ProMoBed: a forecasting and simulation model for estimating future hospital bed capacity

Marlies Van der Wee[1], Timo Latruwe[1], Sofie Verbrugge[1], Pieter Vanleenhove[2], Henk Vansteenkiste[2], Sebastiaan Vermeersch[2]

[1] IDLab, Ghent University – imec, Ghent, Belgium
[2] hict, Bruges, Belgium

Corresponding author: marlies.vanderwee@ugent.be

Healthcare is an everchanging environment, where currently the most important trends are an ageing population and a shift towards chronic diseases. These trends result in growing costs and have forced governments to cut in healthcare budgets and initiate reformations such as a reduction of length of stay (LOS) in hospitals and a transfer towards home care, care hotels or elderly homes. Hospitals play a central role within this landscape as they cover 25-45% of the total healthcare budget within Belgium (CM, 2015) and Europe (Eurostat, 2012). Hence, hospitals are largely affected by these budget cuts and reformations. Novel legislation (will) force(s) hospitals to form networks and reorganize the care offer and a recent study from the Belgian Healthcare Knowledge Centre (KCE) stated that it is possible to reduce the amount of hospital beds across Belgium with 10% (Belgian Healthcare Knowledge Centre, 2017).

A tool which predicts the required bed capacity over long-term periods would help hospitals take strategic decisions. This is the case with the upcoming network formation, but also with the – expected to be continuously evolving – shift towards home care, the reducing length of stay for most treatments or the changes in population and epidemiology. Moreover, since the role of hospitals will change, other instances will take over some roles (elderly homes, care hotels, home care nurses etc.). Those parties could similarly be helped by a tool that predicts the required (bed, chair, revalidation room...) capacity. Besides these long-term evolutions, short-term fluctuations (summer/winter, outbreak of infections) pose operational challenges. Being able to predict such changes would help in re-scheduling nurse shifts within hospitals, improving the work-load and service quality within hospitals.

A market survey performed by the authors shows that most hospitals base their predictions on comparisons with other hospitals (benchmarks such as Forcea (2018) or-Belfius (2017)) or simple business intelligence-dashboards (e.g. 3M (2018), internal tools). These predictions however lack demographic evolutions, changes in epidemiology, regional parameters, governmental decisions or network dynamics. Additionally, the feedback data from governmental instances are generally outdated (>2-3 years). Hence, hospitals frequently lack detailed and correct information to which they can base their policy decisions.

The KCE recently published a study in which the future need for hospital beds is modelled and calculated (Belgian Healthcare Knowledge Centre, 2017). This study is of great relevance and can be seen as 'state of the art' for modelling hospital bed capacity in Belgium. Although the model is of great importance for the Belgian healthcare context, several aspects are lacking from the model, which leads to a difficult translation into practice. These are (1) a fixed prediction horizon (2025) instead of a flexible horizon that allows both short- and long-term predictions, (2) nation-wide aggregated data instead of hospital-specific inputs, (3) geographically broad demographic forecasts, not taking into account regional differences and (4) no room for simulating a large variety of alternative ("what-if") scenarios.

Internationally, there are also models that aim at predicting future bed capacity in hospitals. First of all, there is literature that studies which parameters influence the required numbers of hospital beds, e.g., discharge rates, distribution of patients across diseases, patient length of stay, demographics and seasonal & epidemic scenarios (Barnett et al, 2012, Cavanagh and Chadwick, 2005). Next, there are also specific statistical prediction models. Boyle at al. (2016), for example, present a regression model based on patient influx in the emergency department of one specific hospital. Thirdly, discrete event simulation (DES) models are used. One example is presented by Devapriya et al (2015), who developed a decision support tool based on a DES that receives patient arrival and discharges as inputs. Finally, there are combinations of statistical predictions and simulations. Demir et al. (2017) present such a tool and applied it to the National Health Service hospitals in England, be it on a limited timeframe of 5-10 years. They however do allow hospital decision makers to run multiple scenarios, varying different parameters.

A bed capacity simulation model that combines statistical prediction models with the simulation of different alternative scenarios going beyond the DES input parameters (such as new network formations, governmental decisions, changes in outbreaks of infections, etc.) has – to the best of the author's knowledge – not yet been developed. Such a model would be of greater relevance to hospital decision makers, as it combines the strengths of the different approaches described above:

- The trends in the model are based on statistically validated data and hence reliable.
- The DES incorporated in the model can be used to compare different scenarios and evaluate the impact of the variation of certain parameters.
- The knowledge of domain experts can be inputted in the simulator to allow for defining and simulating alternative scenarios going beyond the DES input parameters.
- The flexibility of the model allows forecasting and simulating for multiple time horizons, ranging from short-term operational impacts to long-term strategic decision making.

Our innovative solution, ProMoBed, tries to overcome subjectivity and simplifications and enables accurate long and short-term predictions by using a simulation

approach where multiple parameters, identified to be relevant in determining the bed capacity and the bed occupancy within hospitals, will be used and refined to get a solid, predictive model. The model is able to forecast both in the long and short run, changes in market shares are explicitly modelled and specific regional demographic changes are included.

More specifically, ProMoBed aims at solving the bed capacity estimation problem by combining the strengths of structured literature research, parameter correlation studies and simulation models. This approach will lead to data-supported results, while still allowing the flexibility of including expert knowledge, situation-specific policies or constraints (such as market share changes), and sensitivity analysis:

1. Structured literature research and statistical parameter correlation studies will generate more precise and valid disease predictions on patient, national or European level. These studies are based on detailed per-hospital data combined with regional, national and European trends.
2. The statistical regression model will combine this input with historic and demographic data to generate reliable estimates of general trends on e.g. patient arrival dates, regional demographics and length of stay.
3. The discrete event simulation model will be able to model situation-specific policies or constraints (for example changes in market shares), to achieve a forecast on needed bed count.

This paper will present the conceptual ProMoBed model, which is still work-in-progress.

In summary, ProMoBed is a huge improvement with respect to the current way of working: transition from subjective expert opinion on a limited set of parameters to up-to-date datasets, basing decisions on the combination of data forecasts and expert knowledge.

References

1. CM (2015) Twaalfde CM-ziekenhuisbarometer. Retrieved from https://www.cm.be/media/CM-Ziekenhuisbarometer-2016_tcm47-19246.pdf
2. Eurostat (2012) Healthcare expenditure by function, 2012. Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Healthcare_expenditure_by_function,_2012_(%25_of_current_health_expenditure)_YB15.png
3. Belgian Healthcare Knowledge Centre (2017) Required Hospital Capacity in 2025 and criteria for rationalization of complex cancer surgery, radiotherapy and maternity services. Retrieved from https://kce.fgov.be/sites/default/files/atoms/files/Download%20het%20rapport%20in%20het%20Engels%20%28550%20p.%29.pdf
4. Forcea (2018) Forcea Health report. http://www.forcea.be/en/solutions/forcea-healthreport-0
5. Belfius (2017) Maha-study 2017. Algemene ziekenhuizen. Retrieved from https://www.belfius.be/publicsocial/NL/Media/MAHA%202017%20persconferentie%20NL_tcm_31-142132.pdf

6. 3M (2018) 3M Health information systems. https://www.3m.com/3M/en_US/health-information-systems-us/
7. Barnett, K. (2012). Best practices for community health needs assessment and implementation strategy development: A review of scientific methods, current practices, and future potential. *Atlanta, Georgia: The Public Health Institute & The Centre for Disease Control and Prevention*.
8. Cavanagh, S. and Chadwick, K. (2005) *Health needs assessment: a practical guide*. National Institute for health and Clinical Excellence.
9. Boyle, J., Ireland, D., Webster, F., & O'Sullivan, K. (2016, February). Predicting demand for hospital capacity planning. In *Biomedical and Health Informatics (BHI), 2016 IEEE-EMBS International Conference on* (pp. 328-331). IEEE.
10. Devapriya, P., Strömblad, C. T., Bailey, M. D., Frazier, S., Bulger, J., Kemberling, S. T., & Wood, K. E. (2015). StratBAM: A discrete-event simulation model to support strategic hospital bed capacity decisions. *Journal of medical systems*, *39*(10), 130.
11. Demir, E., Gunal, M. M., & Southern, D. (2017). Demand and capacity modelling for acute services using discrete event simulation. *Health Systems*, *6*(1), 33-40.