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Optimization Of Medical Resource Allocation Using Linear Programming Techniques

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ABSTRACT

Due to the constantly changing patient hundreds in hospitals either personal or government the hassle increases with additional time assigning one-of-a-kind surgeries, allocation of beds, time hours and so on for various medical offerings in hospitals. These problems may be efficiently solved by using the usage of optimization strategies. In this paper a linear programming trouble (LPP) is formulated and is used to determine the foremost aggregate of different surgeries completed in a non-public medical institution that maximizes the overall profit contributed by means of patients.

Operation research is a systematic approach to problem solving for government choice-making which calls for the system of mathematical, economic and statistical models for selection and control issues to deal with situations bobbing up out of risk and uncertainty. In truth, selection and manipulate problems in any agency are more regularly related to sure, production scheduling, manpower planning and distribution, and maintenance. In this content we are going to speak about about the application of Linear Programming Problem in medical centre.

INTRODUCTION

Optimizing scientific useful resource allocation the use of Linear Programming (LP) techniques involves systematically assigning limited scientific sources (like health center beds, team of workers, and gadget) to numerous wishes or centers to gain most desirable consequences. Here's a detailed method to fixing this hassle using LP.

In fitness offerings area either private or authorities hospitals optimization techniques play an critical function towards achieving their dreams. The healthcare has additionally suffered several downfalls, while the authorities trying to address the all ranging troubles. Poor allocation of different surgeries may also purpose longer waiting time and can also get worse of the distinct patients illnesses. Day by means of Day with the boom in range of sufferers results in growing value of fitness services, with the proscribing bed availability and want to incorporate the rising health prices have intensified the look for options to conventional hospitalization. Thus the demanding situations in improving the healthcare best might also purpose increase in price with the discount of medical mistakes, and increases efficiency of healthcare offerings. The main goal of this article is to determine the most useful mixture of various surgical procedures such that the full earnings contributed by using patients is maximum. In order to obtain the superior answer of the formulated LPP, the answer is received via the use of Branch and Bound method through R software. Linear programming is an optimization technique applicable for the solution of problems in which the goal feature and the restrictions seem as linear feature of the choice variables. The constraint equations, in a linear programming from can be within the shape of inequalities or equalities. In different phrases linear programming is a mathematical programming technique to optimize overall performance beneath a fixed of useful resource constraints as distinctive by way of an organisation.

There are regularly many one of a kind options for improving fitness care policy or enhancing present day exercise in health care groups. The most desirable solution amongst the ones alternatives, i.E., the solution that satisfactory achieves a defined purpose, inclusive of maximizing patient high-quality of existence or minimizing affected person

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waiting time for services, won't be simply apparent. Constrained optimization methods use mathematical strategies to assist correctly and systematically identify the satisfactory (most effective) of all possible solutions to a problem while considering the relevant constraints, consisting of budget limits or staffing ability. Of path, mathematically premier solutions to all problems aren't always feasible; other nonquantifiable criteria, which include political limitations that can't be accounted for by way of described constraints, need to be considered. However, optimization techniques can nevertheless be tremendously informative to decision makers in imparting insights approximately superior goal solutions and the significance of the loss of gain or increased charges associated with the final policy desire. In fitness care, failing to perceive a mathematically superior or most advantageous answer represents a neglected opportunity to enhance financial performance inside the transport of care and clinical effects for sufferers.

Constrained optimization techniques are already extensively used in fitness care areas, which include selecting the most efficient region for new facilities, making the maximum efficient use of working room ability, group of workers making plans, and so on. They can also be instrumental in guiding scientific choice making in actual medical practice in which fitness specialists and sufferers face constraints, consisting of proximity to treatment facilities, medical insurance advantage designs, and the confined availability of health sources. Optimization is likewise beneficial for planning health care expenditure. An obvious example is the resource allocation trouble confronted via a planner with some of investment opportunities, however a set finances insufficient to fund all available possibilities. Perhaps the handiest case of that is wherein the investment possibilities are incremental to contemporary care and fall into awesome categories (e.G., youngsters's services, cardiovascular ailment, most cancers, respiratory ailment, and mental health) with separate budgets. In this situation, decisions about investments in one of a kind scientific areas may be made independently of one another. However, more typically the health care budget needs to be allotted throughout unique conditions. The trouble of choosing the first-rate set of investment opportunities to fund below a fixed budget constraint that allows you to meet an objective, together with maximizing total pleasant-adjusted existence-years (QALYs), can be addressed as an optimization problem. Given some of eligible interventions and a fixed budget, optimization can be used to clear up aid allocation issues.

In the beyond decade, the most enormous pandemic that emerged round the world is Covid-19. Covid-19 is an infectious respiratory sickness this is as a result of a virulent disease referred to as extreme acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The virus become first diagnosed in December 2019 in Wuhan, China, and become first isolated from the decrease respiratory tract of the Covid-19 patient sample. Statistical consequences from the epidemiological studies tested that SARS-CoV-2 is notably contagious and well-knownshows big variability —— the virus has advanced multiple lines and has affected over 2 hundred countries international. Moreover, Covid-19 has infected approximately 6 million humans and has brought about the death of 365,000 individuals global until the stop of May 2020[3]. Although the pandemic appears to be finishing, within much less than one month, five.3 million new showed instances and over forty eight,000 deaths have been pronounced (January 23 to February 19, 2023). As of February 2023, over 757 million Covid-19 cases and over 6.Eight million deaths were documented globally.

Most hospitals are overloaded as the wide variety of Covid-19 sufferers raised unexpectedly. Although most of the people of inflamed cases ought to recover themselves, there was nonetheless a big number of extreme instances that wished scientific treatment and hospitalization. The high variety of sufferers could area a sustained and top notch demand for clinical resources on the modern fitness system and can crush the clinical fitness infrastructure. Take the scenario inside the United States as an example, the medical demands created through the Covid-19 pandemic were properly beyond the capability of the hospital and medical infrastructure. Based at the numbers from the American Hospital Association, there has been beneath sixty eight,four hundred extensive care unit (ICU) mattress that turned into to be had for adult patients in the network medical institution of the entire state. Additionally, the restrained clinic beds, ventilators, personal protecting equipment (PPE), and trained respiratory therapists supplied crucial issues to the fitness systems and those problems had to be addressed right away. Thus, the pressing hassle changed into to solve the lack of clinic space and clinical sources to meet the huge health call for.

Operation Research is a science designed to provide quantitative equipment to decision – making procedures. Many researchers factor out the development of linear programming method as one of the most critical clinical advances of the second one half of of the twentieth century. Programming has confirmed to be an opportunity answer to plan Brach therapy, changing the traditional answers based totally on trial and errors. Linear Programming has been used to formulate balanced diets at minimal price and complying with a hard and fast of nutritional restrictions. In order to reap optimized solutions of healthcare problems related to economics and nutrients. First, we present the components of a food regimen at minimum value the usage of handiest two nutritional regulations aiming at making investigators inside the field of healthcare extra acquainted with the phrases and possibilities of the approach pronounced. Later,

the describe an optimized answer for issues associated with allocation of scientific interventions that complies with a set of finances restrictions and medical visits. Decision tree had been carried out to financial evaluation, this type of fee - effectiveness, to pick the excellent control strategies. The tree may also indicate with interventions use less useful resource and constitute higher first-class of lifestyles.

PRINCIPLES OF MEDICAL RESOURCE ALLOCATION

Generally, there has been a scarcity of clinical resources to satisfy the huge demand from sufferers all through the pandemic; consequently, an green allocation plan changed into needed to properly manage these sources and maximize their usage. In a situation wherein medical assets are limited, the questions of who receives the ones sources and how the resources can be divided ethically and equally end up significant. Ethical concepts want to be observed for allocating scarce scientific resources, and people concepts have been historically categorized into 4 classes: treating humans equally, favouring the worst-off, maximizing total advantages, and promoting and worthwhile social usefulness. Each of the 4 values can be operated in specific ways in actual-existence medical settings; as a consequence, evaluating one precise value as a single criterion on my own become now not enough to determine who gets the scarce medical useful resource. Multiple moral values and frameworks are wished in the pandemic setting to fairly allocate fitness assets. Therefore, within the state of affairs of Covid-19, greater unique ethical guidelines have been designed based on the complicated context. The new moral values consist of six commands: maximize advantages; prioritize fitness works; do no longer allocate on a first-come, first-served foundation; be aware of proof; recognize research participation; and practice the equal concepts to all Covid-19 and non-Covid-19 patients.

Among these principles, maximizing total benefits, in particular maximizing the range of lives or lifestyles years saved, turned into the most critical. This principle become generally appeared as the very best precedence in the course of a deadly disease length, and we also considered maximizing overall benefits as the number one goal in this studies. Maximizing advantages is composed of both saving maximum numbers of lives and maximizing the fine and period of the patients' publish-remedy life. Given the limitations of time and statistics at some point of the Covid-19 pandemic, it is extra affordable to prioritize maximizing the range of sufferers who survive remedy; after that, maximizing the duration of existence could be taken into consideration.

LITERATURE REVIEW

Medical demand forecasting is a crucial process that involves predicting the future demand for health services, healthcare needs and rates of utilization of services based on previous knowledge acquired through a systematic process (Huang, Y., et al.[2020]). By forecasting, healthcare providers can better meet the needs of their patients, improve the quality of care, and ultimately improve health outcomes, which is especially essential during the pandemic period to achieve the goal of maximizing benefits with limited medical resources. However, since the background of research varies, which includes social-cultural factors and also differences in the spread of disease and the demand for medical treatment in each region and country, the method used to study medical demand forecasting may be different. In a complex situation, especially with the emergence of the pandemic, there are many factors that are influencing the spread of the disease and the distribution of medical resources and treatment. Thus, there is no a role of thumb approach to make medical predictions under complicate scenarios, so hybrid methods have often been utilized to forecast aggregate or specific health conditions in the past (Soyiri, I.N., et al.[2021]). In the mid-20th century, linear programming and other optimization techniques revolutionized decision-making for complex problems with well-defined constraints, becoming essential for optimizing infrastructure planning and resource allocation during national health emergencies.

In the late 19th century, advancements in data analysis and collection contributed to the development of statistics as a supporting field. The pioneering works of Galton and Pearson [2018] set the foundation for statistical inference and hypothesis testing, providing valuable understanding of population health trends and disease patterns. For instance, studying the connection between smoking and lung cancer.

A good health system delivers quality sendees to all people, when and where they need them. However, there may be some factors hindering quality healthcare in hospitals. Linear programming model is a planning technique which uses mathematical model in maximizing or minimizing appropriate measure to optimize the value of some objective after identifying some constraints (P. Rama Murthy et al.[2019]). This study focuses on using linear programming model to maximize healthcare pathways by identifying constraints and obtaining optimal result for a quality healthcare

sendee delivery. Linear programming is a technique in operations research and is one of the most versatile, powerful and useful techniques for making managerial decisions (M. C. Agarana, et al.[2022]).

Linear programming technique may be used for solving broad range of problems in different sectors of an economy such as business, government,industry, hospital, libraries, etc. (K. Vanhaecht, et al. [2020]). This study shows how linearprogramming can be used to maximize healthcare quality which is termed as "care pathway". Linear programming is considered the technique to be used for this study because of the following characteristics it possesses: The relationship between variables and constraints is linear, the model has an objective function, the model has structural constraints, and the model has non-negativity constraint. Dantzig invented the simplex algorithm for solving a linear programming problem (Kris Vanhaecht, et al.[2018]).

MEDICAL RESOURCE ALLOCATION OPTIMIZATION FRAMEWORK

In this research, we present a framework to model the problem as a time series capacity allocation problem. More specifically, we use time series data as input for an LSTM model to predict the future hospitalization case number. The predicted data will then be utilized in a linear programming model to determine the optimal number of newly added hospital beds number and the allocation plan, with the objective of maximizing the overall accessibility of all regions involved.

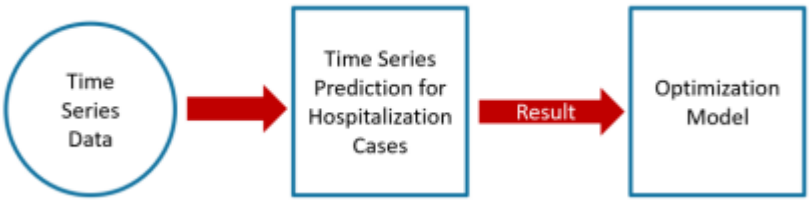

Figure 1. Framework for Medical Resource Allocation Problem

Long Short-Term Memory Model for Medical Demand Prediction - Long short-term memory (LSTM) is a type of recurrent neural network (RNN) architecture used in deep learning. It was proposed by Hochreiter and Schmidhuber in 1997[57]. It is an efficient algorithm for building a sequential time series model.

RNN is one of the artificial neural networks where connections between nodes form a directed graph along a temporal sequence, allowing RNN to exhibit temporal dynamic behavior. RNNs can use their internal status (memory) to process variable-length sequences of inputs[58- 60]. However, RNNs have long-term dependencies problems. They will be gradient vanishing and gradient explosion when learning long sequences. To address these challenges, LSTM networks were introduced. LSTM networks were specifically designed to overcome the longterm dependencies problem associated with RNNs.

LSTM networks are well-suited for classifying, processing, and making predictions based on time series data. The working principle of LSTM architecture is based on the long-term information reminder approach. This architecture contains hidden units called memory cells[33]. The LSTM structure generally includes layers of forget, input, and output gates. These layers determine whether an entry is significant and what information to delete or save[57, 61, 62]. By incorporating specialized memory cells and gating mechanisms, LSTM networks are able to effectively capture and propagate information over extended time intervals, enabling more robust learning and prediction performance. By utilizing the memory-enhancing capabilities of LSTM, we can improve the model's ability to capture temporal dependencies, leading to more accurate and reliable predictions in various applications.

Optimization Model for Medical Resource Allocation Problem - In our optimization model, we assume a place where there are m regions and n healthcare facilities. Each healthcare facility is located at the midpoint of the hospitals within its respective region. It is important to note that m may not be equal to n due to the absence of healthcare facilities in certain regions or the unavailability of facilities for ill patients caused by the contagion, which means patients in such regions need to seek healthcare facilities located in other regions. We also assume that patients in one region could visit hospitals in other regions.

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To determine the demand for each region, denoted as D_i, we utilize the number of hospitalized cases in each region which is predicted from the forecasting model. Additionally, we consider the initial supply of each healthcare facility, represented by SO_j, which corresponds to the number of hospital beds. In our optimization model, we introduce two key decision variables. The first decision variable x_j, represents the newly added hospital beds. If the x_j is zero, it indicates that no hospital bed is allocated to the healthcare facility in that region. Conversely, if the x_j is larger than zero, it means that x_j hospital beds will be distributed to the hospitals within that region. The second decision variable y_i , represents the accessibility of each region. It refers to the relative ease with which healthcare facilities can be reached from each region. A higher accessibility value indicates that the healthcare facilities in a region are well-equipped to meet the demand for medical services, considering the available supply of hospital beds. Conversely, a lower accessibility value suggests that the demand for healthcare resources exceeds the available supply, indicating a potential need for resource reallocation.

DESCRIBING A LINEAR PROGRAMMING METHOD

Optimization models are defined by an objective function composed of a set of decision-making variables, subject to a set of restrictions, and presented as mathematical equations. The objective of optimization is to find a set of decision making variables that generates an optimal value for the objective function, a maximum or minimum value depending on the problem, and complies with a set of restrictions imposed by the model. Such restrictions are conditions that limit the decision-making variables and their relations to assume feasible values. In linear Programming models, the objective function is linear, that is, it is defined as a linear combination of decision-making variables and a set of constants, restricted to a set of linear equality or inequality equations. Therefore, the model composed of an objective function, restrictions, decision-making variables and parameters.

An algebraic representation of a generic formulation of linear programming model could be presented as follows. To maximize or minimize the objective function:

$$Z = c_1 x_1 + c_2 x_2 + ----- + c_n x_n \quad (1)$$

It is subject to restrictions

$$a_{11} x_1 + a_{12} x_2 + ------ + a_{1n} x_n \leq r_1 \quad (2)$$

$$a_{21} x_1 + a_{22} x_2 + ------ + a_{2n} x_n \leq r_2 \quad (3)$$

$$a_{m1} x_1 + a_{m2} x_2 + ------ + a_{mn} x_n \leq r_m \quad (4)$$

$$X_j \geq 0 \text{ (j = 1,2,---------,n)} \quad (5)$$

Where (a) Represents the mathematical function encoding the objective of the problem and is called objective function. In linear Programming, this function must be linear. (b)To (e) represents the linear mathematical function encoding the main restrictions identified.

(e) Non-negativity restrictions, i.e.; the decision-making variables may assume any positive value or zero.

" X_j " Corresponds to the decision-making variables that represent the quantities one wants to determine to optimize the global result.

" c_1 " represents gain or cost coefficients that each variable is able to generate.

" r_j " represents the quantity available in each resource.

" a_{ij} " represents the quantity of resources each decision making variable consumes.

CONCLUSIONS

The demands for efficient decisions in healthcare planning in private hospitals and related to resource allocation problems shows the application of optimization techniques in these problems. This paper uses the integer linear programming approach (ILPA) to determine the optimal allocation. Results shown above that Branch and Bound method managed to obtain the optimal value and optimal combination that meets the objective of the problem and the related constraints.

The health care sector faces major challenges with regard to appropriate diagnosis and treatment, allocation of scarce resources, design of policies, etc. These methods provide an approach for finding optimal solutions to complex problems in the face of constraints. As such, they are complementary to and build on the health economic models and simulation methods that are widely used to guide clinical and policy decision making.

Constrained optimization methods can improve the current reimbursement decision-making processes, which take budget constraints partially into account. In the constrained optimization framework, budget constraints can be incorporated explicitly, together with other types of constraints, like human resource or geographical equity constraints. In addition, when there are numerous treatment options available for treating patients with a specific condition, constrained optimization might prove to be an efficient method for developing treatment protocols or guidelines compared to the classical economic evaluation framework.

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