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Chapter 1

Introduction

By Supriyo Chatterjea

1.1 Background

Healthcare systems around the world are grappling with major challenges such as the growing prevalence of chronic diseases, rising healthcare costs, and a shortage of healthcare workers. Chronic diseases account for 80% of the European Union (EU) healthcare budget of €700 billion, leading to a significant economic impact [1]. Absence due to illness results in a loss of €240 billion in productivity in the EU, equivalent to 2% of gross domestic product (GDP). Without action, the Organization for Economic Co-operation and Development (OECD) has estimated that the average public spending on healthcare costs will increase to 10% of GDP [1].

The shortage of healthcare workers has been a long-standing issue in Europe, even before the COVID-19 pandemic. The overall shortfall of healthcare workers was estimated to be 1.6 million in 2013 [2]. Such shortages have resulted in longer waiting times for patients, increased workload and stress for healthcare workers, and a lower quality of care for patients [3].

It is clear that the healthcare sector needs to undergo radical changes to ensure that future generations have easy access to quality care that is also affordable. One way to achieve this is by leveraging the increasing use of digitization in the sector. According to the World Economic Forum, hospitals produce 50 petabytes of data every year [4]. The question then is how can we leverage the insights that lie within this vast amount of data to transform the healthcare sector and address its most pressing issues, namely cost, quality, and accessibility of care?

This book captures the learnings from the BigMedilytics project, funded by the EC from 2018 to 2021. The project aimed to transform Europe's healthcare sector by using state-of-the-art big data technologies to achieve breakthrough productivity in the sector by reducing cost, improving patient outcomes, and delivering better access to healthcare facilities, covering the entire healthcare continuum – from prevention to diagnosis, treatment, and home care throughout Europe. The €15 million project executed 12 real-life, hospital-related big data pilots across three different themes: (1) population health and chronic disease management, (2) oncology, and (3) industrialization of healthcare (which focused on improving the efficiency of hospitals by optimizing various hospital-related workflows). The pilots spanned eight European countries, the health data of 11 million patients, involved 35 consortium partners, and incorporated diverse data sets originating from the public health sector, insurance companies, Internet of Things (IoT) devices, pharmaceutical industry, and public data sets.

While the BigMedilytics project used advanced data analytics techniques such as machine learning, deep learning, and natural language processing to analyze large amounts of healthcare data, including electronic health records, medical imaging data, and genomic data, what sets it apart is its multi-disciplinary approach. A key learning from the project was that successfully implementing Big Data and AI-driven solutions in a healthcare setting requires a multi-disciplinary approach that focuses not only on developing state-of-the-art technologies but also on a multitude of other aspects such as ethics, privacy, public policy, business models, the experience of care personnel, and, of course, the patient and their family. It is this holistic approach that is critical to breaking down the barriers of the iron triangle (quality, access, and costs) of healthcare and ensuring that big data solutions can scale effectively across different health systems and countries [5].

1.2 BigMedilytics Project Overview

BigMedilytics (Big Data for Medical Analytics) is the largest EU-funded initiative to transform the region's healthcare sector by using state-of-the-art big data technologies to achieve breakthrough productivity in the sector by reducing cost, improving patient outcomes, and delivering better access to healthcare facilities simultaneously.

There are three main reasons to apply big data technologies in healthcare:

- An improvement in health leads to economic growth through long-term gains in human and physical capital, which ultimately raise productivity and per capita GDP.
- In 2019, on average, healthcare accounted for 8.3% of the EU's GDP over all countries. It is continuously becoming more expensive due to a rapidly aging population, rising prevalence of chronic diseases, and costly developments in medical technology. In fact, compared to 2014, the EU-28's total healthcare expenditure is expected to increase to 30% by 2060. This is clearly not sustainable.
- As healthcare is traditionally very conservative when adopting ICT, while big healthcare data is becoming available, the expected impact of applying big data technologies in healthcare is enormous.

The expected increase in healthcare expenditure results in the need to improve the sustainability of current health system models. The effectiveness of a healthcare system depends on quality (determined by efficacy, value, and outcome), access (who can receive care when needed), and cost (the actual expense of patient care) (Figure 1.1).

To improve the productivity of the healthcare sector, it is necessary to reduce costs while maintaining or improving the quality of care provided. The fastest, least costly, and most effective way to achieve this is to use the knowledge that is hiding within the already existing large amounts of generated medical data, currently estimated at around 3 zettabyte. The current trend is toward the digitalization of these large amounts of data, resulting in what is known as big data.

Figure 1.1. Effectiveness of healthcare systems (iron triangle).

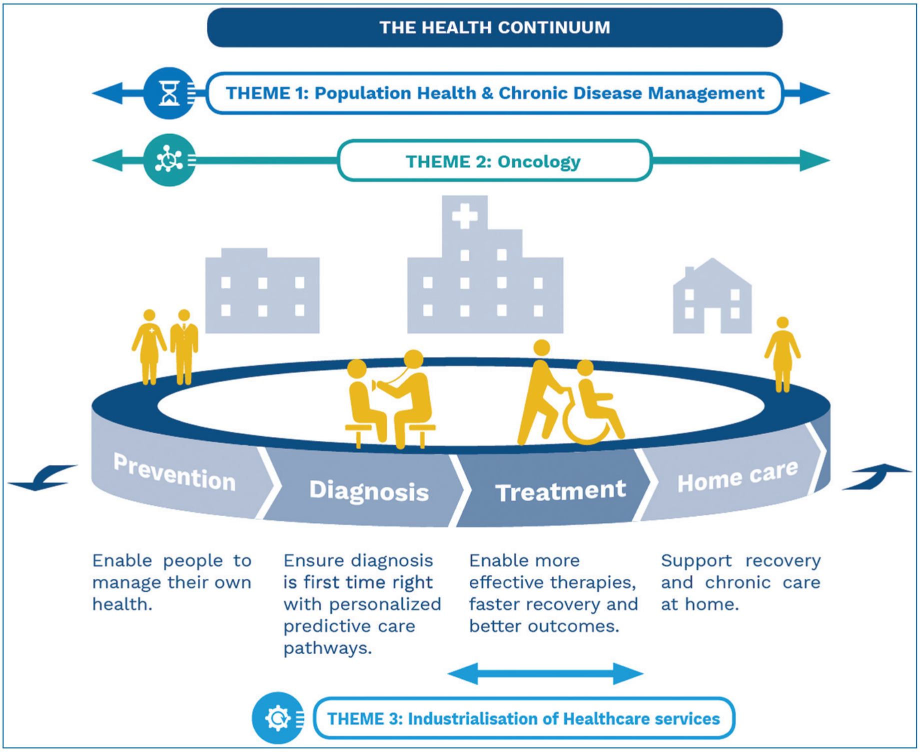

Figure 1.2. The three BigMedilytics themes.

1.2.1 Overview

The BigMedilytics project addressed three themes with the greatest impact on the sector: population health and chronic disease management (described in section II of this book), oncology (described in section III of this book), and industrialization of healthcare services (described in section IV of this book), and deals with the entire healthcare continuum from prevention to diagnosis, treatment, and home care (Figure 1.2). These themes contained separate pilots (called studies in this book). In total, the project was composed of 12 pilots (Figure 1.3). Each pilot was led by a BigMedilytics participant, and other participants took part in the execution of the studies (Table 1.1).

1.2.2 BigMedilytics Deliverables

The BigMedilytics project aimed to deliver the following:

- A Big Data Healthcare Analytics Blueprint (defining platforms and components) based on open Big Data technologies that enable secure collaborative innovation.

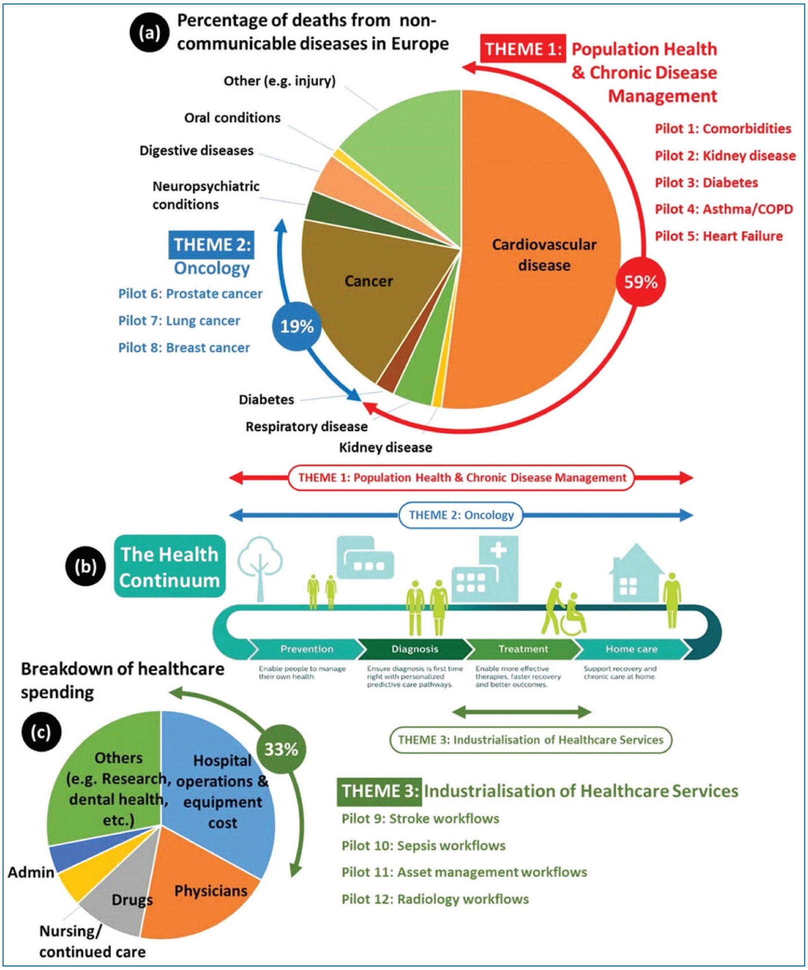

Figure 1.3. The 12 pilots (studies) in the BigMedilytics project.

- Instantiations of the Blueprint are used to replicate BigMedilytics concepts across the 12 large-scale studies, accounting for an estimated 86% of deaths and 77% of the disease burden in Europe.
- The Best "Big Data technology and Healthcare policy" practices take into account aspects related to Big Data technologies, new business models, and European and national healthcare data policies and regulations.

1.2.3 Characteristics of Datasets Used

BigMedilytics used the health records of more than 11 million patients across eight countries in Europe, streaming data from IoT-connected devices at more than a million records per hour and patient-generated data from mobile apps. It also

Table 1.1. BigMedilytics pilot linked to book chapters.

Pilot	Topic	Leader	Participants	Chapter
1	Comorbidities	Incliva	Atos, ITI, OptiMedis, Philips, TU Eindhoven	Chapter 8 (Effects of comorbidities (chronic illness) on hospitalization and mortality risks)
2	Kidney disease	Charité Hospital	AOK, DFKI, HPI, Universitätsmedizin Essen	Chapter 9 (eHealth and telemedicine for risk prediction and monitoring in kidney transplantation recipients)
3	Diabetes	Huawei	Nissatech, Rotunda hospital	Chapter 10 (Remote monitoring to improve gestational diabetes care)
4	COPD/ Asthma	University of Southampton	AstraZeneca, my mHealth	Chapter 11 (Monitoring wellness in chronic obstructive pulmonary disease using the myCOPD app)
5	Heart failure	Erasmus MC	Achmea, TNO	Chapter 12 (Privacy-preserving techniques for analysis of medical data)
6	Prostate cancer	Karolinska	Philips	Chapter 14 (Usability of enhanced decision support and predictive modeling in prostate cancer)
7	Lung cancer	Demokritos	ATC, Politécnica, Hospital Universitario Puerta de Hierro Majadahonda, Leibniz Universität Hannover	Chapter 15 (Monitoring and decision support in treatment modalities for lung cancer)
8	Breast cancer	IBM	InstitutCurie, VTT	Chapter 16 (Artificial Intelligence to support chooses in neoadjuvant chemotherapy in breast cancer patients)

(*Continued*)

Table 1.1. Continued

Pilot	Topic	Leader	Participants	Chapter
9	Stoke management	ETZ	Politécnica, Philips, TU Eindhoven	Chapter 20 (Innovative use of technology for acute care pathway monitoring and improvements)
10	Sepsis management	Incliva	Politécnica, ETZ, Philips, TU Eindhoven	Chapter 21 (Monitoring sepsis patients in the emergency department)
11	Asset management	Philips	OLVG, TU Eindhoven	Chapter 22 (Technological support for paramedical asset management in a hospital setting)
12	Radiology workflows	Contextflow	Atos, Hospital Universitario Puerta de Hierro Majadahonda, Medizinische Universitat Wien	Chapter 19 (Implementation and impact of AI for the interpretation of lung diseases in chest CTs)

ensured that the security and privacy of personal data were guaranteed and managed within national and EU regulatory frameworks.

The BigMedilytics project was an initiative that originated from the Big Data Value Association with the intention to implement a part of the program related to the large-scale projects. The project was formed by a consortium of 35 entities led by Philips.

1.2.4 Objectives

The BigMedilytics project had seven objectives:

- Objective 1: Improve chronic disease and cancer outcomes using big data
- Objective 2: Optimize workflows through industrializing healthcare services using big data
- Objective 3: Guarantee the replicability of big data concepts for healthcare
- Objective 4: Increase the activity through data integration
- Objective 5: Establish secure and privacy-preserving cross-border and cross-organization healthcare services, thus strengthening the EU's Digital Market Strategy
- Objective 6: Define Best "Big Data" practices
- Objective 7: Enable knowledge transfer

1.2.5 Impact

BigMedilytics aimed to have a transformational impact on the healthcare sector by ensuring that big data technologies will be routinely used throughout the healthcare sector in delivering high-quality care while reducing costs. In this sense, the project aimed to:

- Demonstrate an increase in healthcare productivity between 20% and 63% across the 12 studies covering the most prevalent and expensive disease groups across Europe. Evidence suggests that by improving the productivity of the healthcare system, public spending savings would be large, approaching 2% of GDP on average in the OECD, which would be equivalent to €330 billion in Europe based on GDP figures for 2014.
- Enable collaborative innovation across the key players in the healthcare and data value chains.
- Increase in the market share of big data technology providers by at least 25% in the oncology, cardiology, radiology, hospitals logistics, and healthcare IT security market segments.
- Create a lasting impact of big data in the healthcare sector, even after project completion, due to the investment of €78 million by the consortium.
- Contribute to 40–70 times reduction in carbon emissions due to the usage of telehealth driven by big data technologies, thus contributing to Europe's 2020 emission targets.
- Be instrumental in training Europe's next generation of healthcare data innovators.

1.3 Structure of the Book

The goal of this book is "translational", from project to application. There are five major sections (Sections I–V).

Section I contains cross-project themes, including policy (Chapter 3: using causal diagrams to understand and deal with hindering patterns in the uptake and embedding of big data technology), privacy and legal (Chapter 4: lessons learned in the application of the General Data Protection Regulation to the BigMedilytics project), ethics (Chapter 5: ethics: a checklist for investigators, ethics boards and reviewers), and platform businesses (Chapter 6: health platform businesses – from investigations to platforms).

In Section II, five studies (Pilots 1–5) in the population heath domain are presented: comorbidities (Chapter 8: effects of comorbidities (chronic illness) on hospitalization and mortality risks), kidney disease (Chapter 9: eHealth and telemedicine for risk prediction and monitoring in kidney transplantation recipients), diabetes (Chapter 10: remote monitoring to improve gestational diabetes care), COPD/asthma (Chapter 11: monitoring wellness in chronic obstructive pulmonary disease using the myCOPD app), and heart failure (Chapter 12: privacy-preserving techniques for analysis of medical data).

Section III elaborates on three studies (Pilots 6–8) in the oncology domain: prostate cancer (Chapter 14: usability of enhanced decision support and predictive modeling in prostate cancer), lung cancer (Chapter 15: monitoring and decision support in treatment modalities for lung cancer), and breast cancer (Chapter 16: artificial Intelligence to support chooses in neoadjuvant chemotherapy in breast cancer patients).

Industrialization of healthcare is the common topic of the studies (Pilots 9–12) in Section IV. This section contains chapters about stroke management (Chapter 20: innovative use of technology for acute care pathway monitoring and improvements), sepsis management (Chapter 21: monitoring sepsis patients in the emergency department), asset management (Chapter 22: technological support for paramedical asset management in a hospital setting), and radiology workflows (Chapter 19: implementation and impact of AI for the interpretation of lung diseases in chest CTs).

Section V elaborates on the BigMedilytics project itself and its learnings: the BML website (Chapter 24: the interactive BigMedilytics website), the blueprint (Chapter 25: data processing in healthcare using CRISP), technology acceptance (Chapter 26: technology acceptance in healthcare), and the general learnings (Chapter 27: general learnings from the Horizon 2020 project BigMedilytics).

1.4 Conclusion

The authors hope that those rolling out big data/AI solutions in hospitals or health systems can benefit from the learnings captured in this book and also embark on the multi-disciplinary approach that we have both pursued and benefited from, thus scaling such solutions across a variety of health systems and countries.

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