Linking Predictive and Prescriptive Analytics of Elderly and Frail Patient Hospital Services

Elizabeth Williams
School of Mathematics
Cardiff University
Cardiff, United Kingdom
williamsem20@cardiff.ac.uk

Daniel Gartner
School of Mathematics & Mathematical Modelling Unit
Cardiff University & National Health Service
Cardiff, United Kingdom
gartnerd@cardiff.ac.uk, daniel.gartner@wales.nhs.uk

Paul Harper
School of Mathematics
Cardiff University
Cardiff, United Kingdom
harper@cardiff.ac.uk

***Abstract*—Predictive and prescriptive techniques are being evaluated to predict demand for inpatient services within South East Wales. This work is specifically focusing on multi-site hospital services for elderly and frail patients, using classification and regression trees to determine patient clusters with similar attributes, yielding results of up to 89.62% accuracy. By incorporating these results into mathematical models we aim to quantify the value of incorporating the clustering results in a deterministic and stochastic mathematical programme.**

***Keywords*—Machine Learning, Mathematical Programming, Stochastic Programming.**

I. Introduction

Ageing is one of the most common and well known risk factors for most chronic diseases [1]. As patients get older their severity of frailty increases and as a result, so does their dependency on health care resources. Planning for the frail and elderly can be difficult since these patients often suffer with multi-morbidity and can take longer to recover in hospital with more staffing hours and resources required. This often leads to difficulty in clustering these patients for prediction, as there are many different factors which cause longer lengths of stay (LOS). Literature in this field has often been focused on single medical settings where the focus has been on one illness, with recommendations for future research to encompass multi-site services [2], linking predictive and prescriptive analytics [3].

II. Methods

Within healthcare, a vast amount of data is routinely collected when a patient is admitted to hospital. Our analysis utilises a data set of 162,763 records across ten hospitals within the region. Patient attributes that have similar LOS groupings within hospital were determined via classification and regression trees (CART) and clustering techniques. Ten different variables were included which were identified through data analysis as significant. Additionally, a frailty score was generated based on ICD10 hospital codes using a combination of Gilbert et al. [4] and Soong et al. [5].

The authors greatly appreciate the financial support received from the Knowledge Economy Skills Scholarship (KESS2). KESS2 is a pan-Wales higher level skills initiative led by Bangor University on behalf of the Higher Education sector in Wales. It is part funded by the Welsh Government's European Social Fund (ESF) convergence programme for East Wales.

III. Results

The results of the CART analysis yielded results of up to 89.62% accuracy. Using these clusters of grouped patient nodes we can apply these to deterministic and two stage stochastic models, determining the number of beds required for elderly and frail patients.

The overall objective is to minimise the total costs of hospital beds and staffing, whilst accounting for the stochastic nature within healthcare.

IV. Proposed work

The aim of this research is to show the value of using either CART or clustering techniques with deterministic and two stage stochastic programming, building upon the work by Maggioni and Wallace [6]. Our results will indicate which method produces a more accurate and reliable result and the trade-off required. A tool will be created which can predict both short and long-term bed capacity predictions.

V. Expected contribution and impact

This work has been in collaboration with the Clinical Futures Team within the Aneurin Bevan University Health Board in South East Wales, UK. The results from the work will plan for staffing requirements and bed capacities across a network of hospitals. Linking predictive and prescriptive analytics will provide a better insight into the state of the hospital system and services for elderly and frail patients. In practice, it will avoid planning based on averages and aid in making better decisions within the healthcare system.

References

[1] W. Macnee, R. A. Rabinovich, G. Choudhury, "Ageing and the border between health and disease", Eur. Respir. J, 44(5), pp. 1332-1352, 2014

[2] E. Williams, D. Gartner, P. Harper, "A survey of OR/MS models on care planning for frail and elderly patients", Operations Research for Health Care, 31, pp. 100325, 2021

[3] J. Lopes, T. Guimarães, M. F. Santos, "Predictive and Prescriptive Analytics in Healthcare: A Survey", Procedia Comput Sci, 170, pp. 1029–1034, 2020

[4] T. Gilbert, J. Neuburger, J. Kraindler et al.,"Development and validation of a Hospital Frailty Risk Score focusing on older people in acute care settings using electronic hospital records: an observational study", The Lancet, 391(10132), pp 1775–17782, 2018

[5] J. Soong, A. J. Poots, S. Scott et al., "Quantifying the prevalence of frailty in English hospitals", BMJ Open, 5(10), 2015

[6] F. Maggioni, S. W. Wallace, "Analyzing the quality of the expected value solution in stochastic programming", Ann Oper Res, 200, pp. 37–54, 2012