/private system. However, as these policies has not significantly improved the situation in these years and the government are still trying to solve the problem, maybe the time has come to move forward from the conventional strategies to a new way of addressing this issue, and the digitalization could be the possible solution.

Digitalization has proved in fact, to boost every sector where it has been implemented, suggesting that if applied to the health system it could possibly overcome its problematics. On this point the next chapter will focus their attention on seeing the opportunities that digitalization, more specifically Artificial Intelligence, could bring to the sector, not only from a government point of view, but also from a private investor's one.





## **2. CHAPTER -**

### ***WHAT ARTIFICIAL INTELLIGENCE (AI) IS:***

#### ***LITERATURE REVIEW***

### **2.1 Introduction**

Since the first definition by John McCarthy was stated, in the 1956, Artificial Intelligence has made great strides. AI cannot be defined anymore just as “thinking machine” but, in a more exhaustive way, we can consider it as “The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.”. This definition, of the English Oxford Living Dictionary, gives a clear idea on how the prospective towards AI has changed through the past years, and how Artificial Intelligence is slowly but radically entering every sector and it is impacting every corner of the society.

In a condition where this innovation could become the new course of action to solve the problem of waste in the healthcare, there is a necessity to understand the roles that this technology is already playing on the sector.

The chapter will be so structured as follow. The first paragraph will shed light on what the world governments are currently doing on the topic of AI, and why and how businesses need to be redesigned for surfing this disruptive innovation.

The following 5 paragraphs, on the other hand, will explain the roles the AI is playing in the healthcare by describing the five main sectors of activity of machine learning, thanks to the knowledge acquired through the review of the literature.

These paragraphs will be named as the area of activity and roles that machine learning is playing in the sector, therefore: decision support system, big data and internet of things, forecasting, alternative usage of DSS, efficiency.

## **2.2 AI Society**

The issue of analysing and understand what the world governments are currently doing on the matter of AI is examined in the document published by Corinne et al. (2018); in this paper the authors are analysing and comparing what the most relevant countries are doing to build a society which is Artificial Intelligence friendly. In the specific the US report (October 2016), the European Parliament report (May 2016) and the UK report (October 2018), are analysed and compared. The discussion between these three documents is built on three main topics: the development of a good AI society; the role and responsibility of the government, the private sector, and the research community (including academia), in pursuing such a development; and whether the recommendations to support such a development may be in need of improvement.

The article states that every report is linked by the same values with slightly differences regarding specific topics. The key values that are to be followed in order to develop, according to these organizations, a good society are three: transparency, accountability, and a positive impact towards economy and society. USA consider AI as a good framework to base the progressing society because it will enable mankind to improve their capabilities while providing several opportunities, reducing unemployment rate and setting new standards for education, to progress the nation forward despite the contrary beliefs. Additionally, the report sheds light on the incorporation of AI on a national scale than to further the beliefs and standards set by United States. On the other hand, the EU report focuses more on robotics than AI, with the general idea of trying to regulate this new sector with rules, laws and by creating a committee specifically designed to achieve this goal by following ethical values like dignity, freedom and justice. Accordingly, it is established that the United Kingdom foresees its future by adopting a bilateral approach towards both robotics and AI, while also emphasizing to maintain specific standards in regards with privacy and transparency that are of utmost importance to national security. It is evident from the reports that there is an increasing interest in the world towards advancing Artificial Intelligence while addressing the ethical concerns, privacy and singularity, that arise with it. Consequently, the world is transitioning, slowly but gradually, into adapting AI as its future.

Adopting this new type of technology is not an easy move for a company because mostly such a transition requires a drastic change in the business model. However, Garbuio and

Lin (2018) describe a serious of steps for a company that is interested in applying AI. To begin with, a company has to decide the issues that it plans to address, if an AI system is required in order to solve the problem, if it is deemed necessary and the type of AI (assisted intelligence, augmented intelligence, autonomous intelligence). Then a start-up (the article focuses its attention on start-ups) must decide if they are going to implement an existing platform, by leveraging one of those, or if they are going to create a completely new one. The third step involves governance and decision-making responsibility; for instance, in case of an error, there is a matter of deciding if it is caused by the machine or by human interpretation of its results. The next step is in acknowledging that it is better to focus on a single business archetype at any given instance in contrast with adopting several at once.

The last step and probably one of the major issues while introducing AI in a company is the lack of predictability on how managers and physicians will react and behave towards this innovation. As Garbuio and Lin (2018) say “AI requires a major change in the way a doctor or administrator thinks about work, their role, and the processes of the organization. Just as it took years for keyhole surgery to replace open surgery, the adoption of AI will take place in parallel with other approaches”. The idea behind their statement can be applied in every sector in which Artificial Intelligence is making its debut, such an idea is only strengthened by other researchers who share a similar point of view. One of the noteworthy being, Fox and Aranko (2017), as they not only mention the fact that the professionals need to rethink the way they think of their job but there is also the necessity for the end user to adapt to this new technologies, and, in order to do so a new framing needs to be developed. The idea behind Fox and Aranko is that a healthcare framing is needed but this concept needs to be applied to every sector and every business must move from this concept to improve their efficiency.

### **2.3 Decision Support System**

The first area where Artificial Intelligence can be found and used in the healthcare is in Decision Support System. Even if in the DSS the use of machine learning is not as much extensive as in the IDSS, it deserves a comment in this literature. In fact DSS is worldwide considered as the first step towards more complex, AI driven, systems and it has been considerably used in the past decade.

In all relevance is the document published in the 2018 by Razmak et al. In this document they highlight the relationship between the implementation of Clinical Decision Support System among doctors and the actual usage of this technological implementation: thanks to the research, conducted in Canada between 2007 and 2014, they have postulated that there has been an increasing usage of CDSS from 9.80% to 63.70%. The reasoning behind this increase can be found in the technological improvement that has escalated in the past decade; this could also suggest that it is very likely that this type of aid system would start to become a consistent part of our life while improving the overall quality of our healthcare systems.

Among types of DSS is the Knowledge Management System, which is specifically built, as the name suggests, to collect, store and analyse knowledge with the sole purpose of improving services. The document “An Intelligent Case-based Knowledge Management System for Quality Improvement in Nursing Homes” proposes an interesting system that, with the help of AI (this is why Intelligent Case-based), will improve the overall quality of a nursing home in Taiwan. The authors Choy et al. (2018) stated that the usage of KMS will be able to drastically increase the quality perceived by elder patients in the nursing home: “By formulating a customized training program with relevant knowledge to serving staff based on their performance, previous medical errors and complaints can be greatly reduced while service quality for the elderly can be enhanced”. According to them this new way of thinking of the training of nurses has been proved to be successful: the number of complaints and medical errors per month has significantly decreased, in addition to the reduction in the administrative costs.

To better understand how DSS can be integrated with Artificial Intelligence to improve the power and range of activities of the system, the work of Gómez-Vallejo et al. (2016) needs to be mentioned. In their work they use machine learning, applied to decision support system to create a framework that can watch over and diagnose healthcare-associated infections (HAI). On this point they say: “The developed system makes use of different machine learning techniques in order to (i) automatically extract evidence from different types of data including clinical unstructured documents, (ii) incorporate static a priori knowledge handled by infection preventionists and (iii) dynamically generate new knowledge as well as understandable explanations about the system’s decisions”. This system moves from the original definition of decision support system to a more open one,

reaching the edge to become a predictive model. Proven to be successful with an accuracy of 70.21%, CBR (the name of this system) is supposed to become, in the next decade, a huge aid in the detection of healthcare-associated infections in hospitals.

Lastly the work of Akçura and Ozdemir (2014). To address the issue that each year from 700,000 to 1.5 million of injuries are caused by the wrong prescription of medicaments, they have developed a decision support system for physicians that would help them in their daily work. In specific, this system is supposed to help novice doctors to recognise and connect different symptoms in order to prescribe the right treatment. The ability of a physician to select the right course of treatment, in fact, depends mostly on the experience on the field of the former. Thus, by assisting doctors with a DSS, the researchers believe that the number of adverse drug events will decrease while compensating the lack of experience that would otherwise lead to misdiagnosis by novice medical graduates.

## **2.4 Big DATA and Internet of Things**

The second sector where AI finds a role is the world of Big DATA and of the Internet of Things (IoT). Thanks to the invention of the Internet, an increasing number of people are connected on a daily basis resulting in a huge amount of data that is available online which could be exploited not just in term of business opportunities but also as a new way of thinking and solving several health related issues.

In this context, several such opportunities for the development of a new way of treating patients can be found. The first one is directly related to the concept of IoT. All the wearables that we have been using in the past few years to keep track of our steps, which are identified as IoT, hold inside the chance to become a breakthrough in the way diseases are discovered, treated and to a certain level predicted.

This belief is shared also by Wong et al. (2017). These researchers in fact, believe that IoT devices, which are wireless connected devices that can transmit data inside a network, could be a better way to collect data from the patients. These new devices, that should be implemented as part of the cure for the patients (the case only analyse the usage in the elders), are in fact supposed to continuously keeping track of data like bpm, BMI, blood pressure etc. These big data (they are in fact big datasets) will be then analysed by a system called “e-Healthcare system”, this system, which uses AI, collects, analyses and reports all these information and by connecting all these dots it builds a description of the

patient and tries to predict possible diseases or health-related issues that could affect the person.

The second usage of Big DATA, with AI, is related to the overall patient experience with healthcare. Both the works of Pit et al. (2018) and Li et al. (2018) in fact, focus their attention on converting the online qualitative data into quantitative data. To do so, the former have developed a framework which is able to convert the online reviews (for instance: the review of knee replacement surgeries) into a scale that can be interpreted by physicians to understand the overall success of the surgery and the post-treatment procedures. The latter, on the other hand, have developed a different framework that permits search engines to “translate” non-medical words, used by people in their online researches, into medical words. The role of artificial intelligence in both these works can be found in one of the synonyms of AI: machine learning. The AI used in both these projects will in fact, gradually learn from its mistakes that will make during its lifetime, which will be corrected by the work of experts. In this way both these frameworks will become more and more reliable, and more applications could be lately implemented.

## **2.5 Forecasting**

Forecasting is probably the most innovative role and with highest number of opportunities that Artificial Intelligence is trying to fulfil. In the healthcare sector, one of the main sources of expenses and failures comes from the wrong prescription of treatments, derived from the truth that it is truly troublesome to anticipate on the off chance that the remedy will work for a particular illness, due to the high data that have to be analysed within the moment a treatment is endorsed.

This situation becomes more drastic when the treated diseases are chronic ones, like cancer, or when the treatment is related to complex surgeries or post-surgery treatment. It is in this scenario that AI plays its part, this technology in particular, permits to develop predicting models thanks to the ability of the system to collect and analyse historical data, such as medical records, possibility of recurrence, and to see if existing treatments could be applied.

Developing a predictive model is also the reason behind the research of Topuz et al. (2018). To reduce wastes, expenses and to increase efficiency and the overall graft survivability during kidney transplants, this group of researchers have developed, thanks

to AI, a predictive model. After collecting an astonishing amount of data from medical records (more than 31,000 US patients), this team has created a forecasting model that, with an accuracy of 0.684, is able to predict the result that a specific treatment will cause to the graft survivability of kidney transplants.

The second work that must be mentioned is “An Analytics Approach to Designing Combination Chemotherapy Regimens for Cancer” developed by Bertsimas et al. (2016). In their work, they study chemotherapy regimens in order to construct a predictive model that can forecast the outcome of a combination of these treatments with a certain degree of accuracy and reliability. The relevance of this work is that till now, in order to treat cancer, only one chemotherapy regimen at a time has been used because it was impossible, for the human mind or previous technology, to predict how a combination of different regimes could have impacted on the therapy. Using a database of gastric cancers, this research team has been able to develop a satisfying predicting model that if proved to be promising on the field (no actual clinical trials have been tested) could be implemented for other type of cancers and successfully save lives.

Related to this paper is the project of Zolbanin et al. (2015). Their work outlines a predictive model which built to recognise comorbid disease to diagnose in earlier stages the presence of cancer. In this specific model Artificial Intelligence is more than necessary. Prior to this day, all diseases have been treated separately because analysing them together has been impossible both for the human mind and for the computer; by finding the intersections between different diseases, evident from machine learning, the authors believe that it is possible to identify pattern in the ailments that would help to predict the outcomes of cancer. It is then relevant to quote the authors on this idea: “Advances in machine learning techniques and their application in different areas, including medicine, allow more effective analyses of historical data to discover interesting patterns. While traditional methods focused on data analysis ex post, with low accuracy in predictions in most cases, machine learning techniques have extended our barriers in predicting events ex ante”.

AI can be applied in any sector but remaining on the field of preventive medicine is worth mentioning that predictive model can be used not only to predict diseases or treatments outcomes, but also in more empirical situations. To highlight and strengthen the idea, two relevant examples: one is the work of Shynkevich et al. (2016), where by using a daily

updated database full of financial news they have been able to build a model that would help people to forecast movements of healthcare stock prices; the second paper (Jiang et al. 2018) describes a predictive framework that will help to recognise those patients that have a high risk of post-treatment readmission, as a result, the hospital will be able to deploy post-discharge care or managing their conditions once they arrive at home.

## **2.6 Alternative usage of DSS**

The modern society is producing an astonishing amount of data, this implies that new aiding systems are necessary for physicians, as well as for every businessman, to analyse this knowledge and to improve the overall quality and efficiency of the services provided. The high value that a decision support system can bring to a company, as it has been proven in the section of DSS, suggests that the application of DSS can be found in every corner of the healthcare sector. For this reason, DSSs are joining every business, and a proof of this is the work conducted by Safwan et al. (2016). In this work the authors show how similar the evolution of DSS is, compared to Business Intelligence. They are in fact, so much comparable that it can even be said that these two technologies have gone through the same process of evolution. This shows how much decision support systems are becoming a part of several companies.

The usage of DSS is not limited inside the wall of a building but it can be successfully implemented in much wider environment: this is the case described by Neville et al. (2016). In their analysis they show how in situation of great crisis, like cross border large scale disaster, Decision Support System can be vital to save thousands of lives. In this scenario in fact, several difficulties occur that cannot be controlled by human mind: different languages of communication, different level of resources, huge amount of information that need to be analysed immediately due to the life or death situation etc.

In this context a system like the one developed by these researchers makes its standout. S-HELP is in fact, a DSS that has been developed with the only purpose of helping in this cross-border crisis. This system is a decision support tool that provides the user with several information, analysis and scenario projections that will help them in these unpredictable situations.

To conclude, it is worth mentioning the paper of Li et al. (2017). The relevance of this work for this thesis is to show another example of how this technology and healthcare



can work together for the sake of the people. The authors develop in fact, a decision support system in order to find those areas that have shortages of doctors, in this way, the authors suggest that there will be a decrease in the healthcare expenditures and an improvement of the healthcare accessibility and quality.

## **2.7 Efficiency**

To sum up the several reasons why a healthcare company or institution should implement Artificial Intelligence in their businesses there is the word: efficiency. Implementing AI, as shown in the previous sections, can seriously decrease the waste of money of a company while increasing the overall efficiency. The next three examples are relevant to highlight and prove the idea that AI significantly improves the efficiency of any area in which it is applied, not only healthcare.

The first example is due to the work of Nabelsi and Gagnon (2017). In their work they recognise how implementing IT (AI) inside hospitals as well as in any other company, could boost their efficiency. In the specific they show how Supply Chain Management can be positively impacted by this technology. To prove so they work on three different real cases that have shown to be relevant for their topic. To connect to the next example there is the idea behind the last one of these three cases: the application of AI in the internal logistic to increase efficiency.

Applying AI to internal logistic means rethinking the way internal services are provided. In the work of Landa et al. (2018), they start from an existing issue, the overcrowding of the emergency department (ED) and the necessity of increasing bed capacity, to build a model that can suppress this problem without losing quality of the service. On this point, achieving efficiency means dealing correctly with the emergency bed requests in the ED and organising the planned admission without increasing the number of beds, which, if not satisfied, would mean increasing the costs. Thanks to the development of a DES model (discrete event simulation), the researchers have been able to increment the efficiency of an hospital in Liguria, Italy. Depending on the inputs, which could be number of planned admissions or number of emergency requests, the system is able to create different scenarios to make the beds allocation more efficient.

Following the idea of using AI as mean of optimization for the internal logistic of an hospital, there is the research of Rais et al. (2018). In this work the authors propose a

support software to improve the efficiency and effectiveness of the internal distribution of documents. A hub, capable of providing the couriers with specific tasks to avoid waste of time during the delivery service, is developed. According to the researchers: “Computational results show that solution approach based on optimization and process re-engineering can not only improve the performance measure by more than 50% but also reduce resources necessary to maintain the same level of service as before by 16.67%”.

## **2.8 Conclusion**

This final example clearly shows that applying an aiding systems, powered by artificial intelligence, can really improve the overall efficiency of the healthcare sector and it is also clear that AI is playing significant, while different, roles in this sector.

The attention that the world governments are giving towards this technology and the fact that all the applications of machine learning in the healthcare that have been analysed during the previous paragraphs are at a larval stage, indicates that the possibilities that lies hidden in this technologies are countless.

This also means that machine learning has the potential to completely change the way of thinking and designing the healthcare system, and could give the chance to world governments to significantly reduce the amount of money spent in the sector and, from a more philanthropic point of view, to embrace the idea of providing every individual in the world with the basic primary care.

Moving from this point to a more economical one I will give a look, in the next chapter on how AI is impacting the healthcare. I will do so from a business point of view, which means understanding if, as an investor or as a company, it is worth tackling the AI sector in the healthcare. If the impacts will be proved to be significant, I will analyse few more data to try locating a market gap and subsequently proposing some business ideas or investment proposals based on the mentioned discoveries.

### **3. CHAPTER -**

## ***AI IN THE HEALTHCARE SYSTEM: COMPARATIVE ANALYSIS***

### **3.1 Introduction**

Artificial Intelligence is a disruptive innovation that brings to those who embrace it great advantages at low costs. In a sector like the healthcare that, in the past few years, has seen an astonishing growth but at the same time an even greater escalation of inefficiency and money waste, I believe that great business opportunities are offered to those willingly to exploit them. In order to understand if there was some truth behind my assumption, I have built the following analysis.

Starting from testing the hypothesis behind my statement I have then decided to move forward in order to find out which national market would be the most suited for an investment. I have proposed then few business ideas, that I have collected from the study of the literature, and I have applied them to the most suited national market, so those countries where, in my opinion, these ideas would have worked better. The decision to use existing application of AI sits on the fact that as these ideas have already been tested on the field and proved to be successful, it is very likely that the outcome will be repeated, if the necessary conditions will be respected.

For this reason, the chapter will be divided in three different section. The first one will be the hypothesis analysis with the purpose on identifying more clearly the impacts of this technology, not only in the healthcare, but also in any other sector; and to find out if business opportunities lie beneath this innovation.

The second paragraph will move forward from this analysis to better understand the market and to find a market gap. This market analysis will be built with the use of the main determinants of the health system, with regards to AI, and by developing a brand-new variable.

Finally, the last paragraph will discuss about the managerial implications of the discoveries made in the previous sections.

## 3.2 Hypothesis

The hypothesis that I will analyse and test in this section is: “the impacts of Artificial Intelligence on the healthcare are significant and positive”.

To analyse this hypothesis, I will go through three different steps, after proving that each one of them is satisfied I will move forward to the following one.

The *first step analyses* the overall impacts of AI in every sector of the market through the data provided by the “Artificial Intelligence Index”, the 2018 annual report. According to this index in the past 18 years there has been a significant increase in the number of AI start-ups. The comparison with the number of traditional companies, in the period between 2015 and 2018, shows that the number of AI driven start-ups has increased of 113% compared to the 28% of the conventional ones. (*Figure 3.1*)

Secondly, I have analysed the amount of investments on AI start-ups. The index shows that the amount of venture capital investments directed towards these start-ups, in the period between 2013 and 2017, has seen an increase of almost 350%. (*Figure 3.2*)

Ultimately, I have analysed the job market to understand if machine intelligence is offering job opportunities or, as a good branch of the public opinion thinks, it is causing unemployment. According to the artificial intelligence index, in the period between 2015 and 2017 the growth of job opening, only with regards to deep learning skills, has seen an increase of over 34 times. (*Figure 3.3*)

*Figure 3.1, AI startups (1995-2018)*

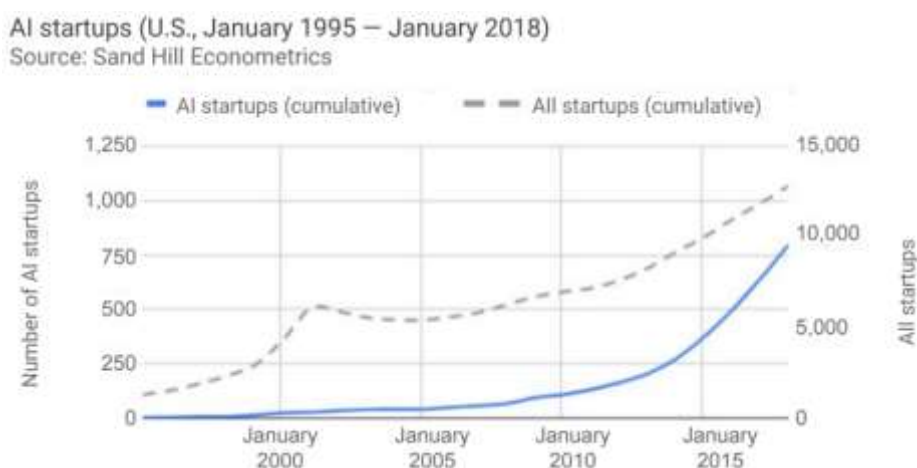


Figure 3.2, Annual VC funding of AI startups (1995 - 2017)

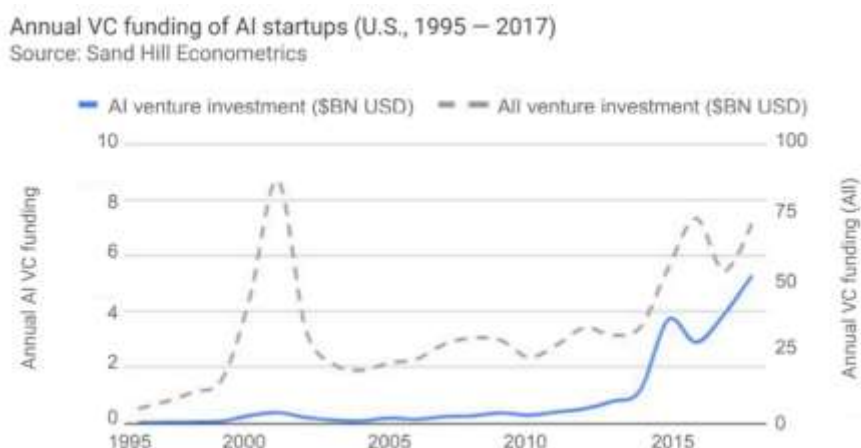
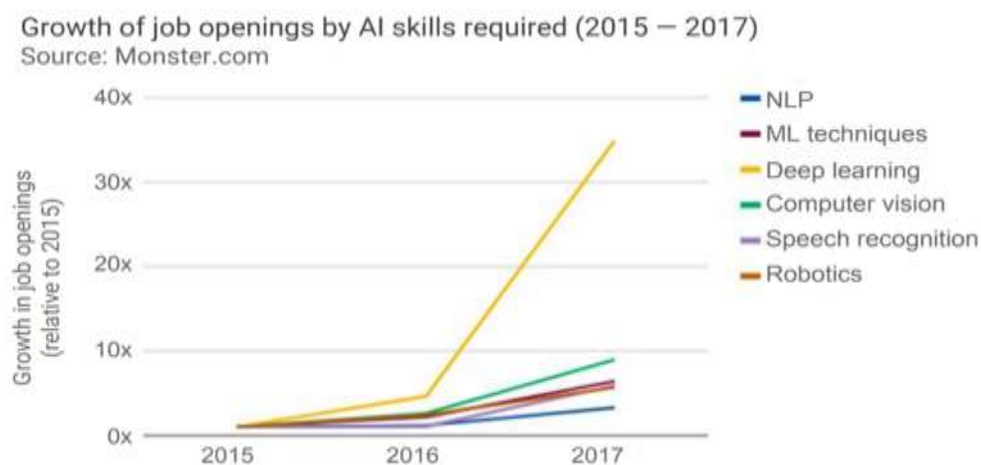


Figure 3.3, Growth of job openings by AI skills required (2015 - 2017)

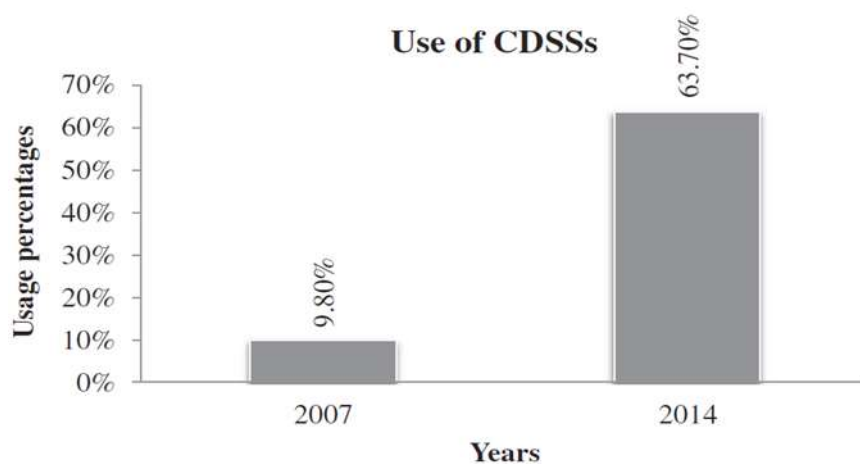


The *second step* narrows down the analysis just to the healthcare sector. To do so I will use the report: “Artificial Intelligence in Healthcare Market by Offering, Technology, End-Use Application, End User And Geography – Global Forecast to 2025” which provides a forecast of the AI growth in the healthcare. According to this report, between 2018 and 2025, AI in the healthcare market is expected to grow from 2.1 to 36.1 billion dollars. If correct it will have a huge impact also on the number of jobs, AI related, that will be available on the market. This implies that the results proposed in the previous steps are very likely to increase.

The *last step* will use data from chapter one to prove and give empirical examples of the efficiency and growth of the application of machine learning systems in the primary care. The documents that I will use for this step are the one provided by Razmak et al. (2018),

Rais et al. (2018) and Choy et al. (2018). Limited on Canadian physicians, Razmak et al. (2018) state, in their paper, that the “Usage rate increased noticeably between 2007 and 2014, climbing from 10% to 63% within 7 years”, as the following chart illustrates. (Figure 3.4)

Figure 3.4, Usage comparison of CDSSs (2007 - 2014)



Talking about the efficiency of machine learning systems, the examples of Rais et al. (2018) and Choy et al. (2018) are significant. The former demonstrates that an active process of reengineering of the logistic services inside an hospital, in the specific of the couriers’ service, can improve the performance of more than 50% while reducing the costs of 16.67%.

The following chart (Table 3.1) is very explicit on this point: the number of hours per week spent by the couriers drastically decrease after the implementation of the new system.

Table 3.1, Results comparison before and after DSS implementation, Rais et al. (2018)

	Solution approach	Total time (weekly hours)	Improvement (by optimization [%])
Without hub	Previous approach	96.0	
	Optimization approach	68.3	28.85
With hub	FFR	47.1	50.94
	Optimization approach	39.8	58.54
	FFR	45.7	52.40

The last work, the one proposed by Choy et al. (2018), explains how AI can improve the service quality of a nursing home. We can see that the number of complaints and of medical errors have both decrease of more than 60%. (Table 3.2)

Table 3.2, Service quality of the nursing home before and after implementing ICKMS, Choy et al. (2018)

	Before implementing ICKMS	After implementing ICKMS
Number of complaints per month	18	7
- Poor attitude of staff	12	2
- Poor catering	4	3
- Poor living environment	1	2
Number of medical errors occurred per month	13	5
- Mistake in operation procedure	6	3
- Poor recording documentation	7	2
Performance review cycle	Two months	Six months

To sum up the results collected:

- Start-ups growth (2015-2018): 113%
- Start-ups investments (2013-2017): 350%
- Job opening growth (2015-2017): till 34 times
- Forecasted AI in healthcare market growth (2018-2025): 1,619%
- AI in healthcare usage rate (2007-2014): from 10% to 63%
- Overall AI performance increase: 60%
- AI related cost reduction: 16%

### 3.3 Market Analysis

After proving the hypothesis to be correct and relevant I have moved to the second part of my analysis: find a market gap. For the analysis several datasets are going to be used: Bloomberg healthcare efficiency index, OECD health spending database, OECD tertiary graduates by field, World Bank Foreign direct investment net inflows (% of GDP), UN human development report.

Thanks to the review of the literature, we know that Artificial Intelligence is a disruptive innovation that can drastically increase efficiency and reduce costs. This means that a suited country market to enter will be the one that has a relatively low level of efficiency

but a high level of expensive (healthcare related). The reason is that this hypothetical country will be more likely to accept an investment on AI, for the sake of solving its internal problems. For this reason, the starting point to find a suited country for investing will be analysing two different variables: efficiency score, health spending.

I have so created a new database, by selecting those countries which data can be found in both the datasets that are provided by Bloomberg or by the OECD. Therefore, from a total of the 50 countries provided by Bloomberg, which is the biggest database, I now have 35 countries with data from both the datasets of Bloomberg and OECD.

After creating this database, I have developed a new variable, which I have called Efficiency rate (Eff-rate), which consists in the ratio of health spending over efficiency score. The purpose of this rate is to find the country that is more likely to be positively impacted by an investment in AI in the healthcare. In the specific, the higher this rate, the higher amount of expenses are enduring in that country and at the same time a low level of healthcare efficiency subsist. I have so calculated the Eff-rate for each one these countries (obtaining for China the lowest rate: 7.93 and for the United States the highest: 271.87) and I have calculated the arithmetic mean of all these rates, which is  $\bar{x} = 56.40$ . From this new table I will select only those countries that held a score above the average, which means selecting those countries that lack in efficiency but are enduring high costs. In order to have a smaller dataset, I have then selected the 10 countries with highest Eff-rate: United States, Germany, Denmark, Norway, Sweden, Netherlands, Switzerland, Belgium, Austria, France.

It is relevant to mention the massive gap between these countries' rates and the average  $\bar{x}$ . In the table below (*Table 3.3*) the 10 countries are highlighted with their efficiency scores, health spending values and Eff-rate. The blue line represents, approximately, the average  $\bar{x}$ .

*Table 3.3, Eff-rate results comparison*

Nation	Efficiency Score	Health Spending	Eff-rate
United States	29.6	8047.3	271.8682432
Germany	38.3	4869.4	127.1383812
Denmark	42.4	4363.4	102.9103774
Norway	58.9	5399	91.66383701



Sweden	53.2	4606.4	86.58646617
Netherlands	50.8	4377.7	86.17519685
Switzerland	58.4	5030.4	86.1369863
Belgium	44.8	3760.7	83.94419643
Austria	49	4043.5	82.52040816
France	55.5	4068.4	73.3045045
United Kingdom	46.3	3341.4	72.16846652
Ireland	58.2	3954.5	67.9467354
Japan	64.3	3970.6	61.75116641
Canada	55.5	3382	60.93693694
Finland	54.7	3077.8	56.26691042
New Zealand	55.6	2894.2	52.05395683
Australia	62	3109.5	50.15322581
Czech Republic	49.8	2149.8	43.1686747
Italy	67.6	2622	38.78698225
Slovak Republic	47.6	1826.9	38.3802521
Portugal	55.4	1924.8	34.74368231
Spain	69.3	2385.7	34.42568543
Hungary	42	1365.1	32.50238095
Israel	67	1780.4	26.57313433
Poland	52.7	1352.2	25.65844402
Greece	56	1423.4	25.41785714
Korea	67.4	1686.7	25.02522255
Russia	31.3	743	23.73801917
Chile	49.3	1164.4	23.61866126
Brazil	32.8	607	18.50609756
Turkey	52.2	934.2	17.89655172
Costa Rica	52.3	930.2	17.78585086
Colombia	36.8	606.3	16.47554348
Mexico	54.6	533.3	9.767399267
China (People's Republic of)	54.6	433	7.93040293

The next step will be identifying five new variables that will allow me to narrow down the number of countries that could be suited for starting a new business or investment decision.

These variables, with in brackets the reason why I have selected them, will be:

Education level (technology acceptance), Number of medical graduates (needs of workforce), Percentage of engineer graduates (needs of workforce), Received FDI (market availability), Voluntary health spending (market availability).

Table 3.4, Results from variable analysis

Nation	Rate	Education	Medical Graduates	Engineer Graduates	Receiving FDI (%GDP)	Vol Spend
U.S.A.	271.868	0.9	7.5	6.90%	1.80%	1785
Germany	127.138	0.914	11.7	22.10%	2.10%	859
Denmark	102.910	0.923	22.1	10.30%	0.70%	819.5
Norway	91.664	0.916	11.1	12.60%	0.40%	952.4
Sweden	86.586	0.855	10.2	18.30%	5.90%	904.3
Netherlands	86.175	0.897	14.4	N.A.	38.10%	1008
Switzerland	86.137	0.891	10.6	15.70%	5.60%	2978.8
Belgium	83.944	0.841	14.8	11.90%	-8.00%	1013.6
Austria	82.520	0.82	14.1	20.50%	3.70%	1396.5
France	73.305	0.839	9.1	14.90%	1.80%	833.7

I will then create a table with, in the first column, the 10 countries that I have selected during the first step of my analysis and, in the first row, these 5 variables. I have then given a score between 1 to 10, according to the performance of each country in each variable (the lowest the score, the better the performance).

Therefore, I have summed up each country score on each variable and I have obtained a total score per country. The total score will be a number between 5 to 50. (Table 3.5)

Table 3.5, Results from ranking analysis

Nation	Education Level	Medical Graduates	Engineer Graduates	Received FDI	Voluntary Spending	Total Score
Austria	10	4	2	7	8	31
Belgium	8	2	7	1	7	25
Denmark	1	1	8	3	1	14
France	9	9	5	4	2	29
Germany	3	5	1	6	3	18
Netherlands	5	3	10	10	6	34
Norway	2	6	6	2	5	21
Sweden	7	8	3	9	4	31
Switzerland	6	7	4	8	10	35
U.S.A.	4	10	9	5	9	37

I have then calculated the arithmetic mean of the total score, which is  $\bar{y} = 27.50$ . I have ranked all the countries from 1 to 10, according to their performance in this analysis (the first one will be the one with the lowest score). The following are the results (detailed for the first 3 and summarised for the remaining 7):

1. Denmark: Education Level: 0.923, Medical Graduates: 22.1, Engineer Graduates: 10.30%, Received FDI: 0.70%, Voluntary Spending: 819.5, Total Score: 14
2. Germany: Education Level: 0.914, Medical Graduates: 11.7, Engineer Graduates: 22.10%, Received FDI: 2.10%, Voluntary Spending: 859, Total Score: 18
3. Norway: Education Level: 0.916, Medical Graduates: 11.1, Engineer Graduates: 12.60%, Received FDI: 0.40%, Voluntary Spending: 952.4, Total Score: 21

The remaining countries scored: Belgium 25, France 29, Austria 31, Sweden 31, Netherlands 34, Switzerland 35, United States 37.

I have then chosen, as possible markets to enter, the 3 countries with the lowest score because they will be the ones that will better fit the requirements imposed by my variables.

### **3.4 From the theory to the business opportunities**

Each one of these countries provide different opportunities to develop relevant businesses. The next suggestions will use the knowledge acquired during the study of the literature and both the analysis to provide examples in which way this thesis can be a starting point to develop more complex studies and economical outcomes.

The examples will be two per each country and they will use the variables from the market analysis as starting point. It is relevant to say that these variables will be interpreted not only as the market analysis suggests but also from a different perspective. Some variables can be in fact, interpreted in opposite ways: for example, low numbers of medical graduates could mean that there is a problem with the availability of doctors in the market but also that only top physicians come out from the medical programs in that country. Therefore, while looking for business opportunities, is important to give examples for both the sides of these variables.

- Denmark is at the top in terms of low voluntary health spending. This means that the government puts a lot of effort on avoiding people from spending money on health by taking care itself of the related expenses.

This kind of situation can be used to develop a new business. It is in all interests of the government in fact, to keep on investing on people's health and to increase the overall efficiency of the system. In this context a business that helps the institutions to increase the efficiency and quality of the healthcare related services by keeping low or even decreasing the expenses would be the right step.

A solution that could tackle this issue comes from the work of Choy et al. (2018). In their paper they have developed a Decision Support System which collects, stores and analyse all the stored medical knowledge (documents, data, feedbacks...) of a nursing home in Taiwan. They then use all this knowledge to create personalised training programs for nurses and physicians.

By adopting a similar system to its nursing homes, Denmark could be able to improve quality and performance of the former while significantly decreasing the administrative costs. If the government will decide to invest in a business that propose this kind of solution it will result in a decrease in the public expenditure in the healthcare.

- With 22.1 medical graduates every 100,000 inhabitants, Denmark stands above the other countries. However, even if during the market analysis high number of graduates has been associated with a high performance (in terms of supply of workforce for healthcare companies), this result can be interpreted also in the opposite direction. It could be hard in fact, for the government to provide to all these graduates sufficient amount of on the field experience during their studies and training, which will eventually lead to several medical errors that will lower the quality and efficiency of the Danish health system.

A company that would be able to tackle this issue and help the government to solve this problem could really be able to make a stand in the market. The work of Akçura and Ozdemir (2014) shows a possible solution for this matter. They have developed in fact, a DSS that helps doctors with low level of experience in the process of drug prescription. By simply inputting in the system the symptoms in fact, the software is able to prescribe the optimal treatment avoiding so adverse drug events.

By implementing it, the government could be able to solve the problem of lack of experience for the novice doctors and, from their point of view, physicians will be able to prescribe the correct treatment and so increasing the overall quality of the health care system. It is clear how investing in a business like this could be an interesting opportunity for both the government and investors.

- Talking about the German market, as this country holds a great percentage of engineer's graduates (22.1%), the top one among the countries analysed, it could be a great opportunity for a company to decide to invest on AI in the healthcare by focusing its attention more on the technological side of the sector rather than the medical one. A business that provides hospitals or any other health related structure with AI optimization will be the perfect way of using this workforce and focusing on the engineer side of this sector. Following the example of Rais et al. (2018), a new business could use AI to improve the efficiency of internal logistic.

These researches suggest a support software to improve the efficiency of the internal distribution of documents. If, by applying this technology also to other areas of internal logistic, the system will prove to increase performance and reduce costs, it will be worth for a company to invest on this product.

- Germany's other side of the coin is a poor concentration of medical graduates, but still on the average if compared to other countries. This situation could mean that in the next future the number of doctors available all over the country could become significantly low, with the risk of not reaching every citizen with the basic health aid. On this point the work of Li et al. (2017) is really edifying, and could be very useful for both the government, which is trying to solve this issue, and companies, that could be interested in an investment opportunity.

The work of these researchers consists in a DSS which identifies those areas that have doctors' shortages and propose a consequential rearrangement of physicians to solve the issue. According to the authors if this system will be adopted there will be a significant decrease of healthcare expenditures and an improvement of the quality of the services. Both are vital factors for government and companies.

- The results show that, as well as Germany, Norway has a low number of medical graduates. This could mean that in a next future this country could suffer from a shortage of doctors, that will badly impact the wellness program of the country.

A good business opportunity, which will also help solving this issue, could be a company that produces IoT devices, like the ones proposed by Wong et al. (2017). The devices, and the related software, keep continuously track of the health of the patients and use a protocol to analyse these data and perform some prediction in order to prevent people from getting diseases.

Adopting these devices would help doctors in their daily activity, due to the decreasing in the need for patients' visits. Everything could be in fact, controlled and analysed remotely thanks to these devices. In addition, the country will not have to fear the rejection from the people of these new gears, because to a high level of education, Norway is on top of that, corresponds a high degree of technological acceptancy.

- The final example concerns the issue of voluntary spending in Norway's healthcare system. Voluntary spending is an issue because the level of health assistance is directly related to the people's wealth.

However, the only way to overcome this situation is for the government to pay for the voluntary medical expenses. This process is highly expensive (the country will need in fact to take care of most of the costs), but an AI related business could facilitate the transition. Norway, by implementing AI, will be able in fact, to reduce the costs of the

healthcare and increase the efficiency of the former. In this way the increase of the public healthcare costs will be less than it would normally be without machine learning.

The system proposed by Jiang et al. (2018) could be fit for the case. They have developed in fact a predictive model that, by using different scenarios, can reduce the readmission risk in the hospital, by predicting which patients are more likely to be readmitted, due to some post-treatment issues, and tackle them by providing post-discharge care.

### **3.5 Limitations and Conclusion**

Even if this analysis has fulfilled its purpose to show that there are business opportunities in the healthcare if tackled with the help of machine learning technologies, it encounters some limits. Both the market hypothesis and the market analysis lack in fact a more in-depth study because the variables used in both the testing are quite broad.

However, as this work gives a wide look to the matter and propose several and different ideas, this issue can be overlooked. If future works will be developed from one of the ideas proposed, more relevant variables, suited just for that specific business proposal and national market, will be used. In this way the limits of this research will be easily overcome.

Moving forward from this, this paper has shown how AI could be a great opportunity for governments that want to reshape those systems, like the healthcare, which are in a constant growth but are struggling to keep up with the huge waste produced, if implemented in the correct way. Artificial Intelligence is not only a great chance for national markets but also, as it has been proved during the development of this analysis, a great investment for any private investors. If tackled in the right way in fact, the machine learning technology could grant companies the ability to make their stand in a market. It is indeed in this context that this paper fulfils its purpose. It manages in fact to shed some light on the matter and to show that great business opportunities are hidden underneath Artificial Intelligence, for those companies that look for them.

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