Utilising cloud computing technology to improve the data interoperability of French healthcare delivery participants

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Executive Summary

This report analyses and evaluates data sharing in the healthcare industry, with a primary focus on how the French Healthcare system could be better equipped to deal with the rapid changes taking place. First, the context on the measures already in place and efforts put in to tackle this problem is set, allowing to assess the available resources to tackle this problem. Then, we identify the pain points and stakeholders of the issue in the problem statement to set out a clear goal to the French government. The importance of reaching these goals is then highlighted by the analysis of the industry threats. This section is followed by a clear map of the healthcare delivery system, which allows to point out the needs of each stakeholders and their nature. In order to understand the lack of linkage between the current solutions, this report detail the most utilised and admired solutions to data usage in healthcare, in 2 key regions. This leads to interim recommendations for a solution to be further explored in Part II, followed by a quick overview of cloud computing. This overview gives a basis for understanding the benefits and relevancy of this technology for the French healthcare system's inefficiencies.

I- Introduction

Digital healthcare system company overview

The ministry of health is a government institution in charge of organising prevention, care, research and innovation in the field of French health. The Directorate-General for Healthcare Provision (DGOS) is the sub-institution in charge of building the healthcare provision of tomorrow. The entity brings together all organisations, institutions and resources involved in health, research or training[1]. Hence, this institution frames the work of 218,300 doctors, including 88,200 employees and 130,100 freelancers and the health access of over 65M people[2]. The health budget in France represents 11.3% of its national wealth, about 1.4 points above the EU average[3] but only 1% of the GDP is dedicated to prevention and innovation[4].

Political issues and technological capabilities of Digital healthcare system

French healthcare regulators have been facing the issue of access to healthcare for a decade. In fact, in 2018, nearly 3.8 million French people lived in an area with an undersupply of general practitioners (5.7% of the population), compared with 2.5 million (3.8% of the population) four years earlier. Such deserts create a gap of life expectancy of 15 years and 8 years for men and women respectively between zones with high health supply and low medical supply[5]. On top of this, Emergency care providers and hospitals are overwhelmed, and their processes are slow due to unreasonable amounts of administrative work. Hence, in 2018, following the realisation that the healthcare system no longer met patients' expectations, fed the discontent of health professionals, was historically marked by profound organisational rigidities and was facing increasing financial tensions, Emmanuel Macron started a restructuring plan for 2022 called “Ma santé 2022 (My health 2022)”[6]. The main goal is to unite healthcare services to increase care providing efficiency and homogeneity. As an addition of the digital health policy efforts in place since 2010, this program was enacted as law in 2019 and aims to stimulate innovation in digital care provision. It is backed up by a digitally targeted investment program. The investment program started at 1€ billion in 2018 and will increase to 3.4€ billions in 2022. First, to tackle the discrepancies in French residents’ medical record, the ‘Dossier Medical Partagé’ [DMP], an Electronic Medical Record for all French residents covered by health insurance was adopted in 2018. Moreover, In February 2020, the ANS (operation managers of French health digitalisation) has published a technical policy framework for the e-health services and platforms foreseen by the new legislation[7], and that will serve as a basis for innovation. For instance, within this framework, a nationwide data platform called ‘Health Data Hub’ [HDH] was created. With more than 65M people’s health data, it is one of the world’s largest continuous homogeneous claim database aimig at facilitating healthcare big data sharing and exploitation in a secured way.

In the meantime, COVID 19 pandemic has posed an issue to French healthcare system in general, with access to healthcare greatly disturbed by overwhelmed hospitals and lockdowns. This further prevents

[1] Le ministère des Solidarités et de la Santé, 2021
[2] TRENTESSE, 2021
[3] French government, 2021
[4] Health Care & Long-Term Care Systems, 2021
[5] Déserts médicaux : L'état doit enfin prendre des mesures courageuses !, 2021
[6] Ma santé 2022 : mise en œuvre – Ministère des Solidarités et de la Santé, 2021
[7] GRAEVE, 2021

detection and observation of patients which both have dramatic consequences. For instance, the lack of medical observation for chronic diseases has increased their mortality of 100 person per day and over 15% of chemotherapies didn't take place during lockdown. Moreover, detection of cancers has fallen by 25% in the pandemic due to lack of routine medical visits. For instance, the number of mammograms as part of organised breast cancer screening between the ages of 50 and 74 has totally collapsed. In the Ile-de-France and Hauts-de-France regions alone, their numbers fell from around 14,000 and 9,000 respectively from mid-March to early May 2019 to zero during lockdown, leading to late detections but more serious cases[8].

II- Problem statement

Before the Pandemic, 45% of the French population felt like their health was threatened by the difficulty to access to medical care and it seems that implementation of the plan "Ma santé 2022" is compromised by a rigid legal and healthcare system. These rigidities lead to unreasonable waiting time to get appointments with specialists (above a year), lack of communication between doctors and high costs for the social security system. The primary reason for this inefficiency despite the government's efforts is that there is not one ubiquitous digitalised healthcare provision system that enables this procedure without the need of administrative interactions. These three challenges are currently hindering the digitalisation process:

1) Unique platform: There is no common standard of use of the health data hub, which creates complications in how patient data is passed between practitioners
2) Usage allowance: Patients do not interact with their data, leading to reticence to data usage and data usage is regulated by the European union.
3) Diversity: Medical practices' need for data and data usage varies from healthcare specialties

Despite these issues, online consultations have thrived since they were authorised in 2019, allowing more than 4,5M people to see a doctor despite the lockdown in April[9] . Moreover, it has some economic advantages as well since the e-health is estimated to generate from 16bn€ up to 22bn€ in 2025 compared to 7bn€ today[10]. E-health start-up creation has also risen with over 16 high potential e-health start-ups in Europe[11]. This growth potential strongly relies on exploiting health data and linking the e-health private offer and public offer. At present, there are several initiatives to unite the French healthcare system over a data cloud, which is hosted by Microsoft. This report will explore these initiatives in further details and provide recommendations on these initiatives, using the health data cloud technology.

What solutions are available for the French government to create a connected healthcare delivery in the next 5 years? How much can e-health reduce costs while delivering better healthcare?

Stake holders:

Due to the nature of the healthcare provision, this report will have three stakeholders:

- patients whose health depends on the quality of the healthcare system

[8] Cancers, infarctus, AVC... la double peine des dégâts collatéraux du Covid-19, 2021
[9] Plus de 4,5 millions de téléconsultations enregistrées en avril (Cnam), 2021
[10] [Etude] Le potentiel du marché de l'e-santé en France s'élèverait à 22 milliards d'euros, 2021
[11] E-santé: de la passion pour la médecine à la réalité du succès, il y a plus qu'un pas à faire! - FrenchWeb.fr, 2021

- providers whose care quality can be greatly improved by the development of a user-friendly healthcare data cloud.
- Since the French social security system reimburses the majority of health costs, governments can greatly benefit from the economies provided by a prevention policy rather than a caring policy.

Issues:

e-health is still a very new practice and much of the regulations as well as healthcare access and providing habits lack flexibility. Reticence and dangers of data usage is a known problematic and I plan to mitigate this by using persona and regulation analysis to understand the blockages. Moreover, I will focus solely on France since customer behaviour varies from country to country but the common regulations in the European union will allow a wider scaling of the solution.

Information available to solve the problem:

There is a lot of data available on analysing the benefits of my solution on costs savings and quality of healthcare provision. Since most healthcare institutions are public, monetary benefits can be analysed through the French government budget split, spending and data analysis that backed up the "Ma santé 2022" project. Moreover, many consultancy and scholarly literature cover the rise and potential benefits of e-health, especially in the context of the covid19 pandemic. In addition, Quid networks will allow me do conduct sentiment analysis on the adoption of this technology. Finally, as I base my analysis on the French healthcare system, language of the studies could be problematic, however, I am a French native speaker which eliminates this barrier.

The following report will aim to prove the following hypothesis

1- Cloud data sharing will allow a prevention rather than care approach to healthcare
2- Cloud data sharing will enhance the quality of healthcare providing
3- Cloud data sharing will cut down on cost for patients, governments and private doctors

III- Industry threats

Epidemiological transition

Over recent years, an epidemiological transition has started in France and globally. "Epidemiological transition" refers to the evolution of the dominant causes of mortality in a geographical area. In the past, in developed countries, mortality was mainly linked to infectious diseases; today, so-called "chronic" diseases are in the forefront. For instance, fifty years ago, the majority of deaths in the world were due to infectious diseases; today 70% are due to chronic diseases and this figure is still growing. The number of people declared to be suffering from long-term illnesses (ALD) in France has risen from 3.7 million in 1994 to 9.8 million in 201412. The ageing of the population, the quality of treatment for infectious diseases and earlier detection of these pathologies explains part of this statistical increase, but not all of it. Other factors have a direct impact, such as pollution, tobacco, alcohol, diet, lifestyle, the impoverishment of certain populations, sedentary lifestyles and so on. The trend is neither

[12] données statistiques et affection de longue durée, 2021

marginal nor relative to the distant future. The World Health Organisation predicts a 15% increase in deaths due to these diseases from 2010 - 2020. This epidemiological transition will require the health system to adapt in the short term to provide both qualitative (therapeutic research, quality of care, etc.) and quantitative (more data usage and online care investments) responses.

Ageing population

Another factor weighs heavily in the balance: the ageing of the population. In 2060, 11.9 million French people will be over 75 years old (twice as many as in 2007); those over 60 will represent 33% of the population13. These new patients will require special attention in primary care. In addition to their possible declared pathologies, the 4th age group is subject to specific illnesses and situations which can lead to irreversible deterioration in their state of health. Accommodation in an adapted structure alone will not be an efficient response to this evolution. Not only do most elderly people wish to stay at home as long as possible, but the lack of space and long waiting times will stop the process (if it is not already the case). Several initiatives have been launched in recent years to respond to this emergency, in particular the PAERPA programme (Elderly People at Risk of Loss of Autonomy). Experienced since September 2013. Its mission is to organise collaboration between the different actors (city professionals, hospitals and actors in the medico-social sector), but this program has not shown ability to efficiently transmit patient data, which makes the interaction between actors difficult.

Overwhelmed Hospitals

Due to medical desertification, for patients, getting a consultation in case of a medical emergency is sometimes a challenge. A survey carried out in 2017 for the Observatory on Access to Healthcare revealed that 60% of them said they had given up seeking treatment because of the difficulty of obtaining an appointment quickly; 46% of those surveyed put this renunciation on the cost of the consultation, and 32% mentioned the geographical distance of the doctor. Hence, more and more, patients are going to the emergency room because it is convenient. A change confirmed by the results of the DREES study: to the question "Why did you come to the emergency room? "61% of patients surveyed ticked the box "for accessibility to care"14.The same survey showed that out of 52,000 patients who went to the 736 emergency reception points on 11 June 2016, only 20% required hospitalisation; three quarters of the patients returned home because their condition was not a first resort15.

this systematic convergence towards hospital emergencies, leads to the following consequences on healthcare delivery:

- There is a bottleneck in the hospital services by patients who could be cared for in the city but chose the hospital instead. This causes the distress of the patients, who have to endure long hours of waiting, is then shared by overwhelmed care teams. Patients whose health is not considered in direct danger wait on average for 2hours before seeing a doctor during peak hours16.
- An increase in the number of procedures and examinations (another additional cost). It is currently estimated that a third of the procedures are unnecessary. The main cause of these redundancies is a break in the course of care which leads to the reproduction of examinations

[13] Résultats de la recherche | Insee, 2021
[14] Pourquoi le nombre de patients aux urgences augmente d'année en année, 2021
[15] Études et statistiques - Ministère des Solidarités et de la Santé, 2021
[16] CHPC - Délais d'attente des urgences en direct, 2021

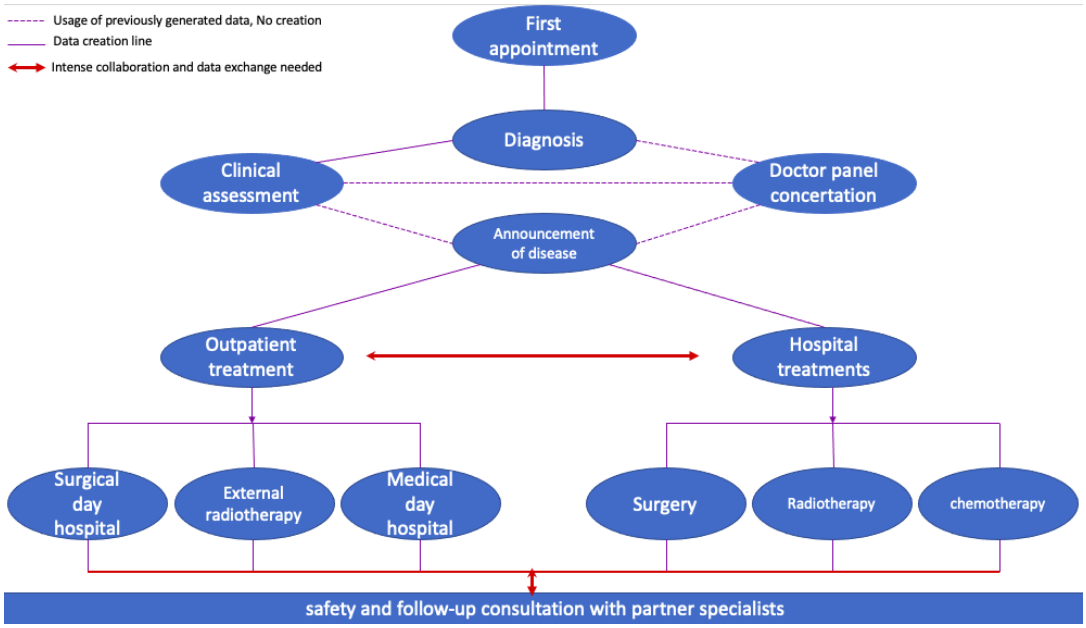
that have already been carried out; in particular when the patient goes to hospital alone, without being recommended by his or her GP17 and without having the history of his or her medical record.

IV- Medical caregiving system overview and processes

The healthcare delivery system

In France, the healthcare delivery system has three scales the “patient path”, the “care path” and the “health path”, ordered from the narrowest to widest definition. The patient path is defined as the care pathway within one health care institution, whereas the care path includes the care of a patient/user in which the actors of the hospital and outpatient health system are involved. On the broader range, the health path results from the coordinated delivery of health and social services to meet people's needs for prevention and care[18]. In its simplest form, healthcare delivery works by maintaining networks between healthcare providers (who provide care for their specialty), patients (who are healed by healthcare providers) and the social security (who reimburse the medical fees of the patient, given that his expenses have been ordered by a doctor). For example, patient A goes to his general practitioner B for a sore throat, B will charge an honorary fee and prescribe antibiotics to A. A will then pay the fee and pay for the antibiotics. Because A and B have declared their contact to the Social security, A will be reimbursed part of his expenses.

However, for chronic and long-term diseases such as diabetes or cancer, the number and nature of the interactions are much more complex.



When healthcare providers don’t have a direct connection, the procedure is longer, with various exploratory tests involving different services who each need to recollect preliminary patient data

[17] usefullness of medical acts, 2021

[18] Du parcours de vie au parcours patient : quelles différences entre ces notions? - Parcours Santé Coordination, 2021

without knowing the tests that have already been done. Each step adds an additional cost and opacity to the healthcare provision process.

Inefficiencies in the healthcare path personas

- Healthcare providers' experience

First, healthcare providers are faced with the incompatibility of their health data hosting softwares, even in the same region or town, which the greatest time consumers (35% of their time)[19]. For instance, in two of Paris' hospitals (Cochin and Pompidou) the softwares for exploiting patient data are respectively Orbit and DXcare. If a patient sees doctor A at Pompidou, does some tests and is advised to see specialist B at Cochin for better results, Doctor A and B will not be able to share their data efficiently because the softwares are not compatible. Hence, Doctor A will have to dictate the patient's data to doctor B who will enter it manually in its own software before treating the patient. "Sometimes, because the other hospital doesn't answer or because they have lost some data, we have to conduct a preliminary analysis or do tests such as X-rays on average 3 times and up to 5 times" says Arabelle, a student in Medicine who interned at Pompidou. This inefficiency is also observed from independent practitioners to independent practitioner and from independent practitioner to hospitals.

With those tasks goes the massive amount of administrative work. For instance, 35.22% of hospital jobs in France are neither medical nor paramedical, compared with 24.3% in Germany[20]. This is even more shocking bearing in mind that around 20% [21]of the administrative staff in French hospitals are in fact full-time nursing staff seconded to administrative work and that France has 2beds less per 1000 person than Germany[22].

Finally, the complex nature of French healthcare data limits the progress of clinical studies and diagnostic and France's healthcare providers are missing on enormous opportunities. For instance, France possesses on of the most complex and complete medical databases with over 500 medical datasets (Epidemiology data portal). This is a great asset, but in practice, they are too complicated to use on a daily basis for patient treatment with over 50 people needed to conduct one analysis[23]

- Patient experience

All of the above inefficiencies have a negative impact on patients' treatment. For instance, in 2016, 28% of further examination procedures are considered repetitive or useless[24] and the number of X-rays has gone up of 1M between 2017 and 2018 with no proportional growth of needs[25]. The multiplication of X-rays not only is time consuming for patients but also enhances the chances of cancer, for instance, children repetitively exposed to x-Rays multiply by 3 their risk of Leukaemia[26]. Moreover, epidemiology studies are a potential to increase the efficiency of treatment and diagnosis of chronic diseases.

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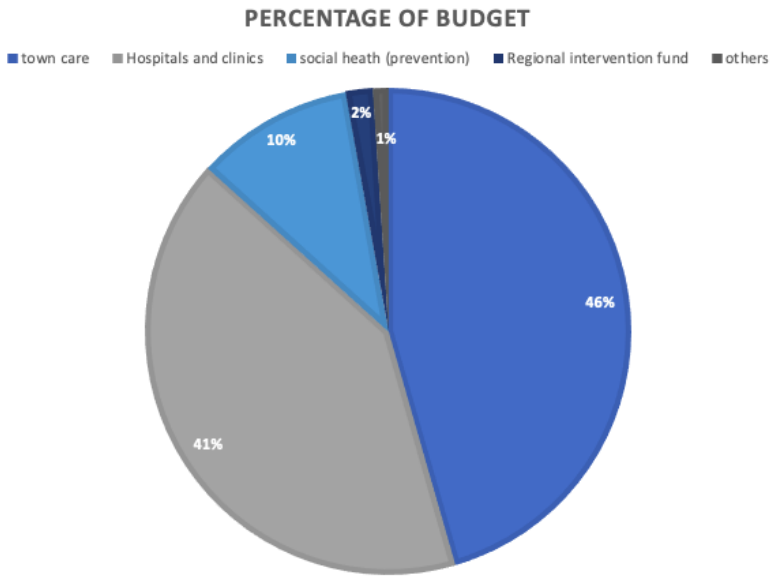
[19] Fact check : Y-a-t-il trop de postes administratifs dans les hôpitaux, 2021
[20] Fact check : Y-a-t-il trop de postes administratifs dans les hôpitaux, 2021
[21] Fact check : Y-a-t-il trop de postes administratifs dans les hôpitaux, 2021
[22] Fact check : Y-a-t-il trop de postes administratifs dans les hôpitaux, 2021
[23] Big data in health | Inserm - From science to health, 2021
[24] Améliorer la pertinence des soins : un enjeu majeur pour notre système de santé, 2021
[25] Améliorer la pertinence des soins : un enjeu majeur pour notre système de santé, 2021
[26] X-Ray Cancer: Know Your Risk and How You're Protected, 2021

- Cost to governments

This topic is even more important since France is the European country that uses the greatest portion of its GDP on healthcare (11%). However, France invests 0.6% of its GDP in new cloud technologies for hospitals, while Germany devotes almost double that amount and has twice as many nurses and 50% more doctors[27]. The cost of healthcare has more than doubled in 10 years and amounted to 208M€ in 2019, broken down in 97M€ for hospitals and 111M€ for ambulatory care which encompass medicaments, medical transports, town care and other medical goods[28]. Of these costs, 78% are financed by the government, with only 22% to be paid by mutual insurance companies and patients. Reducing costs is a key point for the government as the increasing costs already participated to 30% of the 5Billion€ deficit of the social security in 2019, in 2020, with the Covid-19 sanitary crisis, the deficit was of 44,7billion€[29].



V- Current in healthcare provision case studies

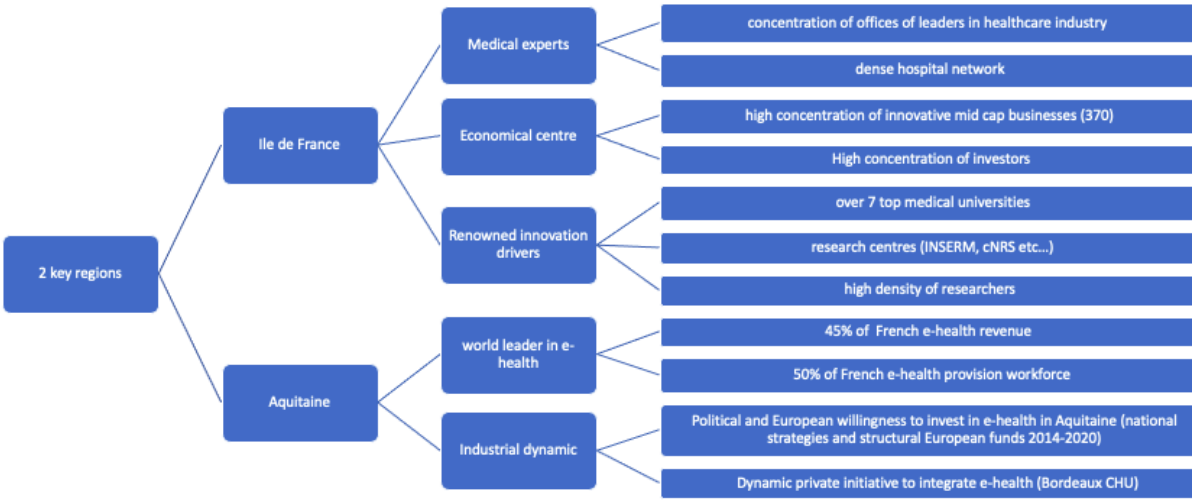
Whilst there are many solutions in the space of e-health at present, they are not linked. After identifying 2 key regions, we will focus on the newest, most technologically advanced and complete solutions on these areas.

Why Ile-de-France and Aquitaine?

[27] Le problème du système de santé en France n'est pas le manque de moyens, 2021

[28] (Les dépenses de santé en 2019 - Résultats des comptes de la santé - Édition 2020 - Ministère des Solidarités et de la Santé, 2021)

[29] Social Security Financial Report" 2021



- Description: i2b2

Informatics for Integrating Biology and the Bedside (i2b2), an open-source clinical data analytics platform, transforms patient data aggregated from the electronic health record (EHR) into a format optimized for various types and stages of research, including feasibility analysis, study design, eligibility criteria, cohort identification and recruitment, and population health studies[30]. Currently, over 200 institutions worldwide use i2b2 to query patient data. Amongst them, The CHU hospital of Bordeaux that takes advantage of his data from the 1,6M patients who were treated there from 2010 to 2016, which consist in more than 1BN information. Information varies from a hospitalisation report to biological test results. For instance, their software allowed to identify a second wave or a resumption of the Covid-19 pandemic and to monitor the hospital load and even anticipate it by monitoring the seriousness of symptoms, age of patients[31], etc…

- Assessment

This software is a model example of how healthcare data can be processed and stored on a cloud. However, several limitations make it less suitable for national adoption. First, significant development effort is needed to implement i2b2 features and integrate new clinical data elements into the platform. As this requires work from skilled programmers, return on investment is less likely to be significant. Secondly complex data is harder to fit into the platform leading to simple queries which limit the rentability of the investments needed to implement the tool since these queries do not facilitate research. Thirdly, this tool does not allow communication between independent specialists and hospital services because it only stores the data of care given to those who were admitted to the hospitals. Finally, it does not link the patients to doctors so it does not tackle the problem of accessibility of medical care. Hence, i2b2 would have to conduct a more user driven approach to extend the usability of its value proposition on a day-to-day basis[32] for doctors, facilitate data transmission between independent doctors and hospitals as well as allow online interactions with patients.

[30] Sanz, 2021

[31] "Comment Le CHU De Bordeaux Utilise Son Entrepôt De Données De Santé Pour Surveiller L'épidémie De Covid-19" 2021

[32] Evan T. Sholle 2021

- Description: Doctolib

Doctolib is the leader in online booking medical appointments booking and teleconsultation. It has a network of 140 000 doctors and hospitals who use its services to optimise their schedule and allows 70M visits per month in France and Germany[33]. It has started a sharing system between doctors and patients. Doctors can share prescriptions on the app and patients can send any useful record of medical history to their doctor. This allows online consultations to be more efficient and medical history to be kept. Moreover, doctors can recommend patients to other specialists via the app, thus eliminating the struggle to find a specialist that accepts new patients. The service is widely accepted by the government since it has been chosen as the primary coordinator of appointments for Covid-19 vaccination.

- Assessment

This service greatly enhances the access to healthcare, both in hospitals and with private town doctors. However, the data sharing process ability seems insufficient as it is only destined to be shared on a one-to-one basis between patients and the doctor they have an appointment with. Hence, patients have to upload their documents every time they see a new doctor and there is no patient dataset enabling epidemiological research. Moreover, this app poses a question of cyber security. In fact, as healthcare data is one of the most wanted data with 340% more than in any other industry[34] and the App has been hacked in July 2020. This led to the theft of data from more than 6000 appointments and occurred via softwares who connect to Doctolib to integrate this service in their own services.

VI- Interim recommendations

Following the previous analysis of the inefficiencies of data sharing for healthcare delivery and the shortcomings of some of its solutions, it is recommended that the government looks into an alternate method to data sharing. In order to keep up with the growing needs in this area, investing in the following areas with the funds provided by the “ma santé 2022” program is recommended:

1) Improving access to existent datasets such as the health data hub and the “dossier médical partagé” which are unused available resources from over 45M patients.
2) Allowing an instant update of these datasets from all healthcare actors after a consultation to create a complete transcript on patient’s healthcare path
3) Allowing an online interaction of patients and healthcare providers, either to update patient data or to send documents to enhance the quality of online consultations.
4) Performance trials with already existent softwares and online healthcare providers such as Doctolib and Philips FORCARE.

VII- Medical cloud computing

As seen with the industry challenges stated previously, cloud technology innovations have become a priority in French healthcare. In fact, its multiple use cases can connect, automate, decrease

[33]"Doctolib | Construire Le Système De Santé De Demain" 2021

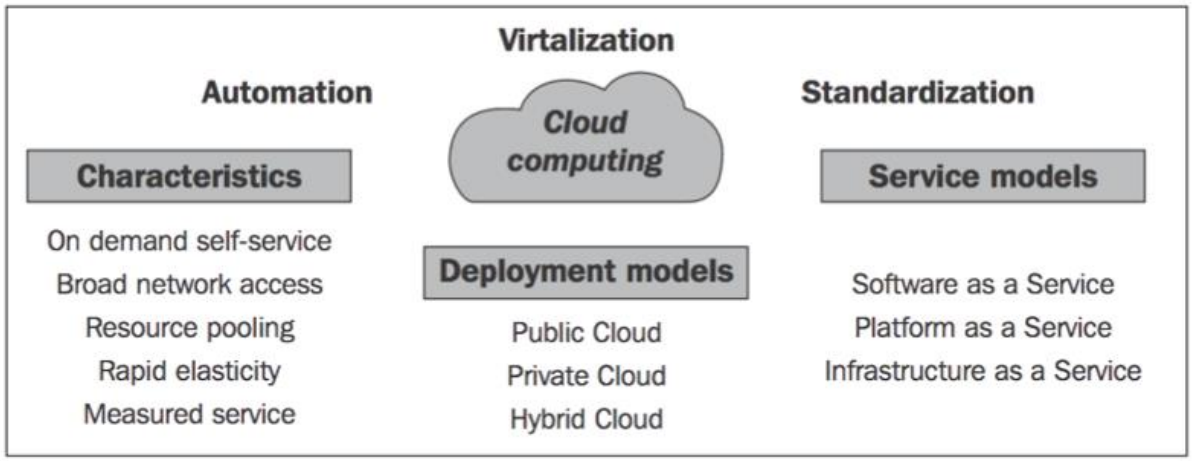
[34]"2017 Global Health Care Sector Outlook" 2021

complexity and increase transparency in many processes. Amongst these use cases patient data sharing is considered the most impactful. The French government has indeed already started its healthcare transformation with the “Dossier medical partagé” and “Health data Hub”. On the 13th of October 2020, the council of state has ruled that the “Health Data Hub” could continue to work with Microsoft’s AZURE cloud if they strengthened the protection of the rights of data subjects over their personal data and take special precautions, all of this chaperoned by the CNIL (French data privacy institution)[35].

How does Cloud computing work in healthcare?

According to the NIST (National Institute for Standards and Technology), cloud computing is a computing model that provides "on-demand and easy access to a set of configurable resources (network, processors, storage, applications and services) that can be provisioned and released with minimal effort for provider interaction”. It is therefore composed of 3 ingredients:
- an ERP (Enterprise Resource Planning) to manage customer relations and the catalogue of applications that the user can deploy in the cloud
- a deployment model (how and on what types of processors the applications are deployed)
- storage and computing nodes, i.e. a hardware infrastructure.

From an overall point of view, the cloud is composed of five essential characteristics and is based on three service models (SaaS, PaaS and IaaS) and three deployment models (private cloud, public cloud and hybrid cloud).

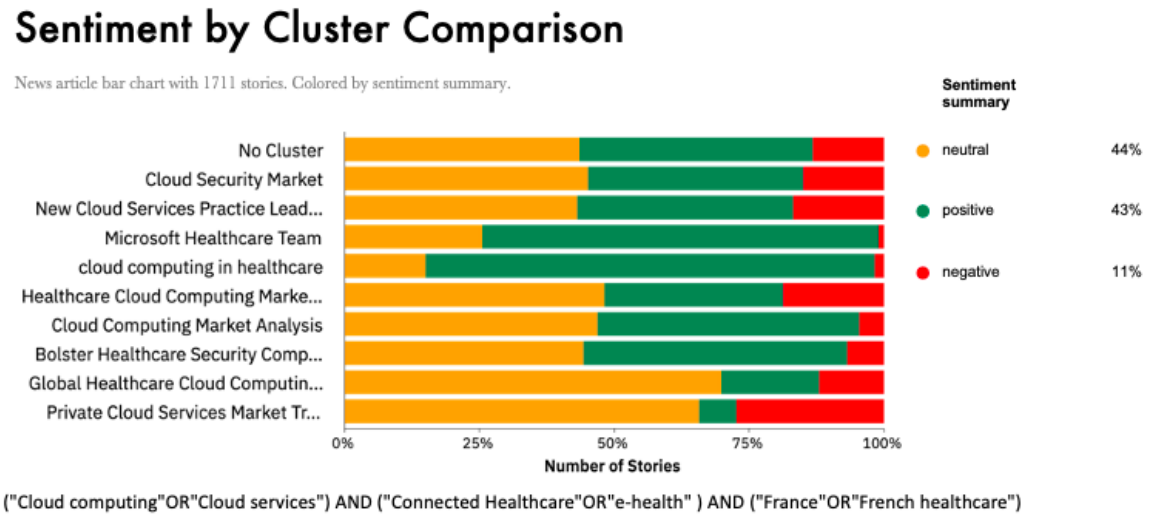


A common misconception is that cloud computing is a single technology. However, its 3 service models make it highly adaptable to one’s needs.
• SaaS (Software as a service) consists in the licensure of a software to the customer and are constructed on a “pay-as-you-go” business models. Ex: Microsoft office 365
• PaaS (Platform as a Service), the most complex of the three shares similarities with SaaS but in this configuration, the cloud provider provides organisations with a rapidly available runtime environment, leaving customers in control of applications that they can install, configure and use themselves. Ex: Salesforce and Heroku.
• IaaS (Infrastructure as a service) is a service where the cloud provider delivers everything from operating systems to servers and storage through IP-based connectivity as part of an on-demand

[35] "French Court Ruling: EU Health Data May Be Hosted On US Companies’ Clouds | Digital Watch" 2021

service[36]. This allows clients to avoid the costs of purchasing software or servers but instead outsource these resources. Ex: Microsoft Azure, IBM cloud.

Utilising these technologies, cloud computing is able to provide data interoperability and to put all actors in the health path of an individual on the same level of knowledge. The adoption of the Microsoft Azure IaaS will evidently provide an incentive to private actors as it is accompanied by a set of data privacy regulations that created a framework of utilisation of patient data.



Cloud computing is widely encouraged as seen from the sentiment analysis above. Developing cloud computing will therefore lead to the following benefits, which we will further explore in part II:

(1). Sharing data facilitates secure collaboration of healthcare actors and access to real-time healthcare data anytime, anywhere. (2). In addition, while there are still security and privacy challenges to be tackled, cloud computing providers work every day to make their services unbreachable, a capacity that private hospital software struggles to maintain. (3). Moreover, cloud computing could reduce costs linked to the lack of transparency in the healthcare system but also those linked to inhouse infrastructural costs by using IaaS. (4). Cloud computing also allows an unmatched speed in updates and access to information, which can suit the demand of industry stakeholders and patients (clinical trials, waiting time, repeated diagnosis and tests, costs, etc…). (5). Finally, cloud computing provides hassle-free scalability and flexibility to always evolving medical records data collection (connected health objects, mobile apps, patient portals, etc…).

[36] "How Cloud Computing Works" 2021

VIII- Interim conclusions

To conclude, it is evident that the French healthcare system suffers from deeply rooted inefficiencies in data usage. Private start-ups and software development firms have already begun to tackle these inefficiencies but there is no link allowing to take advantage of such innovations. This leaves healthcare providers with semi-efficient solutions for worrying threats. In order to combat these threats cloud computing implementation is being explored and there is a drive for creating a French-made solution. It is vital that the DGOS make complete use of the country's many resources of data, innovative companies and regulating power.

Further insights on security and efficiency of cloud computing will aid the DGOS in understanding how cloud computing can be applied to their data sharing system and how it can be further adapted to current solutions. With the current rise of online medicine, need of epidemiological research and business of hospitals, such an adaptation will prove to be popular to all three stakeholders.

Hence, Part II will use data analysis and build a practical case study of a solution to provide more insights on the challenges of the usage of cloud computing and the benefits it engenders.

Appendices

What is telemedicine ?

It is a medical practice using information and communication technologies. It connects healthcare professionals to each other or to patients online. Since 2010, 5 telemedicine acts are recognized in France:

Teleconsultation: this is the remote consultation of a medical professional using information and communication technologies. It can be a general practitioner or a specialist.

Tele-expertise: this allows a health professional to seek the advice of one or more medical professionals at a distance via information and communication technologies.

Telemonitoring: telemonitoring allows a medical professional to remotely interpret data collected automatically at the patient's home, in particular.

Tele-assistance: it allows a healthcare professional to remotely assist another healthcare professional during the performance of a procedure (for example, during a surgical procedure).

Regulation: this is the medical response provided within the framework of the 15 (Samu) activity.

According to a MACSF study, nearly 3 out of 4 physicians believe that telemedicine will be part of their daily lives in 2030. In 2022, the objective is to have 1.4 million teleconsultations supported.

Understanding the French social security

Social protection is the set of support measures that enable each individual or household to cope throughout their lives with the consequences of the occurrence of a risk or social need.
These social risks may cause a loss of income or an increase in expenses for some.
All of these support measures encourage activity and contribute to the preservation of the human capital of the French people.
In France, social protection is based on two main principles of action: professional solidarity and national solidarity.
Because of its level of intervention, Social Security is the heart of French social protection.

Social protection offers 3 forms of response to social needs and risks.

- Monetary benefits paid directly to households and individuals (e.g. reimbursement of care, retirement pensions, family allowances, unemployment benefits, etc.).
- Services complementing monetary services and allowing access to services provided at reduced prices or free of charge. (e.g.: financing of crèches, hospitals, online services...)
- Prevention to promote behaviors useful to one's health, autonomy, family...

Social Security provides first-level coverage for social risks for all French citizens.
At the heart of the social protection system for more than 70 years, it is the "guarantee given to everyone that in all circumstances they will have the necessary means to ensure their subsistence and that of their family in decent conditions" (Explanatory memorandum to the order of October 4, 1945 creating the Social Security system).

The Social Security system protects French citizens against the following risks:

- Sickness: sickness / maternity / disability / death
- Old age: retirement / widowhood
- Family: childhood and youth
- Occupational illnesses / Accidents at work

It is the largest budget within social protection: 477 billion euros have been redistributed by Social Security in 2016 out of the 758.7 billion euros of resources collected for social protection. This represents about 1.5 times the state budget.

The public social security service is made up of more than 400 organizations and 176,000 employees throughout France to support French people throughout their lives.
Social Security brings together a number of players. These include all the Cpam, Caf, Urssaf and Carsat organizations. It is also made up of specific schemes such as the MSA for farmers or special schemes for other professional categories. Other organizations also come to compose it. This is the case of the Ugecam, computer centers, and specific national centers (CESU, Pajemploi, etc.). All of these players are attached to national Caisses, which manage all the networks on the national territory.
Social Security is a redistributive system. Each scheme is made up of bodies responsible for redistributing the contributions and levies collected by them to cover people residing in France.

The “dossier medical partagé (DMP)”

The National Health Insurance Fund (CNAM) implements the DMP. It is created online by the patient, for whom it is a simple faculty and who gives his or her express consent (article L. 1111-14 of the Public Health Code (CSP)) and he can set those who have access to its modification. Moreover, the patient has the possibility of making certain information inaccessible, except to the attending physician, subject to the patient's agreement (article L. 1111-16 of the CSP). The liability of the healthcare professional is excluded in the event of a dispute concerning ignorance of information that was concealed from him/her in the DMP and of which he/she could not otherwise have been aware.

The DMP contains:

- diagnostic and therapeutic elements necessary for the coordination of care, for each act and consultation
- summary of the main elements relating to the patient's stay in the care facility
- periodically and at least once a year, summary by the attending physician, the content of which will be defined by the High Authority of Health
- data necessary for the coordination of care resulting from the procedures for reimbursement and coverage by the patient's health insurance agency
- data relating to the dispensing of drugs, from the pharmaceutical file
- organ or tissue donation, advance directives and trusted person components.

Who has access to the file no matter what ? (Articles L. 1110-4 and L. 1111-7 of the CSP)

when the patient is subject to a legal protection measure, the person in charge of this protection under the conditions set out in article 459 of the Civil Code may access the elements of the medical record under the same conditions as the patient himself. Moreover, the right of access to the file of a deceased person, previously limited to "heirs", is extended to "heirs and his heirs' heirs, his spouse, his cohabitee or his partner bound by a civil solidarity pact". Finally, in the event of the death of a minor, the holders of parental authority retain, without any obligation to give reasons, their right of

access to the entire medical file, with the exception of those elements of the file relating to medical decisions for which the minor, where applicable, has opposed obtaining their consent.

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Utilising cloud computing technology to improve the data interoperability of French healthcare delivery participants

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Executive summary

This report details the potential of Cloud computing models that are available (private, public and hybrid) and the benefits of each models with respects to the efficiency of the French healthcare system. This is done via a case study of a key region for healthcare distribution in France. The report also explores the main providers, their performances, and their pricing. The cloud provider is inherent to the global strategy that will further be developed in France and it is therefore important to study their specificities in depth to conclude on potential improvements other later-on after the adoption of the cloud solution. The three different providers studied were google, amazon and Microsoft.
The report has narrowed down the focus of cloud adoption since France is not developed equally on every region which would hence complicate the report to the point that the main argument would be blurred into the territorial specificities. The result from the study indicates that a hybrid cloud adoption would be beneficial for Bordeaux's CHU on all levels thanks to a cost-benefit analysis.

Executive Summary

I- Introduction

Part I of this report identified the need to improve the efficiency of the French healthcare data sharing system and introduced cloud computing. Part II explores the key to cloud computing adoption and the types of cloud technologies that have developed since the technology's inception. It begins to explain a few associated methods of data sharing and provide a recommendation for the DGOS's course of actions into exploring the link between already existing solutions.

Part I set out three Hypotheses:

1. Cloud data sharing will allow a prevention rather than care approach to healthcare
2. Cloud data sharing will enhance the quality of healthcare providing
3. Cloud data sharing will cut down on cost for patients, governments, and private doctors

The DGOS's position has been addressed based on its depending entities' current capabilities, their abilities to execute and their current cloud progress. This highlighted a lagging position in cloud computing exposure despite large resources of data, as well as the necessity to implement such technologies.
Based on this information, the remainder of the report investigates three different methods of cloud computing and provides a comparison between the different providers of such clouds. The report then applies and builds the selected cloud on Aquitaine, more specifically the Medical group (CHU) of Bordeaux. Subsequently, an analysis of the benefits, including cost-benefit analysis is conducted. The report is unable to give a true case for hypothesis 1 and 2 due to lack of quantitative evidence on the quality of healthcare provision and the healthcare approach.

II- Keys to Cloud computing adoption

An issue surrounding Cloud computing utility for healthcare interoperability is the complex nature of the data that is ranging from images (ex: radiography), text reports (ex: prescription) or numerical data (ex: blood pressure). Moreover, it requires a widespread adoption to achieve its job to be done. If too few hospitals and private doctors operate under the same system (as it is the case today), interoperability is limited. To ensure scalability and efficiency, there are two key factors that have already started to be put in place:

- Joining the network should be an easy experience, with a simple and efficient "plug-and-play" joining process. This is in the process of being feasible with the Health data hub being stored by Microsoft and the use of Microsoft Azure clouds.
- Common (technical, governance and compliance) standards must be established. This is also in process since the DGOS is currently building a law framework for Digitalised heath.

There are many different types of clouds and in those subcategories, several companies operate, which, must be taken into consideration as it might recreate the interoperability problem stated in part one with a new technology. Moreover, there are a variety of independent e-health actors and this market is flourishing with new start-ups that could

benefit from the health data as well as participate to its construction[1]. Data complexity and data privacy rules are the main areas that main hinder interoperability between systems[2]. Common standards are therefore crucial for national adoption; the DGOS being a governmental institution, it is in power to rapidly influence and build the legal framework of cloud computing and data sharing integration. The DGOS must collaborate with the entirety of the ministry of health as they will pave the way that will allow innovations to develop.

III- What are the types of cloud computing?

A) Cloud deployment models

In part one we have explored the different types of cloud computing services and quickly browsed on the deployment models. However, cloud computing is often only differentiated with its services rather than with its deployment model, but it is the deployment model that truly influences the feasibility and implementation of a new cloud[3]. The three deployment models are Public, Private and hybrid. All three abstract, pool, and share scalable computing resources across a network. Every cloud type also enables cloud computing, and all cloud is created using a mix of an operating system, management platforms and application programming interfaces (APIs). One can also add Virtualisation and automation software to add capabilities and increase efficiency[4].

Public clouds

Public cloud refers to a cloud computing model in which IT services are delivered via the internet. It is the most popular of all three clouds because of its defining features of elasticity and scalability as well as a low-cost subscription. The computing functionalities of Public clouds range from common services such as emails, apps and storage to infrastructures for software development testing. Public cloud is therefore most suitable for environments with predictable computing needs (communication services for a specific number of users), for apps and services linked to business operations, as an additional resource requirement to address varying peak demands and for software development[5]. The main advantages for public clouds are:

- The cloud adopter does not need to deploy nor maintain the infrastructure which greatly reduces the capital expenditures
- Public clouds are also highly scalable and allow users to comply with unpredictable demands.
- The public cloud is entirely managed by the cloud provider, therefore requiring minimal IT knowledge and expertise.

[1] Cloud Computing in Healthcare: The Complete Guide | True North ITG, 2021

[2] Appendix 1

[3] Cloud Deployment Model - an overview | ScienceDirect Topics, 2021

[4] types of cloud computing, 2021

[5] what is public cloud, 2021

- Because Public clouds are so flexible, they offer a pay as you go option which makes prices more adjustable to the needs and therefore limits unnecessary costs.
- Because the public cloud allows cost agility, it helps organisation follow a lean growth strategy and to focus investments on innovative projects.[6]

However, Public clouds come with drawbacks such as the lack of cost control as the total cost of ownership can rise exponentially with the computing necessities of businesses. Public clouds are also by nature, the least secure clouds, which is an issue considering we are aiming at storing highly sensitive and attacked medical data. Public cloud users also lack visibility and control on the infrastructure, and it may not need compliance needs.

Private clouds

Alternatively, private clouds are a solution dedicated for one organization, meaning that users do not share the cloud resources with another organisation. The data centres for the cloud are secured and delivered via a secure private network. It is customizable to meet businesses' needs of capacity and security, leading to greater visibility in the structure of the cloud, making it more compliant with highly regulated and sensitive environments[7].
The main advantages of the private clouds are:

- Private clouds allow to work in exclusive environments that are dedicated to the customer only and therefore cannot be accessed by third parties.
- Private clouds also provide high security due to their exclusive character. This leads to easier conforming to regulations as it is possible to run protocols and customize security and privacy based on the customers' unique requirements.
- The unique and custom aspect of the private cloud makes him a great partner for customers with high scalability requirements but who cannot afford to loosen the security of their data.
- Private clouds usually offer high SLA performance and efficiency[8]
- As a private cloud is unique, it is very flexible to modify and transform structurally according to customers' needs. They can adapt to rapidly evolving businesses that have to adapt to changing business workflows

However, private clouds are expensive and have a relatively high total cost of ownership compared to public clouds. Private cloud solutions are also harder to use by mobile users since they must comply with higher security requirements. Lastly, private clouds are more rigid to unpredictable demands as they can lack scalability, especially when the cloud data centre is limited to on premise computing resources.

Hybrid clouds

[6] Leffingwell, 2021

[7] what is private cloud, 2021

[8] Public vs Private vs Hybrid: Cloud Differences Explained, 2021

Lastly, there exists hybrid clouds. A hybrid cloud functions as a single computing environment created from multiple environments connected via local area networks (LANs), wide area networks (WANs), virtual private networks (VPNs) and/or APIs. The characteristics of hybrid clouds are complex, and the associated requirements may vary depending on the user who defines them. For example, a hybrid cloud may include at least one private cloud and at least one public cloud; at least two private clouds, at least two public clouds or even a bare or virtual environment connected to at least one private or public cloud[9]. Note that any IT system becomes a hybrid cloud when applications can be moved between separate environments that remain connected. Some of these environments, however, must be fed from consolidated computing resources that can scale on demand[10]. In addition, all of these environments must be managed as a single environment, using an integrated management and orchestration platform.

The hybrid clouds offer the following advantages:

- Hybrid clouds present as a policy driven option. Indeed, they can distribute data through public and private structures based on required security and performance of data sharing and analysis.
- Hybrid cloud users also see the advantage of scaling securely their cloud system. Sensitive data capacities can be scaled up on the private cloud while the rest can be easily scaled up on the public cloud.
- Reliability is also a key advantage of Hybrid clouds. Indeed, they rely on multiple data centres spread out between public and private which also diminishes the risk of cloud incapacitation.
- Finally, Hybrid cloud still allow cost control. Indeed, costs are optimized since only the sensitive data is stored on more expensive private clouds while the rest of the data can be managed on a public cloud with less security. Hence, the legal framework is respected while keeping some flexibility in cost control.

However, hybrid clouds are not the miracle solution, they have an unpredictable or hard to manage price since they juggle between public and private clouds. Moreover, they are difficult to manage and require strong compatibility and integration of all infrastructures, spanning across different locations. This makes direct control harder over the infrastructure. Lastly, it can easily generate added complexity in organisation as they operate and manage an evolving mix of private and public cloud

B) What type of deployment model for healthcare?

The DGOS must decide between the options enumerated above. However, at first glance, it seems that hybrid cloud's benefits seem to supersede those of public and private clouds.

[9] Cloud Computing in Healthcare: The Complete Guide | True North ITG, 2021
[10] Corso, 2021

Indeed, by relying on the hybrid cloud, the healthcare sector not only could meet the challenges of security and compliance, but also gain flexibility and better manage its IT expenses. Indeed, hybrid cloud is on the road to be the dominant deployment model in healthcare as it is expected to increase from 19% today to 37% within two years. The sector ranks third in terms of the number of hybrid cloud deployments underway across all industries[11]. According to a cloud index study of 2300 health IT professionals, more than 28% of respondents said that security and compliance were their top decision criteria when choosing where to run their workloads[12]. Hackers targeting medical records containing personal data, such as patient healthcare and insurance information, are particularly challenging hospitals and vendors to provide technology solutions that can manage the movement of sensitive data while mitigating risk. Moreover, more than half of respondents also said that cross-cloud application mobility was 'critical', demonstrating the need for the ability to seamlessly migrate applications, associated data, network services and security policies between different cloud types. Hybrid cloud deployment models' innovations could allow hospitals to manage different types of applications and data, leverage automation and create new service lines, such as telehealth or remote monitoring, enabling better patient care[13]. According to the same study, while 88% of respondents said they expect the hybrid cloud to have a positive impact on their business, hybrid cloud skills are in short supply in IT departments. Talent with these skills ranked second only to artificial intelligence and machine learning.

In addition to assessing the type of deployment model best suited for healthcare, it is necessary to dig in the service models that can compose a hybrid cloud. [14]

Infrastructure as a Service (IaaS)

IaaS is the lowest level of cloud solution and refers to cloud computing infrastructure as a fully outsourced service. An IaaS provider will provide pre-installed and configured hardware or software via a virtualised interface[15].

Benefits of IaaS solutions:
- Reduces total cost of ownership and capital expenditure
- Users pay for the service they want, on the go
- Access to enterprise-class IT resources and infrastructure
- Users can scale at any time according to their needs

Platform as a Service (PaaS)

This type of cloud computing is similar to IaaS but more advanced. With PaaS, providers offer not only an infrastructure, but also an IT platform and a solution stack as a service. The

[11] Le cloud hybride dans la santé va doubler d'ici deux ans, 2021

[12] Azumah, Tadayoni and Sørensen, 2021

[13] Nutanix Enterprise Cloud Index, 2021

[14] cfaafia, 2021

[15] What is IaaS? Infrastructure as a Service Definition, 2021

computing infrastructure may have a graphical user interface, runtime system libraries, programming languages or an operating system.
PaaS services are mainly used by companies that need to develop, test, collaborate and deploy cloud solutions for particular applications. However, the hosting of the application is done by a third party, namely the PaaS provider[16].
PaaS providers offer customers a fully configured deployment and sandbox environment to develop, test and deploy their cloud applications.

Benefits of PaaS solutions

- Community - Most of the time, many people are involved in building cloud applications in PaaS environments. This creates a strong support community that can help a development team throughout the process.
- No more upgrades - Companies are not required to update or upgrade the infrastructure software. Instead, the PaaS provider manages all upgrades, patches, and routine maintenance of the software.
- Reduced costs - Businesses are less exposed to risk because they don't have to invest in hardware and software upfront.
- Simplified deployment - The development team can focus on developing the cloud application without having to worry about the testing and deployment infrastructure.

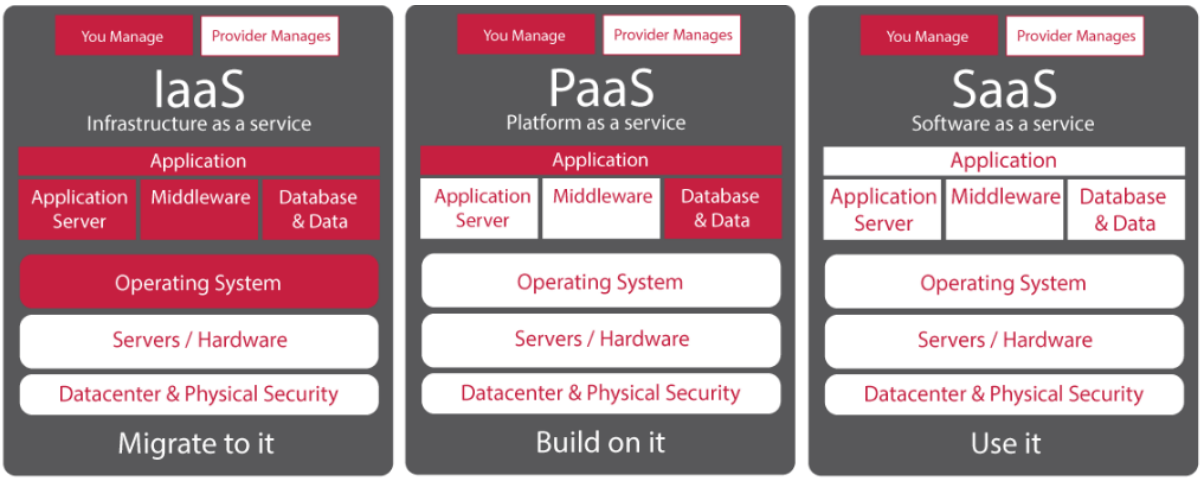
Software as a Service (SaaS)

When talking about cloud services, most people think of software as a service (SaaS) provider. SaaS providers deliver fully functional web-based applications to customers. The applications are mainly aimed at business users and can include, among others, web conferencing, ERP, CRM, email, time management, project tracking[17].

Advantages of SaaS solutions:
- Eliminates infrastructure issues
- Customisation of service offerings
- Bundled maintenance and support
- Rapid scalability

[16] Qu'est-ce que la Plate-forme-as-a-Service (PaaS) ?, 2021

[17] What is SaaS (Software as a Service)? Everything You Need to Know, 2021



[18]

C) Recommendations

Whilst there exist other cloud services, this section highlights the most used ones for all types of cloud. the graph above illustrates how IaaS, Paas and Saas are integrated in the hybrid cloud. The hybrid cloud solution recommended to the DGOS is composed of IaaS and PaaS for the private entity and SaaS for the public entity of the cloud.
This configuration will let the healthcare services benefit from the freedom and flexibility advantages of all three service, while limiting the cost and management drawbacks of services like IaaS and SaaS.

IV- Narrowing the focus

The previous two sections discussed the different kind of cloud services and development models available for healthcare data management. It concluded that a hybrid cloud would be the best solution given the complexity of the data and the mobile access requirements. Given the complexity of implementing a hybrid cloud in the entire French healthcare system and the disparities of healthcare technological development around the French territory, I decided to focus on the region Nouvelle Aquitaine. In part one, we have highlighted that it was one of the key French regions of e-health. Let's now explore further its capabilities and suitability for hybrid cloud implementation.

Bordeaux and more broadly, Aquitaine, are the leading French region for hospital IT with 1,200 jobs and 50% of national turnover in that sector. Indeed, there exists a multitude of actors promoting the growth of connected health and nourishing the e-health start-up ecosystem. In fact, E-health companies and start-ups shine through innovation and the development of cutting-edge technology. Among these start-ups, BforDoc improves the

[18] Les différents types de cloud computing, 2021

patient's care by preparing the consultation, Nomadeec which is a mobile telemedicine platform or Synapse which uses artificial intelligence to help doctors prescribe medicines. Bordeaux is also represented by companies such as Interaction Healthcare/Simforhealth, a Bordeaux-based company specialising in the design of digital applications for patients and health professionals. The company has supported more than 22,000 healthcare professionals worldwide. It is one of the 2 000 most innovative companies in France[19].
These startups could not have developed without a strong will from the regional institutions to promote e-health development. Indeed, the Nouvelle-Aquitaine region participates in the creation of these e-health start-ups by supporting them via numerous organisations and incubators. For example, ESEA is an organisation that responds to the challenges of improving the quality and coordination of care and patient care. The organisation is linked to the GRADes (Groupement Régional d'Appui au Développement de la E-santé = Regional group for the development of E-health) which ensures the development of E-health in New Aquitaine.

The main missions of the ESEA are:

- Supporting and promoting the use of digital technology in health care for independent health professionals, health establishments, social and medico-social establishments, and users in the region.
- Patient orientation.
- Coordination of the health care pathway.
- The sharing and exchange of health data in a standardised and secure framework
- The development of cooperation and partnerships

In addition, the New Aquitaine region benefits from European funding to support digital transformation via the ADI (New Aquitaine Development and Innovation Agency). Among the various sectors of activity supported by the ADI, e-health is a key issue[20].
The Aquitaine region has also launched a broadband programme to facilitate mobile networking and data sharing throughout the region. The New Aquitaine region has invested 230 million euros to develop a public fibre optic network where private operators do not go. This allows the development of telemedicine, remote monitoring to ensure medical follow-up, remote assistance to help another health professional, or teleconsultation. This has been done in order to ensure the quality of care even at a distance or for people with limited mobility. To this end, fibre optics have already been installed in more than 600,000 homes by 2021 and the region is aiming for 100% broadband by 2030[21].

Hence, with a dynamic innovative e-health environment along with participations from the regional institutions, Aquitaine seems to be the perfect environment to develop our cloud solution. Indeed, not only will the implementation be facilitated by the technological capabilities of the region, but the e-health start-up will also be able to benefit from the cloud's data. Moreover, the Aquitaine region also benefits from the Dossier Médical Partagé (DMP)

[19] E-health, the key business sector | BORDEAUX Business, 2021

[20] Bordeaux, 2021

[21] Béteille, 2021

that we talked about in part one, that will already allow a basis for hosting patient data. This is a great advantage as creating their own patient data platform and providing the services that the start-up ecosystem prides today would require a significantly greater amount of cost and efforts. This way, Aquitaine has the perfect set up to provide a public cloud centre while leaving some of the expanses and work to private sectors.

V- Hybrid cloud platforms

Hybrid cloud is not limited to healthcare data and has a broad range of applications across practically every industry. As a result, whilst many hybrid clouds have been created, they are all tailored to the company or industry's needs. However, a lot of them rely on common cloud providers. The following section provides a comparison of the main cloud providers with whom to build our hybrid cloud: AWS, Microsoft Azure and Google cloud.

Computing capabilities

Amazon Web services: The Amazon Elastic Compute Cloud service provides scalable computing capacity in the cloud. It provides good flexibility of use and offers a very wide range of services.

Microsoft Azure: Azure Virtual Machines provides virtualisation capabilities for a wide range of cloud solutions, including development and testing, application execution and data centre expansion

Google cloud platform: Google's Compute Engine solution offers outstanding performance in terms of VM start-up times. While the range of services is not the most extensive, Google's pricing is very competitive.

All three major cloud players offer the ability to automatically adjust the number of VMs based on demand in order to maintain a high level of performance while keeping costs down. In terms of VM performance, Google has a very high bandwidth and slightly better VM start-up time than its competitors[22]. The number of virtual machine templates available is comparable with Microsoft Azure and Amazon (around forty for each). For its part, Google offers 18 different templates[23].
The compatibility of the three players with the various operating systems and databases is very extensive. However, there is a slight advantage for Amazon, which - unlike its competitors - supports the CloudLinux OS and the MariaDB database...

➔ In terms of VM performance, Google Compute Engine stands out with a very high bandwidth.

[22] (2021)

[23] Comparatif 2020 des services de Cloud, 2021

Storage capabilities

Amazon Web Services: Amazon's Simple Storage Service has extensive documentation. On the archiving side, specific options can be found in the Amazon Glacier offering.

Microsoft Azure: Microsoft Azure Storage offers scalable storage for structured and unstructured data, with attractive pricing for large-scale projects. The Backup and Archive solution offers options for archiving.

Google cloud platform: Google Cloud Storage is a very comprehensive solution that offers good levels of performance and reliability. Google also has offerings suitable for archiving or disaster recovery via the Cloud Storage Nearline solution.

For object storage, Amazon Simple Storage Service (S3) offers a particularly comprehensive service, with extensive documentation including self-service webinars, sample code, tutorials, forums, etc. Google and Microsoft services will be equivalent in terms of reliability and robustness, but less documented. Compared to Google Cloud Storage, AWS also offers a wider choice of storage. For archiving, the offerings are very similar. What will determine the choice of a solution will above all be the type of API that the hospital in Bordeaux needs. As for pricing, it can vary according to the region, and evolves very regularly. In the first quarter of 2017, the following prices (in GB/month) can be retained for standard storage: $0.03 for Amazon, $0.024 for Microsoft Azure and $0.026 for Google. For archiving, Glacier's offering is $0.007, while Microsoft Azure Storage and Google Cloud Storage are around $0.01[24].

➔ AWS offers a wide range of storage and archiving services

Analytics capabilities

Amazon web services: AWS offers a wide range of BI services and a large selection of NoSQL databases. The platform offered by Amazon makes it possible to create practically any Big Data analysis application[25].

Microsoft Azure: Power BI, machine learning tools, Data Lake Analytics... Microsoft also has a wide range of BI tools as well as cognitive services for more advanced functions (such as Cortana).

Google cloud platform: Google offers a very wide range of search and analytics. Its BigQuery data service has a non-technical interface.

Big Data processing involves the use of very specific technologies such as MapReduce, developed by Google. It is therefore not surprising to see Google offering very advanced search and analytics engine services.

[24] (2021)

[25] Hybrid Cloud with AWS, 2021

Although it has a less extensive catalogue, Microsoft Azure has a wide range of analytical tools such as Data Lake Analytics or Data Factory, which links cloud and on-premises data sources and manages data pipelines. Finally, AWS offers a wider range of BI services and tools (the latter still having a head start in research and analytics)[26]. AWS stands out for its QuickSight business intelligence service, which uses In-Memory capabilities to increase processing speed.

➔ Google stands out for its highly advanced search and analytics services

Pricing

The 3 cloud leaders offer very different pricing models and discount conditions. The comparison cannot be reduced to the price of virtual machines because many parameters must be taken into account to determine the overall cost of the services: size of the VMs, options chosen, geographical location of the customer, length of the contractual commitment, etc. Given the multitude of parameters to be taken into account and the totally different pricing models, it seems more relevant to present the discount mechanisms rather than to establish a price comparison

Amazon Web Services: At Amazon Web Services, the system of reserved instances allows you to benefit from a discount (up to 75%) compared to the prices of on-demand instances. These are discount coupons that can be applied to instances that meet certain criteria (region availability, instance family and operating system). According to RightScale engineers[27], "a customer committing to one to three years can get a discount, and the longer the contract period, the bigger the discount. If the customer pre-pays for some or all the resources to which their contract gives them access, then the discount will be even greater.

Microsoft Azure: Microsoft is increasingly focusing on a new "Cloud Solution Provider" (CSP) licensing model that allows cloud providers to sell Microsoft services along with their own offerings and solutions. In this way, customers can have all their cloud-based IT services from a single provider, with the provider taking care of provisioning, management, support and billing. In addition, Microsoft offers interesting online configuration and costing services. In particular, a "price calculator" is available for Microsoft Azure, with numerous configurable services (computing, storage, development tools, etc.).

Google cloud platform: Google offers a system of sustained use instances, called Sustained Usage Discounts (SUD). The mechanism, which is set up automatically and without any initial commitment, allows the customer to benefit from a discount on their invoice calculated according to the duration of use of instances of a certain family during the current month. In simple terms, the more virtual machines the customer uses, the lower the price[28]. On its website, Google gives the following example: "In Compute Engine and Cloud SQL, it is possible

[26] Before you continue to YouTube, 2021

[27] Weins, 2021

[28] Top 2020 des fournisseurs de Cloud : AWS, Microsoft Azure, Google Cloud, l'hybride et les acteurs du SaaS, 2021

to get up to 30% automatic discounts on workloads running for a majority of the billing month. "[29]

With this in mind, it appears that Amazon Web services the provider that offers the most mature service of hybrid cloud. Indeed, It provides a large flexibility of use as it is the most adaptable of all which will allow to fit with hospitals' already installed software. When adopted, it does not require rearchitecting of the current operating system but adapts to it using rehosting. This technique simply moves current applications to the cloud but taking advantage of the environment. Moreover, AWS is certified to host health data in France, which removes the legal barriers of cloud adoption. Finally, AWS also partners with CloudSanté, a cloud service specialised in helping healthcare system achieve interoperability.

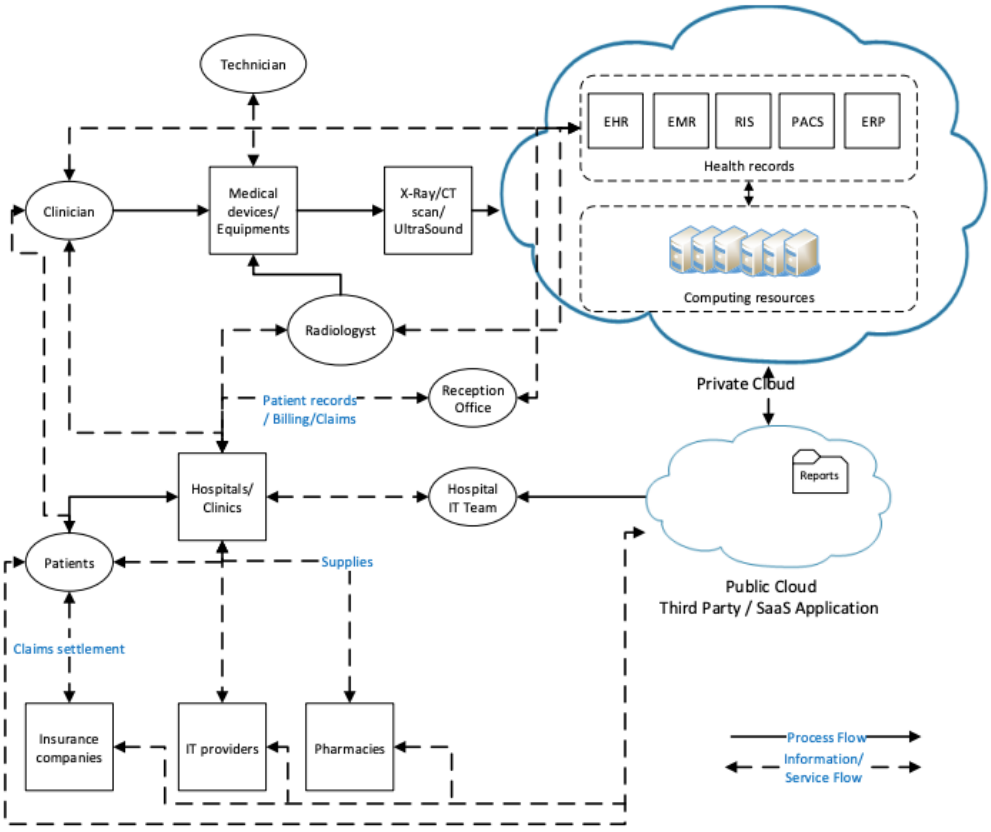
VI- Implementing AWS's hybrid cloud In Bordeaux's hospital

Now that we have determined the right service for Bordeaux's hospital, we can set up a plan to implement it.
According to the requirements of the IHE (Integrating the healthcare enterprise)[30,] the following concepts are integrated in a cloud service for healthcare:

- The domain: the institution administrated by the healthcare institution. In our case, this will be the hospital, pharmacies, and private doctors.
- Users: the customers of the healthcare cloud, he is part of at least on domain of the hybrid cloud and as a specific role in the domain. In our case, this could be a radiologist operating in the radiology department of the hospital (domain)
- Objects: the entities managed by the healthcare system. Objects are referenced with a unique ID assigned to their corresponding domain. For example, a patient.
- Attributes: are elements that define an object. For example, the allergies, blood pressure and age of a patient.
- Services: part of the cloud entity, it is one of the components of the hybrid cloud.
- Hosting infrastructure: A Hybrid cloud.

[29] Carey, 2021

[30] Integrating the Healthcare Enterprise (IHE) - IHE International, 2021



The above chart[31] illustrates the flow of Bordeaux's hospital cloud using AWS. On the top right corner, the rehosting capabilities benefits of AWS are well illustrated. Indeed, this allows us to integrate EHR (Electronic health records), which corresponds to the DMP (dossier medical partagé) that the DGOS put in place, hence limiting the cloud architectural works. Thanks to this cloud, patients can access the cloud online to request care and to book an appointment for a medical procedure. Before the appointment, medical staff can check patient's history to ease and accelerate the diagnosis process and update it with the latest information. Then, clinicians proceed to analysis of the data and diagnosis by retrieving the information added to the EHR by the medical staff. The **private cloud** will store the entire report of clinicians. Further on, insurance companies, pharmacies, patients, and private doctors can connect to the **public cloud** to access the necessary information[32].

Scenario

Patient A has a medical condition that requires an investigation. He books a general appointment and adds specific information about his condition. This will generate a service ticket that will be placed into the cloud. Later on, service tickets will be resolved and assigned to the corresponding healthcare instance: pharmacy, private doctor, lab etc…Then, an appointment will be booked based on the availability of the instance (not for pharmacy) and

[31] A Cloud Architecture for Healthcare, 2021

[32] Building a Hybrid Cloud Environment Using Amazon Cloud, 2021

of the patient as well as the location of the patient A. Parties involved are then informed of that appointment. Patient A and medical instances will be able to track he status of the service ticket (have the test been completed? are the results out?) since patients also have access to their own DMP with a login. This will allow both parties to plan for the appointment: doctors can check Patient A's data and patient A can update his profile[33].
Then, after the appointment, Patient A's doctor will update his DMP with the new information. The cloud services will then forward the doctor's new information to potential other partners to ease the procedure of care and will also inform PatientA of potential further steps he has to take. On their side, systems send the prescriptions to pharmacies that can arrange for medicines to be delivered and available.

The service tickets are stored in the public cloud and acts as a reference for patientA's DMP, which is stored in the private cloud. This allows a restricted and secure access to patient data from third parties like nurses and pharmacies. This allows to respect legal structures while allowing access to data to a large number of professionals. For instance, thanks to the DCOM technology, Patient data can be anonymised once they fall into third parties' hands and de-anonymised when they reach the private cloud once updated with the third parties' additional information. Moreover, in the emergency room, a separate "emergency private cloud" can be introduced to have fully encrypted medical data, this makes the process faster than DCOM anonymization and allows fast communication of data between emergency providers.

VII- Benefits of that cloud adoption

Improved performance

The above hybrid cloud solution seems like a platform that fully optimizes healthcare solutions for Bordeaux's hospital. The first set of benefits is that it improves performance for the healthcare providers along with patient experience. Indeed, all healthcare agents can utilize and exchange patient information optimally from the hybrid cloud. This leads to an easier long-term and chronic disease monitoring. Effectively, telemedicine and online medicine can be implemented more efficiently and in line with the healthcare providers. Before that solutions, long term disease monitoring platforms operated as a separate entity that could be adopted by hospitals but did not cover the entirety of the patient's record. Moreover, private cloud data centre, thanks to anonymization DCOM, can benefit epidemiological research and improve studies on rare diseases[34].
The patient's health path is also facilitated thanks to online bookings and automated direction to the right provider. Note that the appointment sorting via service tickets can also remove the bottleneck in emergency rooms. The cloud also allows to facilitate prescription renewals and limits timely routine check-ups. Moreover, Patients can have access to their health information and provide it to healthcare providers outside the hybrid cloud's coverage. For instance, in case of an emergency outside Aquitaine, the patient can inform healthcare providers of his medical history more accurately.

[33] A Cloud Architecture for Healthcare, 2021

[34] How Does Cloud Computing Benefit the Healthcare Industry?, 2021

Cost reduction

One of the main advantages of implementing the cloud is that it allows tremendous cost reductions. Indeed, as discussed in part one, the lack of data sharing led to an overlap in costly tests like MRIs. Because the patient data will be readily available to healthcare providers in the area, this will prevent such overlaps.
Moreover, the cloud service could save costs by helping health providers plan their capacities better. Indeed, Amazon web services comes with data analytics function allowing to manage the occupation of MRI machines, beds and operating blocks thanks to predictive analysis based on the service tickets.

In order to have a better assessment of the cost reduction and respond to the problem statement, I built a simulation model to simulate the effect of the hybrid cloud on costs.
First, some data on the Bordeaux CHU. The hospital network has 3000 beds and is the principal hospital network of New Aquitaine. It employs 14,000[35] people with 60% being care providers. In a year, it follows about 1million patients among which 10% are recurring patients coming on average 10 times a year. The budget for healthcare solely is €340Million[36]. From the AWS outpost pricing calculator, it is estimated that the Bordeaux's CHU could need to invest about 900,0000€ yearly for this cloud. Moreover, from part one, we know that a maximum of 28% of tests conducted (X-rays, MRIs, bloodtests…) are redundant due to a lack of data sharing. Hence, based on the proportion of tests conducted, I estimated[37] the average cost[38] of those tests. This allowed to do a cost-benefit analysis of the implementation of the Hybrid cloud. The analysis used SimVoi monte carlo simulation for 10000 trials and estimated an average cost saving of 105million euros. In the worst case, the cloud is still profitable since it generates a cost saving of 54Million euros. This corresponds to a cut of 8% of hospital expenses. Since the social security reimburses most of the tests cost, the Hybrid cost could also benefit it if applied nationwide.

It is important to note that other costs classified as opportunity costs can be saved with the cloud. Indeed, with more prediction tools on bed or operating blocs provided by the tool, hospitals can manage them more efficiently and optimise the utilisation of their resources. Hence, it would reduce the number of unnecessary vacant beds, therefore generating additional revenue.
Another unquantifiable cost would be patient satisfaction from the efficiency of the hospital therefore attracting more patients.
Finally, such cloud implementation, as it anchors Aquitaine in a technology and innovative healthcare environment, could boost the collaboration of healthcare technology startups and hospitals, therefore generating more revenue for the region, which could then be allocated to renovating the hospitals' facilities and improving at home care.

[35] Cheminade, 2021
[36] key figures, 2021
[37] Appendix
[38] What Should a Scan Cost?, 2021

Summary

This section highlights the enormous benefits that can be realised by Bordeaux's CHU as soon as it employs a hybrid cloud solution. It strengthens the case for adoption of cloud in healthcare institutions for the DGOS.
Hypothesis 3: "Cloud data sharing will cut down on cost for patients, governments and private doctors" has been strongly supported by this analysis. If Bordeaux's CHU reflects these benefits with new prices and renovations for its facilities, they will be able to engage in a stronger and better healthcare provision system.

VIII- Future opportunities

As stated in the intangible benefits, Hybrid cloud could be developed to further explore the optimization of resource utilisation and further collaboration between innovators in the healthcare segment. Whilst Hybrid cloud might not be the solution for all healthcare provision, Bordeaux's CHU and further on the DGOS should look to develop their capabilities in healthcare data sharing. The following opportunities were found to be investigated further:

- Contact tracing and disease surveillance as well as extended epidemiological transition studying. This would allow to place France in a prevention rather than action system and would confirm Hypothesis 1[39].
- Staffing predictions and more flexible employments would allow to further reduce the costs of hospitals as well as the opportunity cost of empty beds. [40]
- Improving remote infant and dependant adults monitoring. For instance, hybrid cloud and HER Cloud can feed prediction algorithms for infants with heart diseases thanks to data entered daily by parents.
- Faster and instant wound analysis can be generated to provide access to urgent care in remote and un medicalised areas. A wound can be photographed and then analysed with the Glacier capabilities of AWS in advanced imaging algorithms. This could also be integrated with EHR technologies to cut down on the examination cost and limit the waiting time in emergency rooms[41].

IX- Conclusion

This report provides the DGOS with a broad understanding of Cloud computing, its underlying technology and how it can be applied to healthcare to address its inefficiencies in France. The analysis has shown that whilst the DGOS has put efforts in adapting healthcare to the cloud trend, the measures were not sufficient, and the data not sufficiently integrated in the cloud

[39] The Future of Cloud Computing in Healthcare: Looking to 2021 and Beyond, 2021

[40] Restoring Healthcare - Understanding the human capacity, 2021

[41] (Why the Healthcare Cloud Holds the Key to Future Innovation, 2021)

to ensure interoperability. However, it has also shown that the DGOS can transform the French healthcare system to be a pioneer in this field as well as address its budgeting struggles. Indeed, with epidemiological transition, the ageing population, and the rise of online health due to trends accelerated by the covid19 pandemic the current system is becoming increasingly inefficient and urgently need a switch in functioning. Otherwise, e-health offer will be extremely diluted, therefore creating further inequalities and digging the hole between medical centres and more reclused areas (medical deserts).

Thus, the report recommends that, as explained with the Bordeaux CHU, the DGOS gradually implements hybrid cloud as a standard in healthcare provision structures. In addition, it is recommended to link the already existing data capabilities to further expand the benefits of the cloud platform and accelerate its adoption. This is further reinforced by the cost-benefit analysis with a cost saving of up to 8% of total healthcare costs in one single hospital.

It must however be noted that this analysis has limitations. Indeed, the hybrid cloud might not be compatible to all healthcare providers and that the costs implied to link an area as large as France may be proportionally superior to those associated with implementing the cloud in only one area of France and one hospital network specifically. Moreover, we elected as a case study the most dynamic part of France regarding healthcare data management and e-health. Some areas might need to catch up with Aquitaine in order to develop the capabilities necessary for a hybrid cloud adoption. Finally, the cost analysis could not be conducted as precisely as desired since healthcare data is extremely secured and has limited access. Hence, it relies heavily on assumptions based on market studies and hospital financial data.

France’s future prospects in such fragmented and full of potential area if they act now, collaborating heavily between their current capabilities, the private capabilities of private actors and the expertise of Amazon web services. Such action would set France as a standard setter and repolish the reputation of a once first ranked nation for healthcare provision efficiency.

X- Appendices

Healthcare data legal framework[42]

Because of the sensitivity of health data, their computerised processing is particularly regulated by law. Indeed, health data constitute personal data, and even so-called "sensitive" data. As such, it is subject to the provisions concerning personal data, harmonised at European level (I). In addition to this initial framework, there are specific provisions, justified by the medical nature of health data, which imposes particular constraints of reliability, availability and security, in order to guarantee the continuity of care in particular. France has therefore set up a special regime for the hosting of such data (II). We can emphasise on this occasion how the law is evolving and adapting to technological developments, since, for both personal data and hosting, the legal framework underwent a major break between 2017 and 2018.

I) General framework for sharing health data

In France, the processing of personal data, whether in terms of their collection, transmission, use or storage, is governed by the amended Act 78-17 on Data Processing and Liberties of 6 January 1978. At the European level, this framework is harmonised by Directive 95/46/EC of 1995, repealed and replaced from 25 May 2018 by European Regulation 2016/679 of 27 April 2016 (General Data Protection Regulation or GDPR).
Until 25 May 2018, personal data must be processed in accordance with the provisions of the French Data Protection Act, as amended in 2004 (to transpose the 1995 Directive) and 2016 (Law 2016-1321 for a Digital Republic). After this date, due to the primacy of directly applicable European law, it is the RGPD that basically applies; however, there remains an amended Data Protection Act, the provisions of which supplement the RGPD.

II) Main principles

a. Basic principles

Since the 1970s, the protection of personal data has been based on a number of major principles:

- Fairness in the collection and information of data subjects;
- Determination of the purpose of the processing, and proportionality of the collection in relation to this purpose (data are not collected without justification "just in case");
- Rights of access, rectification and objection for data subjects;
- Security of data, including limiting who has access to it;
- Limitation of the duration of data retention, depending on the purpose of the processing and legal obligations;
- The free movement of data within the European Union, where their protection is harmonised, and the prohibition of the transfer of data to countries that do not provide equivalent protection.These principles are included in the GDPR.

[42] Mattatia, 2021

3) Rights of data subjects

In general, data subjects have several rights:
- Right to information on the processing operation, the identity of its controller, the nature of the data collected, their storage period, their possible transfer outside the European Union, etc.
- Right of access to the data collected;
- Right to rectify or update erroneous or outdated data;
- Right to erase inaccurate or outdated data;
- Right to object to the processing, but only on legitimate grounds (except in the case of canvassing, particularly commercial canvassing, where this right is absolute).

Cost-Benefit model

The following are the projected numbers of redundant examination produced, the average price of an image examination and the average price of a biological examination.

		LOW	BASE	HIGH
NB of redundant examinations	**16%**	**12%**	**20%**	**28%**
Average Image exam price	**$192**	**$188**	**$208**	**$228**
Average biological exams price	**$57**	**$40**	**$60**	**$80**

The average prices were calculated using the proportions described in the financial report of Bordeaux's CHU as well as the American average prices for the procedures. Indeed, I was unable to retrieve such cost in a French hospital without the deduction of what is taken care of by the social security. Therefore, I was able to retrieve the costs using American prices that consider costs with and without insurance. The costs were then weighted with the proportions used in Bordeaux's CHU financial report. The percentages were given a triangular distribution to simulate the low case and high case scenarios of costs.

MRI (11%)	X-ray (59%)	CT-Scan (20%)	Echographies(10%)
509.25	76.75	477.5	110
Average Image Price			
208			

The following table was outputted:

Mean	$105,820,881
St. Dev.	$13,674,755
Mean St. Error	$136,748
Skewness	+1.883
Minimum	$54,133,865
First Quartile	$69,592,237

Median	$102,698,265
Third Quartile	$151,326,469
Maximum	$196,938,463

Skills used from learnt modules

The art and science of management: the frameworks and methodology content of this module played a structuring role in this dissertation. Doing the market analysis as well as describing the technologies are deeply related to the individual project conducted at the end of this module. Quid has also played a key role in part one. This module also introduced the concept of disruptive technologies.

Critical analytical thinking: this was used to further perfect the structure of the dissertation as well as provided a critical mindset useful in research for this report. Arguments were backed up with evidence, following the argument structuring framework learned in this module.

Strategy by design: this module helped to identify the key stakeholders of the dissertation as well as defining the problem statement. This module was the base of part one and anchored the dissertation in a deep strategic and design mindset. Moreover, the choice of solution was guided by strategy by design theories as they aimed to fit the goal of the French healthcare system.

Product, technology, and operation management: this module allowed to identify the healthcare path and relating it to the clou architecture. The notion of bottleneck was also used in part one to identify one of the problems of the French healthcare system.

Decision Science: the notion of simulation and concepts of SimVoi were used in order to conduct the cost benefit analysis

Design thinking: In part one, an interview and personas of each stakeholders were created in order to build a solution that comes from the needs of each of them. This guaranteed a solution as useful as possible.

Computational thinking: this module heled understand the hey concepts of cloud computing and its architecture as well as to grasp the performance metrics in the comparison of cloud providers.

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