

Applications of Operations Research in Healthcare Industry

V V Lopa Mudra, Lashika Arora, Dikshita Jangid, Tushar Makhija, Tarun Yagees A

Submitted: 25-10-2022

Accepted: 04-11-2022

I. INTRODUCTION

Meeting the customer expectations are of primary importance to hospitals when it comes to building their brand and trust that people have in them. The hospital sector has been using a rule of thumb than a strategic research-based approach for a long time, because of this there have been several issues faced by the hospitals from crowd management in the outpatient department to optimally using operation facilities and nurse burnout. The gap between the customer satisfaction and perceived quality of service and the actual experience in the facility is what determines how satisfied or dissatisfied the customer is. So, a research-based approach using essential operations research tools will help a great deal in improving every area of services in the hospital and ultimately help every customer have a positive experience in the hospital. So here, we look at how to implement appropriate tools to solve issues faced by the hospitals, due to the conventional rule of thumb approach, and suggest measures to better the service in all aspects to help give a much more positive experience to everyone who visits the facility.

II. LITERATURE REVIEW

Chapter 5 of Applications of Operations Research models to problems in Health Care by Professor Bruce L. Golden from R. H. Smith School of Business - This paper talks about distribution of emergency supplies on time. Places near to accidents and natural disasters need emergency supplies immediately than the ones situated away from the location of accident or disaster. In real life, ideally, more urgent locations should be visited before than the less urgent ones. The tool used to solve the problem of visiting the location on time is Target Visitation Problem (TVP) which is hybrid of Travelling Salesman Problem (TSP) and Linear Ordering problem (LO). It has been concluded that the order of visiting the locations to distribute emergency

supplies is not important, but the time taken to deliver the emergency supplies is of priority. Target Visitation Problem (TVP) balances the need to visit the location of emergency to handover emergency supplies quickly with the aim of efficiency, thus solving the problem.

Murphy Choy, Michelle Cheong - Nurse scheduling is considered as a NP hazard in the healthcare industry. There must be a strategic approach for nurse scheduling so that there is continuous and adequate patient care services available. This becomes complicated when additional factors such as unforeseen accidents, type of disease, health worker specialization, nurse preferences (vacation, leaves etc.), legal requirements, industry standards, avoiding of consecutive shifts and many more factors take the form of constraints. The resulting shift schedule must be fair in the distribution of shifts and the mentioned additional factors for proper functioning of the hospital. The tool used to solve the nurse scheduling problem is the Flexible Mixed Integer Programming model. The Flexible Mixed Integer Programming model considers all the constraints required. The resulting schedule is a balanced schedule as it considers all the additional factors. This tool is an improvement over the traditional manual approach which was costly as well as inefficient in giving a balanced schedule.

Somayeh Ghazalbash, Mohammad Mehdi Sepehri, Pejman Shadpour and Arezoo Atighehchian - Operating room scheduling is one of the most important and complex part of the healthcare industry. Before scheduling a time for an operating room, a number of constraints such as qualifications or specializations of fellows and residents, assigning assistant surgeons to training operations, the required equipment for surgery in the operating room, balanced distribution of surgeries among surgeon groups, medical precaution constraints of infected patients, training plan of residents, finish time of the last surgery and many must be evaluated such that the idle time of

the operating room and Cmax which is the completion of the last patient's surgery are minimized. The operations research tool used to solve the operating room scheduling problem is the Novel Mixed Integer Programming Model. The Novel Mixed Integer Programming Model solves the nurse scheduling problem in teaching hospitals with minimizing the idle time of operating rooms and Cmax. This tool also considers all the constraints mentioned above and gives the optimal schedule. This model can also be extended by adding more constraints such as ICU bed availability, ward bed availability and many more for future use.

Jingyu Zhang, Jennifer E. Mason, Brian T. Denton and William P. Pierskalla- Due to advancements made in health care industry there are patients which are diagnosed with multiple disease. Diabetes for instance is complex as diabetes causes long term issues that affects most parts of the body and as diabetes develop symptoms very slowly so it goes undetected for years.

1. Disease prevention and screening are important in determining the health of the population. OR has been an immense help to inform decisions related to prevention and screening for a long time.
2. Treatment decisions are important in cases where patients have chronic diseases like HIV, Diabetes. OR helps in taking decisions related to drug treatment and organ transplantation
3. OR has helped in one field which decision making in the field of diabetes.

The tool which are mainly used in prevention, screening, treatment choices are dynamic programming, mathematical programming and simulation. In flu vaccination they used continuous-state discrete-time dynamic programming.

The use of OR in medical industry has impacted a lot as now the doctors are able to analyse the reports and now can make near optimal decisions. The dynamic programming has helped to increase the life expectancy and has also helped in making policies cost effective and accurate, the Markov model is used to prevent heart disease and the mathematical programming is used to take complex decisions to increase the effectiveness of the treatment.

Chapter 2 of Applications of Operations Research models to problems in Health Care by Professor Bruce L. Golden from R. H. Smith School of Business - The blood bank vehicles act as a major part in saving a person's life as it is used by the hospitals in time of emergencies. The problem with the hospital is to shorten the distance

it takes to make visits to blood collection camps. In cases of emergencies the two main points to keep in mind is to check the efficiency of the route and to reach the hospital quickly.

The formulation of Transport salesman problem (TSP) is used to solve this problem.

The Transport Salesman Problem (TSP) is taking all the routes into consideration of the driver and helps the driver to reach efficiency during his journey and also helps the hospital in cases of emergencies as the driver can deviate from the route and reach the hospital in time.

Seyda Gur and Tamer Eren- One of their main problems is to schedule the operating room properly as they are a big part of the revenue for the hospital and the other problem is to utilize the operating rooms effectively and efficiently. The tools used in scheduling of operating rooms is mixed integer linear programming, constraint programming, simulation, and dynamic programming. By using the different operational methods, the problem of scheduling operating rooms is somewhere resolved as the managers can schedule the operating keeping in regard several factors like staff satisfaction, uncertainty, and other factors.

AbdulrahimShamayleh - PACU (Post Anaesthesia Care Unit) is the first stage after a surgical procedure takes place, and both a PACU room and a PACU nurse should be available for the patient or else the patient will have to wait in the OR. If a PACU room and a PACU nurse are not available before an operation begins, the procedure is halted until both can be made available. This can increase operating time and costs and is inefficient. To improve utilization of the Operating Room and the efficiency of the entire system Simulation model was used to evaluate and model the surgical theater. A simulation model was developed with the help of different sequencing (First Come First Serve, Longest Cases First, and Shortest Cases First) and the number of open operating rooms, and the results obtained will help the operating room manager in efficient scheduling and offer them flexibility with operating times.

SuryatiSitepu et al - Hospital capacity planning is measured by the number of beds, and doctors and nurses accordingly, and these capacity decisions have been traditionally made based on target occupancy levels. This problem can be solved by using a linear programming problem with the help of branch and bound method. With the help of this model, managers can find all the decision variables that would help minimize operating costs.

G. K. Bahr, J. G. Kereiakes, H. Horwitz, R. Finney, J. Galvin and K. Goode - A computer tool is employed to compare the dose distribution for potential treatment options. Every time a patient is treated using a configuration that is more complex, concepts for various multifield configurations are created and submitted to the University. If after initial evaluation there's dissatisfaction with all the arrangements evaluated, the procedure is repeated, this time with better possibility of delivering an acceptable solution. This trial and error process can prove to be time consuming. Spatial optimization of treatment plans can be achieved by using Linear Programming. The authors approached this challenge by removing as much of the human intuition from spatial treatment planning as possible and using the computer as a tool to plan the therapy under specific parameters, preconditions, and limitations.

Deepak Yaduvanshi, Ashu Sharma and Praful Vijay More - Waiting time is a major factor that comes in when one tries to evaluate their experience in hospital services. Hospital services operations, particularly the outpatient department (OPD) play a key role in providing quality healthcare. The interpersonal skills of the hospital staff, availability of medicines, hospital infrastructure and medical information plays a key role in managing OPD and creating a positive impact on patient satisfaction (Natarajan, 2006). Due to poor hospital services operations, patients tend to spend a lot of time getting the services they need (Dellaert et al., 2015; Lohlnet et al., 2015). The Tool used to solve this problem is Queuing theory. It helped analyze the process flow and break it down and help suggest areas of improvement to further optimize the hospital operations. In the process of applying, it in many areas were taken under review and it helped reach better and more detailed suggestions as to what changes to make and where to make it. The optimal number of staff to be appointed per patient and guidance instructions to patients as they enter were also found out by observing the current functioning and the availability of staff.

Chapter 7 of Applications of Operations Research models to problems in Health Care by Professor Bruce L. Golden from R. H. Smith School of Business - The boarding of post-anesthesia unit as intensive care unit beds unavailable is a problem faced as the post-operative bed availability is often ignored while operating room schedules in hospitals are produced. If hospitals can learn to utilize their operating rooms (OR) more effectively, they can serve more patients and serve them better. The post-anesthesia care unit

(PACU) boarding is undesirable for several reasons. First, it increases stress on the staff. Second, there is evidence that PACU boarding extends a patient's length of stay and increases hospital costs (see Zollinger 1999). Third, PACU boarding can have a negative impact on new surgical cases. Therefore, to tackle the boarding problem, an accurate model of patient flow is required. The Tool used to solve this problem is Integer programming and simulation. It helped develop an accurate model of flow of patient flow that can be used to test proposed solutions. This further helped to point out the fact that a small number of easy alterations have a significant impact in reducing the number of boarders. By considering the patient flow of all service lines together and assigning surgical block time to improve the flow through the system can reduce the number of boarders.

Nurse burnout issue in healthcare was reported as early as 1979 (F.J Storlie, 1979). In 1995 Cullen identified the factors that were embedded within healthcare, institutional, societal and nursing systems that caused stressful conditions and burnout for nurses (Cullen, 1995). As a result, the nursing profession has had a chronic problem of absenteeism, and reduced productivity (Cordes, 1993). The healthcare system in the United States is severely strained because of a shortage in nurses and nurse burnout (P.VU, 2008). The Tool used to solve this problem is Data-integrated simulation-based optimization. A heuristic (HEU) policy assigns a newly admitted patient to the nurse who has performed the least assigned direct care among all the nurses. A partially-optimized (OPT) policy seeks to minimize the difference in workload among the nurses for the entire shift by estimating direct care from simulation to evaluate nurse-patient assignments. A data set provided by the hospital which was used to create the simulation used as base to form the policies. The data set had 8 variables. It helped assess the balance of nurse workload. It was found eventually that the OPT performed better than the HEU.

Sam Afrane and Alex Appah - Long wait times are a sign of ineffective hospital services which all healthcare systems struggle with. Unless an appointment system is in place, the first-in-first-out queue discipline is typically used in healthcare settings. Alternatively, a set of patient classes with different priorities may be used, such as in an emergency room that prioritises the care of patients with life-threatening injuries. Long waiting periods often cause patients to feel unsatisfied and have harmful consequences. Queuing theory and

modelling, a useful tool for determining staffing requirements for the best performance with reference to hospital queuing issues. Queuing theory is used for examining waiting line performance indicators and making decisions in healthcare delivery systems. Following findings from a descriptive survey, it assisted the hospital in determining the ideal number of doctors and the number of efficient consulting hours needed to shorten patient wait times. Thus, it may be claimed that queuing theory and modelling are helpful contemporary tools for making decisions about capacity and resource challenges.

Carter Claiborne Price - Every major hospital faces difficulties with nurse resource allocation and effective bed management. Throughput is frequently strongly tied with the availability of beds further down the line for patient care and recovery for surgical services in general and cardiac surgical services especially Surgery schedules at large centres that are negatively impacted by downstream capacity, which reduce efficiency and throughput. Despite this effect, choosing the right combination of downstream beds is frequently decided based on things like space availability, financial limitations, and custom. Simulation model that maximises throughput while utilising the available physical resources for a heart surgery unit's post-operative bed flow. The simulation experiment showed that by changing the bed mix, the heart surgical service line could enhance throughput and increase yearly profit if more nursing personnel could be hired or by transitioning to a more effective setup the hospital may boost capacity without adding extra ICU or IMC rooms.

Irem Ozkarahan - Meeting the rising demand for healthcare services while cutting costs to enhance quality of treatment requires high use rates in surgical suites. The goal programming model, which can generate schedules that are best suited to the hospital's requirements. By prioritising requests for a given day based on surgeon preferences, room use, block constraints, and critical care capabilities, the strategy reduces downtime and overtime while enhancing satisfaction among surgeons, patients, and staff. To assess the model's suitability for achieving abstract goals, different accomplishment functions are also tested.

III. ANALYSIS AND FINDINGS

In operations research, one tool can be used to solve multiple problems that fall under the same category. The majority of the problems which were related to nurse scheduling, operating rooms scheduling, staffing, bed allocation, etc. were

solved by using LPP & Simulation models, which were mostly related to scheduling and planning of different things. Whereas Queuing theory has been used to solve problems relating to managing queues and analyzing waiting lines performance in hospitals. Similarly, one problem can be solved through various tools like Target Visitation problem and Travelling Sales problem was used for routing problems (such as the routing of blood bank vehicles and vans carrying emergency supplies). We have also observed that LPP and several types of LPP like Mixed Integer LPP were the most used Operations Research tool in the Healthcare industry. And almost all operations research tools that were used have the flexibility or provision to change or adapt to the environment, constraints, issues etc. over a period of time, thus making them more relatable.

IV. CONCLUSION

We attempted to understand the applicability of Operations Research in various areas of Healthcare sector. In this paper, in order to improve programme quality and efficiency as well as to provide the best results, we discussed a variety of issues and the many OR techniques used to address them. From our study we could observe that tools like models of LPP and simulation are widely being used to improve the existing solutions of scheduling and staffing problems in Healthcare industry.

REFERENCES

- [1]. Target visitation problem and distribution of emergency supplies - Chapter 5 of Applications of Operations Research models to problems in Health Care.
- [2]. A flexible mixed integer programming framework for nurse scheduling - Murphy Choy, Michelle Cheong.
- [3]. Operating room scheduling in teaching hospitals - Somayeh Ghazalbash, Mohammas Mehdi Sepehri, Pejman Shadpour and Arezoo Atighehchian.
- [4]. Applications of Operations Research to the Prevention, Detection, and Treatment of Disease - Jingyu Zhang, Jennifer E. Mason, Brian T. Denton and William P. Pierskalla.
- [5]. Routing Blood Bank Vehicles: An application of the Travelling Salesman Problem with a Centre - Chapter 2 of Applications of Operations Research models to problems in Health Care by

- Professor Bruce L. Golden from R. H. Smith School of Business.
- [6]. Application of Operational Research Techniques in Operating Room Scheduling Problems - Seyda Gur and Tamer Eren.
- [7]. Queuing theory and the management of waiting-time in hospitals: the case of anglo gold ashanti hospital in ghana - Sam Afrane and Alex Appah.
- [8]. Maximizing cardiac surgery throughput - Chapter 4 of Applications of Operations Research models to problems in Health Care.
- [9]. Allocation of surgeries to operating rooms by goal programming - IremOzkarahan.
- [10]. Surgical Theater Utilization and PACU Staffing - AbdulrahimShamayleh.
- [11]. Optimization Model for Capacity Management and Bed Scheduling for Hospital - SuryatiSitepu et al.
- [12]. The Method of Linear Programming Applied to Radiation Treatment Planning - G. K. Bahr, J. G. Kereiakes, H. Horwitz, R. Finney, J. Galvin, K. Goode.
- [13]. Application of Queuing Theory to Optimize Waiting Time in Hospital Operations - Deepak Yaduvanshi, Ashu Sharma and Praful Vijay More.
- [14]. Reducing Boarding in a Post-Anesthesia Care Unit - Chapter 7 of Applications of Operations Research models to problems in Health Care by Professor Bruce L. Golden from R. H. Smith School of Business.
- [15]. A data-integrated simulation-based optimization for assigning nurses to patient admissions.