

REVIEW OF OPERATIONS RESEARCH TECHNIQUES FOR MODELING HUMAN RESOURCES IN HEALTHCARE ORGANIZATIONS

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Abstract

Nowadays, health care systems are facing extreme pressures to obtain desired service level in spite of rapidly changing environment, scarce resources and financial challenges. Managing scarce resources in the best possible way is the main task of operations research, since it focuses on the application of analytical methods to facilitate better decision-making. Thus application of operations research techniques can surely be very valuable for managing healthcare organizations, in order to improve efficiency, achieve objectives and obtain desired service level. The main goal of this paper is to show how application of operational research models can improve decision making process, especially addressing efficient workforce allocation. This paper presents the review of different groups of quantitative models which can be applied to various aspects of managing human resources in healthcare organizations. Ability to analyze and predict demand of health care services is of great importance, so at the beginning we present how time series analysis and various econometric models can be used to explore time and location dependent variations of the demand. Furthermore, queuing theory and optimization models can be applied in order to obtain the optimal allocation of human resources that leads to improvement in patients' and employees' satisfaction and economic efficiency of the whole healthcare system.

Key words: Human Resources Management, Operations Research Models, Healthcare Management

JEL Code: C60, I10, M50

Introduction

Organization and management of healthcare system are very complex tasks in every society, due to the unique nature of healthcare services. Thus, managing operations in healthcare organizations is a question of extraordinary social relevance. Nowadays, health care systems are facing extreme pressures to obtain a desired service level in spite of the rapidly changing environment, scarce resources and financial challenges. Effective resource allocation is both a

consequence and a solution for overcoming these challenges. Moreover, today's health-care systems are characterized by multiple objectives, multiple evaluation criteria, and multiple decision-makers within the system, while resources and budget are extremely limited. Therefore, various quantitative methods are widely used to aid decision making process and improve overall efficiency. Optimal allocation of material, financial and human resources is extremely important in this sector and operations research models can be applied for different kinds of organizational issues. The World Health Organization stated that "One of the most important roles of the World Health Organization is to assist countries in making optimum use of scarce health resources." This is also the role of operations researchers. These public safety systems have received a great deal of attention in the operations research community, since they provide important services and the problems are amenable to mathematical modelling and solution.

Operations Research exists as a scientific discipline since the 1930's and the first papers dealing with the healthcare problems date from 1950's. Despite the proliferation of papers in the academic literature, there are still major issues around getting quantitative models widely accepted and used as part of mainstream decision-making by clinicians, health managers and policy makers. Some possible reasons for this include (Teow, 2009):

- Low levels of managerial/mathematical background in the health care sector
- Scientific papers are often written for operations research professionals, focusing on specialised and technical topics, and not reaching healthcare professionals
- Lack of process-related data for modeling
- Lack of in-house operations research expertise
- High cost of engaging external operations research consultants

The main aim of this paper is to present the review of various quantitative models, which can be applied to improve efficiency of human resources in healthcare organizations. Nowadays, when the demand for medical services is growing and the same trend is expected in the future, staff scheduling and rostering has become increasingly important area in every organization. These issues are characterized with complex constraints due to numerous legal and organizational regulations that should be satisfied together with personal preferences of employees. In the process of human resources modeling three main phases can be identified:

- analysis and forecasting of the demand for healthcare services
- determination of the optimal staffing level (the necessary number of staff needed to satisfy forecasted demand)

- staff scheduling and rostering.

The structure of our paper will follow the above mentioned phases. In the next chapter we will introduce the major specifics of healthcare management, which explain how modelling of human resources in healthcare sector differs from the other types of organizations. The second chapter focuses on the various statistical and econometrical methods for demand analysis. The third chapter presents some basic models from queueing theory that can be easily applied in determination of the desired staffing level. It is very important to emphasize the necessity of coherence between all the phases in order to incorporate the stochastic nature of demand in a staff scheduling and rostering process. The fourth chapter presents several types of operations research models dealing with an optimal allocation of employees. This chapter is followed by concluding remarks.

1 The characteristics of healthcare management

The complexity of today's healthcare system and its high importance in every society imposes the conclusion that planning, organizing, leading and controlling of this sector is impossible without the proper implementation of management techniques. Contrary to the development of industrial management, healthcare management is characterized by different and slower path of development. Furthermore, we can conclude that the complete practical integration of healthcare and management techniques, which would result in the maximal synergistic effect, has not been achieved yet. Awareness of the importance and necessity of healthcare management exists, but its practical implementation is still at a relatively low level. The reasons for this are diverse and require a continual and systematic education about the possibilities and importance of managerial techniques and skills, which can contribute to the quality improvement of healthcare services and achievement of better financial results. Because of the basic similarities with the economic system, healthcare systems in the developed countries are treated as health industry, which is not led by doctors but the intellectuals with specialized knowledge and skills for the management and administration of healthcare organizations. Nowadays, implementation of modern management becomes essential, not only at the central level but at the all parts of a healthcare system. Attention is also focused on the development of an integral information system and the application of mathematical modeling, in order to support decision making at strategic, tactical and operational level.

2 Analysis and forecasting of the demand

In order to obtain efficient planning of various activities in healthcare organizations it is necessary to accurately predict the demand for medical services during the planning period. Goldberg (Goldberg, 2004) mentions that “ability to predict demand is of paramount importance”, but this area has seen little systematic study. Very challenging factor that influences the demand of healthcare services is randomness, specially when patients arrive without an appointment (which is the case of emergency and radiology departments in hospitals, ambulance service, etc.). The demand patterns tend to be highly time and location dependent and the same can be concluded for the duration of medical interventions. Therefore, classical planning techniques, which assume the deterministic character of the demand, can not provide a relevant basis for decision making process. The adequate demand forecasting, which takes into account the stochastic nature of frequency and duration of medical interventions, allows better utilization of available resources that can enable improvements in quality of services, patients’ and employees’ satisfaction and costs reduction.

The literature show compelling evidences to assume that the level of demand for healthcare services varies over time and depends on the hour of the day, day of the week and month of the year. Taking into account these regularities, it is possible to predict future variations of the demand and consequently the number of personnel that should be available at the certain periods of time. For this purpose, it is necessary to perform various statistical analyses to examine whether it is possible to determine the daily, weekly or monthly patterns. Some of statistical techniques that are mainly used in this phase are: correlation analysis, nonparametric tests and contingency tables. After detailed statistical analysis it is also important to choose the most suitable forecasting model. Based on an extensive literature review, the seasonal character of the demand for healthcare services can be assumed. Therefore, the forecasting methods that incorporate seasonality are most often the best choice. For example, Baker and Fitzpatrick (Baker & Fitzpatrick, 1986) were the first who applied Winters exponential smoothing model to obtain accurate forecasts of the daily volume of emergency and non-emergency calls at the ambulance service of South Carolina. To choose the exponential smoothing parameters, goal and quadratic programming were applied. The resulting forecasts were compared to those obtained by using a multiple linear-regression model and a single-objective Winters exponential smoothing model and the smoothing method yielded more accurate forecasts.

Time-series models were developed to the emergency medical service of the Canadian city Calgary (Channouf et al, 2007). The estimated models were compared in terms of goodness of

fit and forecasting accuracy. The results showed that an autoregressive model of daily volumes and a multinomial distribution for the vector of number of calls in each hour conditional on the total volume of calls during the day, are superior for their data.

Zuidhof (Zuidhof, 2010) analysed the demand of ambulance services in Amsterdam. Holt Winters exponential smoothing models, seasonal autoregressive integrated moving average (ARIMA) models and multiple regression models were used to forecast the daily demand. In this case, the best forecast has been obtained by multiple regression model.

Besides abovementioned univariate and multivariate time series analysis, artificial neural network can also be designed to forecast the demand for healthcare services of specific areas during different times of the day (Setzler et al, 2009).

The aim of this chapter is to present scientific and practical challenges of demand analysis and forecasting and to mention some interesting papers dealing with this topic. There are many more various quantitative approaches for forecasting demand for healthcare services and their application mainly depend on the characteristics of original primary data.

3 Determination of the optimal staffing level

Furthermore, it is important to embed observed regularities in the demand into human resources allocation process, by determining the optimal staffing level for different periods of time. In that way, the balance between demand and supply of medical services can be achieved, which consequently leads to the improvement of quality of services and increased satisfaction for both, patients and medical staff. The usual organizational problem of many healthcare organizations is that the number of available staff has been determined ad hoc, regardless of the demand and system load, which might negatively influence the efficiency of the whole system. Here, the application of queueing theory in healthcare organizations might improve patients' and employees' satisfaction by reducing the time spent in waiting lines (Bekker & DeBruin, 2010), (Yankovic & Green, 2011), (Brahma, 2012). Waiting is a part of everyday activities in all segments of life, but people are even more sensitive when waiting for medical services to resolve their health problems. It is important to state that waiting for scheduled medical treatments is not a subject of queueing theory. Mathematical analysis of waiting lines is dealing with queues that occur when patients arrive without an appointment. In a long period of time, most of healthcare organizations have sufficient capacities to serve even larger number of patients than the real demand, but the queues occur due to the unequal distribution of arrivals over time. Therefore, waiting lines are short term phenomena. The increase of a number of service providers (i.e. servers) leads to the greater quality and

satisfaction, but also consequently to the higher costs. Those quantitative models are very applicative and suitable for determination of the most efficient way of the mass services system functioning (Ernst et al, 2004). The overwhelming system capacity might cause the unnecessary costs, but on the other hand, insufficient number of servers could lead to the longer waiting times or other negative consequences, sometimes even with the fatal outcome. Queueing theory models ensure the achievement of balance between the available resources and quality of services at the one side and financial boundaries at the other side. Erlang B (Zuidhof, 2010) and Erlang C are queueing models that are most often applied in healthcare organizations.

Besides queueing theory and other analytical methods, simulation models are frequently used for modelling various processes in healthcare organizations. Group of authors (Ghanes et al, 2015) used discrete event simulation on order to determine the best way of staffing in the emergency department in one French hospital. DeRienzo (DeRienzo et al 2016) developed a discrete event simulation model of nursing staff needed in a neonatal intensive care unit and then validated the model against historical data. They assume that the discrete event simulation tool model can provide healthcare managers a valid method of modeling patient mix, patient acuity, staffing needs, and costs in the present state and future state.

4 Staff scheduling and rostering

Employee scheduling in healthcare organizations is a very complicated task due to the nature of vital medical services that must be provided 24h every day. Besides that, there are numerous legal and business regulations and agreements, which must be complied during this process. Compared to business organizations, determination of the optimal staffing level and scheduling employees is more complex in healthcare institutions, which are faced with very variable demand, chronic lack (or excess) of the workforce for certain profiles and limited budget. A great challenge for health care managers is also balancing between satisfaction of patients and satisfaction of employees. The application of quantitative models facilitates staff rostering process, by cost reduction and time saving. The great value of schedule is that it links demand (through determinate staffing levels) and supply (available staff) which ensures better organization of work and higher level of satisfaction. Mainly, optimization models and simulation are developed and applied to aid staff scheduling and rostering. Usually it is difficult to transfer models from one organization to another one without significant changes, thus one of the future trends is to make a schedule more adaptable to constant changes and personal preferences.

Kumar (Kumar et al., 2014) presented how linear programming solves the nurses scheduling problem in hospitals. Nurses should benefit from this study by having a higher quality schedules while the employees in charge of scheduling should enjoy the positive benefits of an optimization tool to solve problem related to healthcare. Kwak and Li (Kwak & Li, 1997) illustrated the use of linear goal programming to assist and guide scheduling process in a hospital. The purpose of this study was to assign the personnel to the proper shift hours that enable management to meet the objective of minimizing the total payroll costs. Filho (Filho et al., 2012) used the Constraint Satisfaction Problem approach to solve human resource allocation problems in cooperative health services. Authors proposed a new tool for planning human resources utilization in hospital plants by using simulations for measuring the performance of the proposed heuristics.

Conclusion

The main goal of this paper was to show how application of operational research models can improve decision making process, especially addressing efficient workforce allocation. We presented the review of different groups of quantitative models which can be applied to various aspects of managing human resources in healthcare organizations. Ability to analyze and predict demand of health care services is of great importance, so we described how time series analysis and various econometric models can be used to explore time and location dependent variations of the demand. Furthermore, queuing theory and optimization models were discussed in order to obtain the optimal allocation of human resources that leads to improvement in patients' and employees' satisfaction and economic efficiency of the whole healthcare system. Important prerequisite for the comprehensive implementation of quantitative methods is the improvement and standardization of electronic records in healthcare organizations. It would provide an integral database for realization of scientific research projects, improve business organization throughout the healthcare system and facilitate the process of monitoring and evaluation. The application of mathematical models greatly accelerates and simplifies the process of human resources allocation, which is especially important in complex healthcare organizations. Integration of quantitative methods, management and health is necessary in order to improve the overall healthcare system in today's rapidly changing environment.

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