Healthcare Population Management

A simulation model to support decision making in 'right care at the right place' in a network of healthcare providers

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Preface

The programme of the master Business Analytics ends with the Master Project Business Analytics. This project has to be done in the form of an internship at a company. I started working in the healthcare sector in July 2018 and quickly found my passion for data-driven innovation in this sector. For me it was obvious to write my thesis about an innovative subject that could contribute to improving healthcare. I am happy that I got the opportunity to write my thesis about a recent movement in the healthcare sector at Q-Consult Zorg.

I want to thank Karin de Booij for her supervision and advise during the time of writing my thesis, but also for her patience and support on finding a suitable subject in advance. Unfortunately, due circumstances, Karin could not supervise me until the end and therefore, I want to thank Els Roorda for substituting Karin. Furthermore, I want to thank René Bekker for his supervision, and especially for helping me through the last phase of my thesis. At last, I want to thank my family, my friends, Thomas and my colleagues for their unconditional support.

Josan Preijde, January 2020

Summary

The current way of organizing healthcare in the Netherlands is under pressure. The population is aging and spend more time being ill. As an effect of these trends, the costs in the healthcare sector are increasing. This growth in healthcare expenditures is unsustainable. As a result different healthcare providers need to work together to provide 'the right care at the right place'. Data plays an important role in the 'the right care at the right place' movement, since it can help giving insight in the current health status and gives an estimation in what will happen when patient flows change. The goal of this research is as follows:

Develop a model that can support decision making in 'the right care at the right place' in a network of healthcare providers.

The research goal is divided into two parts:
1. *Develop a simulation model that can simulate patient flows through a network of healthcare providers*
2. *Develop an optimisation framework for optimising the resources in a network of healthcare providers*

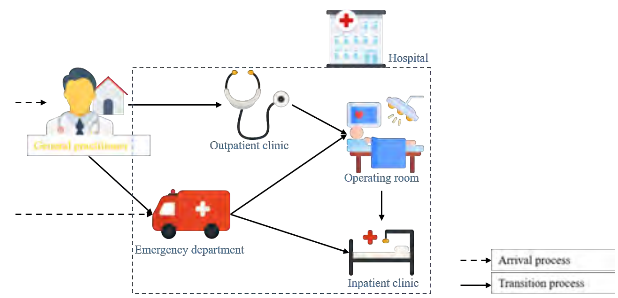

Figure 1: Overview of network

This research uses open source data to determine the number of arrivals, the referral rate between different providers and the trend in expected healthcare demand in the upcoming years. Research on modelling healthcare networks shows that simulation is the best suitable method for modelling a network of healthcare providers. Simulation allows the most realistic representation of the network, it is able to capture the complexity of the interaction within a network and it is able to measure the effects of changing scenarios. Figure 1 shows the network that is considered and how patients flow through the network. Only the emergency department delivers care 24/7. The other providers are accessible during working hours. Every node (provider) in the network is modelled as a queuing system, with a finite capacity; when the waiting queue has reached a certain capacity, patients are assumed lost or go elsewhere outside the network. The simulation model reports the following performance measures: the blocking probability, the average number of patients in the queue (percentage of total queue length), average utilization of servers (percentage of total number of servers).

Simulation metamodelling is used as technique to develop an optimisation framework for optimising the resources in a network of healthcare providers. A simulation metamodel is a computationally efficient approximation to a simulation model. The simulation metamodel takes the input parameters of the simulation model and approximates the output. The technique used to construct the simulation metamodel is supervised machine learning, comparing a linear regression and gradient boosting model to find the best performing model. The simulation metamodels are trained on 1,000 data samples generated by the simulation model. The metamodels are validated using K-fold cross validation and their performance is measured by the Root Mean Square Error (RMSE) and determination coefficient (R^2).

The validation of the simulation model and simulation metamodel, as well as the application of both models, show that the models can support decision making in 'the right care at the right place' in a network of healthcare providers. The simulation model can support the research goal in the following ways: (1) to get insight in blocking probability, average queue length and utilization depending on the input parameters, and (2) to calculate the effects of changing input parameters (e.g. arrivals) on the blocking probability, average queue length and utilization of the network. The simulation metamodel can support the research goal in the following ways: (1) to quickly generate the average blocking probability of the network, (2) to efficiently measure the effects of changing scenarios (input parameters), and (3) to efficiently construct a look-up table for finding the right parameters to a corresponding average blocking probability.