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Data Driven Approach to Enhancing Efficiency and Value in Healthcare

Richard E. Guerrero Ludueña



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Data Driven Approach to Enhancing Efficiency and Value in Healthcare

Métodos basados en datos para mejorar
la eficiencia y el valor en el sector sanitario

Memoria presentada por Richard Eduardo Guerrero Ludueña
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Data Driven Approach to Enhancing Efficiency and Value in Healthcare



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BARCELONA

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To Carolina and Victoria

Abstract

National Health Systems across Europe are facing the same challenges to achieve a high quality of healthcare, including, for example, the need to adapt to demographic changes and a growing demand for care; improving efficiency and financial sustainability; an ageing population associated with a high incidence of certain chronic diseases (e.g., Alzheimer's and dementia); growing incidence of preventable diseases such as cancer, heart disease, diabetes, respiratory, mental health, and others representing a huge cost for society and the economy; and huge differences in health and healthcare between and within the countries.

Healthcare is changing, and the era of data-driven healthcare organisations is increasingly popular, mainly due to progress in open data initiatives; digitalisation of medical records; technical advances and new analytical tools; pharmaceutical R&D data availability; and mobile healthcare applications. All of these new trends can be exploited by data-driven approaches (e.g., machine learning, metaheuristics, modelling & simulation, and data analytics) to increase efficiency and value in health services.

Despite extensive research and technological development, the evidence impact of those methodologies in the healthcare sector is limited. In this Thesis we argue that an approach without borders in terms of academic societies and field of study could help to tackle the lack of impact of data-driven approaches to enhance efficiency and value in healthcare.

This Thesis is based on solving practical problems for particular context in different levels of healthcare management, with the research drawing upon both theoretical and empirical analysis.

The research is organised in four stages. In the first part, a variety of techniques from Modelling and Simulation were studied and used to analyse current performance and to model improved and more efficient future states of healthcare systems. The focus was primarily concerned with the analysis of capacity, demand, activity, and queues both at hospital and

population levels. In the second part, Genetic Algorithm was studied and used to solve a Routing Home Healthcare problem. In the third part, Social Network Analysis was studied and used to visualise and analyse email networks. In the final, a new healthcare system performance metric is proposed and implemented using a case study. New frameworks to implement these methodologies in the context of real-world problems are presented throughout the Thesis.

Working in collaboration with the University of Southampton, Wessex Academic Health Science Network (AHSN), and NHS England, several projects were developed and implemented for healthcare improvement in the UK. The work aims to increase early detection of cancer and thereby reduce premature mortality. The research was conducted working closely with NHS Trusts and Clinical Commissioning Groups (CCGs) across the Wessex region in England to produce bespoke endoscopy service modelling, as well as population level models. At a regional level, we produced a Colorectal Cancer Screening Programme model in the South of England, and an analysis of endoscopy activity, capacity and demand across the region was conducted. We estimated the future demand for endoscopy services in five years' time, and we found that the system has enough capacity to attend the expected future demand. A new healthcare system performance metric is presented as a tool to improve healthcare services.

Genetic Algorithm metaheuristics were implemented and applied in a variant of the Home Health Care Problem (HHCP), focusing on the route planning of clinical homecare.

Working with the IMIM (Hospital del Mar Medical Research Institute, Barcelona) and the Agency of Health Quality and Assessment of Catalonia (Agència de Qualitat i Avaluació Sanitàries de Catalunya [AQuAS], Barcelona), a project was developed to estimate future utilisation scenarios of knee arthroplasty (KA) revision in the Spanish National Health System in the short-term (2015) and long-term (2030) and their impact on primary KA utilisation. One of the findings was that the variation in the number of revisions depended on both the primary utilisation rate and the survival function applied. Projections of the burden of KA provided a quantitative basis for future policy decisions on the concentration of

high-complexity procedures, the number of orthopaedic surgeons required to perform these procedures, and the resources needed.

A Social Network Analysis (SNA) project was developed in collaboration with the Wessex Academic Health Science Network (AHSN) in the UK. The analysis focus on organisational email knowledge extraction with SNA and Data Mining.

A new healthcare system performance metric - based on the Overall Equipment Effectiveness (OEE) measure - is proposed and evaluated using real data from an Endoscopy Unit from a UK based hospital.

To summarise, this work identifies four key techniques to use in the investigation of health data - machine learning algorithms, metaheuristic, discrete event simulation and data analytics. Following a review of the different subjects and associated issues, those four techniques were evaluated and used with an applied-focus to solve healthcare problems.

Key learning points from all different studies, as well as challenges and opportunities for the application of data-driven methodologies are discussed in the final chapter of the Thesis.

Acknowledgements

During 2011, I was presented with some interesting options: either return to industry after a MSc degree in Valladolid, or undertake a research-based PhD. The idea of the PhD was appealing because I would be able to make a contribution to knowledge and that would make a positive impact on society. After six months as a full time PhD student I discovered the need of be in contact with real-life problems so I decided to do both. Since then I have participated in numerous start-up programmes, and I have lived in various countries and worked in different organisations. Over the years I have met and worked with some incredible people, so in no particular order here goes:

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Publications

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- Castells, X., Comas, M., **Guerrero, R.**, Espallargues, M., Allepuz, A., Sabatés, S., Pons, M., Coll, M. (2014). Impacto de la cirugía para el recambio de prótesis de rodilla en el Sistema Nacional de Salud. *Agència de Qualitat i Avaluació Sanitàries de Catalunya*.

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 - **Guerrero-Ludueña, R. E.**, Keogh, B. (2016). Lack of data?... Using open data and open source tools to produce an online visualisation platform: The Cancer Waiting Times standards of the NHS in England example. *ORAHHS 2016 – 42nd Operational Research Applied to Health Services conference*, 24-29 July 2016, Pamplona, Spain.
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List of Abbreviations

ACO	Ant Colony Optimisation
A&E	Accident and Emergency
AHSN	Academic Health Science Network
AI	Artificial Intelligence
AQuAS	Agència de Qualitat i Avaluació Sanitàries de Catalunya
APIs	Application Programming Interfaces
BCSP	Bowel Cancer Screening Programme
BSG	British Society of Gastroenterology
CCG	Clinical Commissioning Group
CI	Confidence Interval
CIS	Centre for Implementation Science
CN	Clinical Network
CO	Combinatorial Optimisation
CRC	Colorectal Cancer
CRM	Customer Relationship Management
CS	Computer Science
DEA	Data Envelopment Analysis
DES	Discrete Event Simulation
DL	Deep Learning
DM	Data Mining
DV	Data Visualisation
EPR	Electronic Patient Records
ERCP	Endoscopic Retrograde Cholangiopancreatography
ESCL	Endoscopy Safety Check List
ESNA	Email Social Network Analysis
ESNA -KDD	Email Social Network Analysis - Knowledge Discovery in Database
EU	European Union
EUDCP	Endoscopy Unit Day Care Plan
FOBt	Faecal Occult Blood test
FS	Flexible Sigmoidoscopy
FYFV	Five Year Forward View
GA	Genetic Algorithm
gFOBt	Guaiac Faecal Occult Blood test
GP	General Practitioner

HEN	Health Evidence Network
HHCP	Home Health Care Problem
HIV	Human Immunodeficiency Virus
ICD	International Classification of Diseases
IMIM	Hospital del Mar Medical Research Institute
INFORMS	Institute for Operations Research and the Management Sciences
INSNA	International Network for Social Network Analysis
IT	Information Technology
ITU	Intensive Therapy Unit
IV	Intravenous Catheter
JAG	Joint Advisory Group on Gastrointestinal Endoscopy
KA	Knee Arthroplasty
KDD	Knowledge Discovery in Databases
KPI	Key Performance Indicator
LoS	Length of Stay
ML	Machine Learning
MLC	Multi Label Classification
NCHA	National Clinical Homecare Association
NHS	National Health Service
NP-hard	Non-deterministic Polynomial-time - hard
OEE	Overall Equipment Effectiveness
OFE	Overall Fab effectiveness
OGD	Oesophago Gastro Duodenoscopy
ONS	Office for National Statistics
OPCS	Classification of Interventions and Procedures
OR	Operational Research
PAMH	Pre-Admission Medical History
PEG	Percutaneous Endoscopy Gastroscopy
PPCD	Post Procedure Care and Discharge
PRINCE2	Project in Controlled Environment - version 2
QAP	Quadratic Assignment Problem
R&D	Research and Development
SA	Simulated Annealing
SD	Standard Deviation
SNA	Social Network Analysis
SODA	Strategic Options Development Analysis
SSM	Soft System Methods
STR	Self Tuning Regulator
TPM	Total Productive Maintenance
TSP	Travelling Salesman Problem
TWR	Two Weeks Referral
UB	University of Barcelona
UoS	University of Southampton
WHO	World Health Organisation

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