ISSN No:-2456 – 2165

A Study of Operations Research in Healthcare

By

Admin Group 7

Nandan Shah	(A031) – 74021016537
Ninad Thawait	(A032) – 74021016605
Pranav Kohli	(A033) – 74021016356
Prithika Kharwar	(A034) - 74021016350
Priti Bhatt	(A035) – 74021016102

Date: 4th October 2017

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Signature Marks

ISSN No:-2456 – 2165

ACKNOWLEDGEMENTS

The following research paper has been done under the guidance of Mrs. Tahereem Bardi, our Operations Research professor for the third semester, at NMIMS university's Anil Surendra Modi School Of Commerce. We would like to thank her for her support and also show our gratitude towards her for giving the valuable insights which has made this research paper possible.

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ABSTRACT

For more than 30 years, Operations Research teams have shown great interest in the field of healthcare and medical delivery systems and how they function around the globe. In the past few years, the birth rates have been decreasing considerably, especially in developed countries. Along with that, the average global lifespan and longevity has also been rising. Healthcare has obviously proven to be an important aspect in today's modern and fast paced world, where optimization of scarce resources is the utmost need of the hour. The attention has gradually expanded from merely resource allocation and has moved forward towards strategic planning, in order to include operational issues, namely- resource scheduling and treatment planning.

This research paper studies the various application and uses of Operations Research in the area of healthcare delivery systems and their effectiveness. This paper reviews and assesses the major contributions involving contemporary optimisation issues in this particular area of study. The study highlights the research activities in current use, throwing light on the optimisation issues faced by the industry, along with the methods used to find solutions to the optimisation problems and putting them into practice.

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KEYWORDS

Keywords used in the analysis:

Location selection, P-medium models, demand forecasting, network models, demographic groupings, scheduling, simulations, optimization, diminishment, hybrid, crises, constrains, logistics, stock level, drug allocation, disease diagnostics.

Specialised healthcare, preventive healthcare, organ allocation, medical simulation, vaccine algorithm, HIV prevention program, medical screening programmes, treatment planning, medical therapeutics, diabetes complications, healthcare cost, dynamic programming algorithm, linear formulations, non-linear formulations.

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OBJECTIVES

To show that Operations Research has a crucial and vital role to play in making and developing a stronger healthcare system, in order to improve the system's performance and its impact and effect on the public health.

Another aim is to showcase the current working definitions of operations research, implementations research and the present healthcare systems research to provide greater clarity for scientists, policy makers and donors working towards the betterment of the global healthcare systems.

METHODOLOGY

The following research is a secondary research, and is qualitative in nature combined with a few statistical numbers in lieu of the current global healthcare scenario. The major source of information for this paper and its analysis has been other published papers, books, articles, web blogs and medical journals that provide an insight to the systems and challenges for our topic. We also went through a few hospital journals and medical magazines with related articles.

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1. ANALYSIS

A. HEALTHCARE PLANNING

In today's world where countries are emphasizing more and more on providing a better lifestyle for their people and to provide a better lifestyle, it is very important for the country has to have a sound health care system.

Planning is setting of up objectives and then devising strategies to attain those objectives in such a way that there is minimal wastage. Planning is really important in healthcare because wastage or misuse of resources could lead to be fatal. Healthcare planning is making sure that proper and adequate healthcare facilities are provided where they are most needed.

Operations Research can be used for optimization and cost-control measures. OR in health can help estimation of future demand for services in order to build enough capacity or selection of hospital locations for covering a target population or design of the emergency facilities for efficient handling of patients.

a). Location selection

Location selection is selecting a location for the health care facility which will help cover maximum number of people and also be a viable location. Daskin and Dean reviewed location covering, maximal covering and P-medium models for addressing the location planning issue in healthcare. They presented a novel application of the set covering model for analysing cytological samples.

b). Healthcare Centres

Location problems arising in developing countries like India have been discussed by several authors.

Smith studied planning of sustainable community healthcare in the rural areas of developing countries. They considered both top-down and bottom-up hierarchical location models for the efficient planning of community health schemes and proposed a Mixed Integer Program for determining the locations of maximal number of

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sustainable facilities which can cover the maximum number of people.

Their integer-programming model is adequate for rural areas of under-developed countries where, during bad weather conditions, accessibility is diminished because of the lack of all-weather roads.

c). Emergency vehicles

It is really important that the emergency vehicles like ambulances are optimally used because if it isn't used in the best possible way then there are people's lives at stake. Because even the slightest time saved can help save someone's life. A few researchers have studied this problem using different methods.

The three objectives that measure the service levels are:

1. Maximisation of the population covered by one vehicle;
2. Maximisation of the population with backup coverage; and
3. Minimisation of the total travel distance from locations at a distance bigger than a pre-specified distance.

d). Demand Forecasting

Demand forecasting is forecasting the future demand for a particular product or service. Accurate demand forecasting is really important in healthcare planning, its results providing the input to several optimisation problems. Forecasting methods can be qualitative or quantitative, researchers usually focus on quantitative analysis because it is more accurate than the qualitative method. However, the problem with that is that it requires good and historical data.

These are four common methods for forecasting demand for healthcare services: percent adjustment, 12-month moving average, trend line, and seasonality forecast. These four methods are all based upon the organization's recent historical demand. Healthcare financial managers who want to project demand for healthcare services in their facility should understand the advantages and disadvantages of each method and then select the method that will best meet the organization's needs.

They used data from daily patient arrivals at the emergency departments of three different hospitals and

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considered the following methods: time series regression, exponential smoothing, seasonal autoregressive integrated moving average and artificial neural network models.

B. HEALTHCARE MANAGEMENT & LOGISTICS

The delicate nature of Healthcare sector demands and involves logistics in a variety of ways which involve maintenance of medicine stock levels and asset allocation. Logistics is the back bone of supply chain in hospitals and ensures smooth operations, procurement, and internal distribution and Information technology systems.

There have been many studies and discoveries are the logistics sector. Some of the contemporary studies have been discussed in the next paragraph:

In 2003 Swaminathan proposed a multi-objective optimization heuristic for apportioning rare drugs to centers, having considered proficiency, effectiveness and equity of the drug allocation process.

They particularly tended to enhancement of the flow between the central sterilisation departments and the Operating theatres by building up a cost minimisation model involving transportation and stock inventory. For this specific instance of problem, they utilized Dynamic Programming to discover a solution in polynomial time.

e). Management and Manufacturing

Several researchers have looked into manufacturing and management areas of healthcare. This section discusses a selected few:

The principal stage ascertains the number of patterns to be cut and the second stage finds the cutting arrangement. The problems were subject to request, availability of materials, regular as well as additional working hours and due date constraints.

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They utilized two integer-programming models: one for taking care of the issue of minimising trim loss and the other for reducing the aggregate cost associated with material inputs, number of set-ups, work hours and overdue time.

They tended to five distinct targets: minimisation of death cases, minimisation of years of life lost, minimisation of occurrence, minimisation of prevalence, and minimisation of loss of quality of life.

Blood donation centre management policies, decisions and theories of perishable inventories are assessed in Prastacos (1984) and Nahmias (1982).

Patient scheduling, resource scheduling and logistics in healthcare are likely the most broadly referenced administration issues in customary OR diaries.

f). Patient Scheduling

An optimised patient– staff/patient– facilities schedule can prompt an impressive cost diminishment and an expansion in service quality.

The issue of scheduling patients for surgery at a hospital in Sweden given certain medicinal, monetary and time constraints is addressed by Persson and Persson (2009). To anticipate long lines, patients are permitted to be scheduled for surgery at different clinics as indicated by the Swedish health policy. They built up a hybrid simulation and integer programming approach for taking care of the issue.

Patient– staff scheduling is examined in Ogulata et al. (2008). They created progressive numerical models to produce the schedules and considered three sub-issues:

(1) Selection of patients;

(2) Assignment of patients to the staff; and

(3) Scheduling of the patients for the duration of the day.

The targets are to expand the number of patients, to adjust the workloads of physiotherapists, and to limit waiting times of the patients on their treatment days. They tested their models with real-world data from hospitals.

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Dynamic age of patient calendars, having varying needs, to general human healthcare facilities are displayed as a Markov decision process. The model is settled utilizing Approximate Dynamic Programming and the quality of solutions is broke down through recreation.

They enhanced existing multiclass, open queuing, arrange models and exhibited that parallelisation can for sure diminish the process durations for the patients requiring various diagnostic or treatment procedures. They compared the results with those obtained through simulation.

A Mixed Integer Program is utilized as a benchmark for approving the solution quality.

g). Resource Scheduling

It has been a dynamic territory of research in healthcare for expanding limit use, cost control measures and enhancing strategic and operational efficiencies of administrations and offices. Unique consideration has been given to nurse scheduling however a few different issues have additionally been addressed.

h). Operating Room and Physician Scheduling

In spite of the fact that of much intrigue, the issue of scheduling doctors as well as working rooms in healthcare has not received as much consideration as nurse scheduling.

Their models can decide how much working room time every specialist should be assigned yet, much of the time, cannot give detailed information on the timing of the assignments.

Thus, heuristics in light of fractional branch-and-bound are used in Beaulieu et al. (2000) for scheduling doctors in crisis rooms to such an extent that the sum of penalties related with "deviation" constraints in minimized.

An Integer Programming model is produced in Santibanez et al. (2007) to schedule surgical blocks for every strength into working rooms, considering working room time accessibility and post-surgical resource constraints. The model was utilized by the doctor's facilities in a British Columbia Health Authority.

An Integer Programming model, together with Simulation, is likewise utilized for apportioning operating room capacity to specialties on a weekly basis. Minimisation of inpatients' cost (measured by their length of stay) is expected.

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The occupant on call scheduling issue is demonstrated as a Mixed Integer Program and understood by heuristic techniques that adventure the system structure inserted in the model.

Worries on bed inhabitance are reflected in work by Belien and Demeulemeester (2007). They tended to the issue of building surgery schedules with levelled resulting bed inhabitance and considered two sorts of constraints:

(1) Request limitations to guarantee that every specialist (or surgical gathering) acquires a specific number of working room, and

(2) Limit requirements to confine the accessible obstructs every day. Heuristics in view of blended Integer Programming and a metaheuristic are created to limit the normal aggregate bed shortage.

The timetable of crisis medicinal occupants is compelled by an extensive number of tenets: confines on number of consecutive work hours, number of day and nightshifts, inhabitant staffing prerequisites as indicated by rank levels for the day and night shifts, restrictions on the number of consecutive day and night shifts assigned, vacation periods, weekend time-off requests and a fair distribution of responsibilities among the residents.

i). Others

A few scientists have investigated assembling and administration regions of healthcare. This segment talks about a chose few. Aktin and Ozdemir (2009) built up a two-stage approach for coronary stent producing from a one-dimensional cutting stock issue.

The first arrange figures the quantity of examples to be cut and the second stage finds the cutting arrangement. The issues were liable to request, material accessibility, standard and in addition overtime working hours and due date constraints.

They utilized two integer programming models: one for taking care of the issue of limiting trim misfortune and the other for limiting the aggregate cost related with material input, number of set-ups, work hours and overdue time.

They tended to five different targets: minimisation of death cases, minimisation of years of life lost, minimisation of incidence, minimisation of prevalence, and minimisation of loss of quality of life.

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They demonstrated that the blend of OR and Health Economics has a gigantic potential for giving viable data to the leaders.

C. HEALTHCARE PRACTICE

Apart from tending to other healthcare management aspects, OR specialists have made huge contribution to drug treatment planning, infectious disease prevention and control, pandemic preparedness, crisis response and organ donation.

a). Disease Diagnosis

A survey on the utilization of the Analytic Hierarchy Process to various issues in medical decision making is likewise given in Liberatore and Nydick (2008). They compressed 50 distinctive articles from seven categories: diagnosis, patient participation, therapy/treatment, organ transplantation, project and technology evaluation and selection, human resource planning and healthcare evaluation and policy.

They applied worldwide optimization and dynamical frameworks for anticipating epileptic seizures.

Bortfeld et al. (2008) addressed uncertainties in radiation therapy for cancer patients. They gave a robust optimization formulation of the problem that generalizes mathematical-programming formulations. They likewise examined extensive computational outcomes utilizing clinical information.

Paltiel et al. presented "Asthma Policy Model" as a Markov state-transition simulationto forecast asthma-related symptoms, acute exacerbations, quality-adjusted life expectancy,healthcare expenses and cost effectiveness. They gave extensive discussions of the results from simulation on a 10-year horizon.

At last, coronary risk prediction is tended to by Alexe et al. The authors presented the Logical Analysis of Data and examined how it can be utilized for disease prediction.

b). Treatment Planning

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Within Medical Therapeutics, an area that has been getting special attention is radiation treatment. Still, several other areas of planning and intervention have been the subject of study as reflected in the papers by Paltiel et al., Lee et al. and Zenios.

As of late, Holder gave a comprehensive discussion of linear- and non-linear programming models for Intensity Modulated Radiotherapy Treatment (IMRT). Moreover, Ehrgott et al. (2008) gave an extensive survey of the optimization models, techniques and theories concerning IMRT plan.

The issues are described in quadratic, linear, piece-wise linear and non-linear formulations. The authors gave details on how to generate practical solutions and discussed several optimization tools and programming environments.

Minimisation of aggregate treatment time in cancer radiotherapy utilizing multileaf collimators was studied by Wake et al. The approach considers a Mixed Integer Program that happens to be a modification of a cutting-stock problem formulation.

D. SPECIALIZED AND PREVENTIVE HEALTHCARE

a). Organ Donation and Transplant

Most research work on organ transplantation focuses on policies for allocating donated organs to the waiting patients, liver and especially kidney transplants being the most monitored problems.

- Segev et al. (2005) presented a software solution for optimising kidney pair donation based on maximum edge-weight matching algorithm. A graph is constructed by the algorithm in which each node is an incompatible donor–recipient pair and each edge is a potential match between the two connecting nodes. By entering the blood type, antibody and antigen information for each pair of nodes, the graph can be constructed.
- Alagoz et al. (2004) had taken up analysis of liver transplants. A study was conducted on how to optimally time liver transplant to maximise the patient's total reward. It suggested that most research work on the optimal allocation of organs are focused on designing an optimal allocation system.

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- A biologically based discrete-event simulation to test changes in allocation policies for liver diseases was designed by Shechter et al. (2005).

b). Prevention of Diseases

- Optimisation problems related to the prevention of diseases concern mostly vaccine selection. Sewell and Jacobson (2003) developed the vaccine selection algorithm to cover the entire immunisation schedule. They developed an integer-programming model to assess the economic premium that exists in having combination vaccines available.
- Hall et al. (2008) addressed a vaccine formulary problem for generic childhood immunisation schedules. An integer-programming model was formulated to find the most number of vaccines that can be administered without extra-immunisation. To solve the model, an exact Dynamic Programming algorithm along with a random heuristic for the integer-programming model is developed.
- An annual vaccine-strains selection problem was formulated as a stochastic dynamic program by Wu et al. (2005). The theory of shape space that maps each vaccine and epidemic strain to a point of a multidimensional space was used
- For HIV prevention, a resource allocation problem was addressed. A linear-programming model for improving on past allocation strategies was developed. Brandeau et al. (2003) used non-linear optimisation techniques along with epidemic modelling to determine the optimal allocation of limited resources for epidemic control in multiple, non-interacting populations.
- A Markov model of costs, quality of life and survival associated with a HIV-screening programme to analyse gains and effectiveness of screening for HIV during the highly active antiretroviral therapy was used. Prediction of future patient numbers as well as associated cost of healthcare at different AIDS clinics in India was estimated by using simulation.
- Partner notification along with contract tracing can prove to be of a great help with the view to control infectious disease spread, in the same time determining the optimal level of investment required is challenging. Armbruster and Brandeau (2007) presented a simulation-based methodology to evaluate cost the and effectiveness of different levels of contact tracing.

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2. CONCLUSION AND RECOMMENDATIONS

Amid the most recent decade, OR research groups have turned out to be progressively more keen on handling various testing issues in medicinal services. By tending to the fundamental streamlining issues, both deterministic and non-deterministic models have been utilized to catch this present reality needs and give a methodical system to examination and assessment. Numerous new issues have been illuminated and many already referred to "best" arrangements and in addition arrangement systems have been made strides. They helped impressively to enhance arranging, conveyance and administration of social insurance administrations.

Recreation and related non-deterministic research in OR cover around 15% of the current distributions in medicinal services applications. Scientists have tendepideed to for the most part the improvement issues related with hospital admission, hospital services, patient recovery, resource planning, facility utilization, logistics, supply-chain coordination, vaccination, bioterrorism and emergency response.

The dominant part of current productions in the deterministic side of OR include scientific programming models and address an extensive variety of arrangement strategies including column- generation, shadow pricing, primal-dual, branch-and-cut, branch-and-bound and interior-point methods.

Dynamic programming models have been used for surgery and emergency room scheduling, vaccine formulary, as well as capacity planning. Key application areas include: treatment selection and radiotherapy treatment planning, emergency-related resource/budget allocation, location planning for medical services, staff and shift scheduling, and epidemic modelling.

An intriguing developing range investigate includes consolidating unique OR philosophies for taking care of certain unpredictable classes of issues in social insurance. Neural Networks have been utilized as a part of a linear programming model for improving radiotherapy planning. Stimulated Strengthening has likewise been utilized as a heuristic optimization approach for radiotherapy planning and arrangement.

Another region of research investigated strategies that have been effectively utilized as a part of certain application spaces and analysed whether such systems are likewise reasonable for healthcare services and have made parallels with the defence segment. Practices and systems effectively utilized as a part of the assembling division (Lean manufacturing, Six Sigma, Theory of constrains).

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Considerably less work seems to have been completed with conceivably promising methodologies, for example, scenario planning, robust optimization and reliability modelling. In particular, adaptability and reliability are vital for healthcare delivery systems to perform well despite capacity limitations or closure of facilities.

Handling the extensive variety of optimization issues in medicinal services will absolutely require a lot of research work and can prove to be a major challenge. Distinguishing the optimization issues and catching significant parameters in numerical models can be a hard task. Finding and capturing relevant arrangement strategies or figuring new approach for unravelling solutions to the models can be tricky. Despite the fact that OR analysts have just managed numerous new issues and methodologies of solutions, much still stays to be explored and fathomed in this huge, and additionally, complex issue area.

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