A New Neuroinformatics Approach to Optimize Diagnosis Cost in Neurology:
An Operational Research Tool

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Abstract—Cost optimization approach of operational research is a predictive power and economy of compactness that is applied to solve specific clinical needs relevant to healthcare cost reduction. Technology helps the healthcare management, decision making, and policy that we have implemented in the interest of improving quality of patient care and treatment outcomes, thereby reducing costs and improving efficiency. The treatment cost of brain tumor is high. Sometimes, cost becomes a problem for individuals to get their complete treatment, which makes their health at risk and may lead to higher cost in future. Here we address neuroinformatics approach to optimize diagnosis cost in neurology through an operational research tool (optimization) on how the diagnosis cost of neuro-patient can optimize. In this context, we introduce a new and unique optimization approach in healthcare, yet what we are clearly lacking for applying applications of operational tools to translate this understanding to the different level to apply the concept in healthcare. The costs of treatment achieved by three standard initial basic feasible solutions (IBFS) methods (North-west corner method, Minimum cost method, Vogel’s approximation method) are 763, 763, and 779. The optimal solution is 761, and three random tests (RT’s) are 826, 783, and 788. Optimal solution provided an overall difference in treatment cost with IBFS 2, 2, 18 and with RT’s 65, 22, and 27. These results establish the basis for a deliberate integration of operational research tools and neuroscience into diagnosis of cost optimization mechanisms for neuro-patient.

Keywords—Cost optimization; stepping stone method; Modified distribution method; linear programming problem (LPP); Initial Basic Feasible Solution (IBFS); Random Tests (RT’s); Neuroinformatics
1 Introduction

Recent years have witnessed the intensifying corrosion of the treatment cost optimization predominance to the benefits of other approach in healthcare (e.g., In China, 390 people in a million are suffering from lung tuberculosis, which is the 10% of Globe TB rate). The Chinese govt. aims to minimize this rate to 163 people per million and stabilize it by 2050 [1]. Another major disease is lung cancer its ratio is also high and the survival rate of people likely to be 5 years with rate of 18.1% based on 2007-2013 SEER database [2]. One of the optimization approach have been introduced in output of convolution layer of CNN’s to optimize and accelerate the training rate of deep network after additional information of connections [3]. Segmental fine-tuning provides a computer aided diagnosis, which provides an overall accuracy of 82% which other traditional TL achieved 70% to 74% [4].

Historical development, planning, optimization, and design making application of OR models in healthcare for public health are discussed in [5]. [6] Discusses the clinical problems, methods to optimize a system, and software facilitates the problem design. The concept of Queuing theory of operation research has been applied to reduce the patients waiting time by applying Monte Carlo modeling method [7]. To manage and control the patients waiting list of radiotherapy treatment, optimal scheduling strategy have been introduced [8]. To maximize the utilization of devices and minimize the outpatient waiting time, real life optimized model have been introduced to improve the work efficiency [9]. In healthcare planning and management systems, the responsibilities are major part to maintain in hierarchal order, so that each and every level of individuals should ensure their roles and responsibilities. The modern framework have been introduced for individual levels (cure and care provider, entire healthcare organizer, healthcare planning & control management) to maintain hierarchal level, which ensure responsibilities of all managerial areas [10]. Simulation models of operational research model for the decision and policy maker, clinicians, and health management of healthcare system have been produced to improve the work efficiency [11]. The team work capabilities that support collaborative distributed work to get powerful impact and effectiveness in healthcare service management, which improves healthcare system [12]. The impact of technology and effective collaboration work achievements of patient care, mobile devices designed and implemented for effective healthcare team functionality to develop the healthcare systems [13]. The health information technology (HIT) tradeoffs model in design and evaluation has been introduced to develop seven tradeoff patterns to understand HIT mediated changes [14]. The concept of effective care, cost optimization, effective team works, effective communications, comprehensive decision making, safety awareness, and its performance build effective clinical team of healthcare and social care environment [15]. We can summarize the existing concept of optimality, but cost optimization concept have not yet introduced in any research paper of healthcare. This paper addresses cost optimization methodology to develop an overall system of the healthcare. We are the first to propose a best cost optimization concept in healthcare.
2 Background Study of Brain-Tumor

A brain is a complex and vital organ that makes up the central nervous system (CNS), where all vital functions are controlled. When tumor grows in the CNS, it affects a person’s through processes, the way they talk, or movement. This disease is a particular abnormal condition that negatively affects the structure of function of part or all of an organ, and that is not due to an external injury. This disease affects the people at different levels, like physically, emotionally, socially, and financially. The introduced methodology makes aware of structure and functionality of brain, symptoms of brain tumor, initial level of test, grade of tumor, risk and possible side effects of treatment, treatment, and its cost. It is important to have an open and honest conversation of their issues with healthcare team and doctors to express their feelings and preferences. The healthcare team members and doctors have special skills, knowledge and experience to support patients and their families.

2.1 Structure and functionality of brain

Structure: The brain is made up of three main parts (The cerebrum, the cerebellum and the brain stem), these are the membranes, which surround and protect the brain and spinal cord. The cerebrum covers a largest part of brain which divided into the frontal lobe, Parietal lobe, Occipital lobe, and Temporal lobe. The cerebellum covers the back part of brain, just below the cerebrum. The Brain stem is a major part of brain, which is divided into Pons, and Medulla oblongata.

Functionality: The cerebrum contains two cerebral hemisphere on either side of the brain that control opposite sides of body. The cerebellum controls the same side of body. The brain stem conveys the messages for functions that are controlled by cerebrum and cerebellum travel the brain stem to the body, which controls the beating of the heart and breathing.

Fig. 1. Structure and Functionality of Brain
2.2 Brain-tumor sign and symptoms

Something that can signal a problem, which are the symptoms or sign, may need medical care. If some parts or specific parts of brain are not working well or feeling headache or other changes, means changes may or may not cause a brain tumor. It is important for everyone to know the symptoms which concerned about any changes we experience, which help to get correct diagnosis and treatment. Determining the cause of symptoms is the first step towards getting the treatment. It needs the consultation of doctors who will figure out the cause of problems and will suggest the diagnosis for treatment accordingly. The sign and symptoms are listed in figure 2.

Fig. 2. Structures and Functionality of Brain
Table 1. Initial level of test

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intravenous (IV) gadolinium-enhanced MRI</td>
<td>It gives clear picture of brain tumor.</td>
</tr>
<tr>
<td>Spinal MRI</td>
<td>Diagnose a tumor on or near the spin.</td>
</tr>
<tr>
<td>A functional MRI (fMRI)</td>
<td>Information of specific area of brain, which are responsible for muscle movement</td>
</tr>
<tr>
<td>MRS using MRI</td>
<td>Magnetic resonance spectroscopy (MRS) provides an information on the chemical</td>
</tr>
<tr>
<td></td>
<td>composition of the brain.</td>
</tr>
<tr>
<td>CT Scan</td>
<td>Helps to find bleeding and enlargement of the fluid-filled spaces in the brain,</td>
</tr>
<tr>
<td></td>
<td>called ventricles.</td>
</tr>
<tr>
<td>PET-CT Scan</td>
<td>Helps to find out more about tumor while a patient is receiving treatment.</td>
</tr>
<tr>
<td>Molecular testing of tumor</td>
<td>Helps to identify specific genes, proteins, and other factors, such as tumor</td>
</tr>
<tr>
<td></td>
<td>marker, unique to the tumor.</td>
</tr>
<tr>
<td>Neurological test</td>
<td>Helps to detect the brain functionality.</td>
</tr>
<tr>
<td>Vision and hearing test</td>
<td>Helps to detect the changes in the optic nerve and field of vision.</td>
</tr>
<tr>
<td>Neurocognitive assessment</td>
<td>Helps to detect the functionality of brain.</td>
</tr>
<tr>
<td>Electroencephalography (EEG)</td>
<td>Helps to measure the electrical activity of brain.</td>
</tr>
<tr>
<td>Evoked potentials</td>
<td>Helps to measure the electrical activity of nerves.</td>
</tr>
<tr>
<td>Cerebral angiogram</td>
<td>Helps to find the arteries in the brain.</td>
</tr>
<tr>
<td>Lumber puncture or spinal tap</td>
<td>Helps to find tumor cells.</td>
</tr>
<tr>
<td>Myelogram</td>
<td>Helps to find out the tumor status in spinal fluid, spinal cord or other parts of</td>
</tr>
<tr>
<td></td>
<td>brain.</td>
</tr>
</tbody>
</table>

Initial level of test: The data have been considered from some of reputed Indian diagnosis center. Dr. Pervez Ahmed Khan is a Consultant - Neurosurgery at Batra Hospital, New Delhi has provided data’s of diagnosis and its respective details for the set of diagnosis from supply point i to demand point j. Diagnosis which result for similar symptom have been grouped together as Gj with per unit cost, for all j. We have proposed a methodology of optimality to optimize the cost of brain tumor treatment. The expertise of medical science people like, doctor, and health care team may use our proposed approach to get an optimal solution.

In table 1, the different diagnoses are described, and in figure 3, diagnoses have been categorized as a group with the similar result and it is per unit cost.

Brain-tumor grades: In general, diagnosis of brain tumor starts with magnetic resonance imaging (MRI). This diagnosis is used to measure the tumor’s size. While receiving a treatment, patient need a regular monitor of health through brain MRI at every 2 to 3 months, as depends on tumor grade, MRI scans time length get increased. It gives detailed pictures than CT scans and preferred to diagnose a brain tumor. During treatment, if tumor get grows, other option will be considered for the treatment. As symptoms are explained, MRI may be of brain, spinal cord, or for both, depends on tumor suspected and determine which types of MRI required. It also depends on the result of neuro-examination, done by internist or neurologist. To detect, where is the tumor located? A staging system is used to describe it. There are several factors, which help doctor to find the tumor cell, whether it is growing out of control or a lot of dead cells that help him for appropriate brain tumor treatment plan.
and determine prognosis. Based on different grades of tumor, doctors suggest different types of treatment.

**Table 2. Grades of Brain-tumor**

<table>
<thead>
<tr>
<th>Grades</th>
<th>Status of tumor and its treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Slow growing and unlikely to spread. It can be cured by surgery</td>
</tr>
<tr>
<td>II</td>
<td>Less likely to grow, it can be cured after treatment</td>
</tr>
<tr>
<td>III</td>
<td>Rapidly dividing cells but no dead cells, can grow quickly, need immediate treatment</td>
</tr>
<tr>
<td>IV</td>
<td>Blood vessels growth and areas of dead tissue, tumor can grow and spread quickly</td>
</tr>
</tbody>
</table>

**Risk factors of developing brain-tumor**

- People of any age can develop a brain tumor, but as per doctors’ report, it is common in children and older adults.
- The ratio of brain tumor in men and women: men are more likely than women but are specific types of this disease are more common in women which is meningioma.
- One of the factor is hereditary genetic and its chances are up to 5%.
- Exposure to infections, viruses, and allergens increase the risk of CNS lymphoma.
- Electromagnetic fields, which are energy from power line or from cell phone use. World Health Organization (WHO) recommends limiting cell phone use and promotes the use of a hands-free headset for both adults and children.
- Ionizing radiations including x-rays, have been shown to be a risk factor for brain tumor.
- Head injury and seizures have long been associated with brain tumors, which increase the risk.
- n-Nitroso compounds: There are certain reasons of this disease, which are cigarettes smoke, cured meats and cosmetics.

**Treatment and its cost:** For standard care, all the treatment options get considered, which helps doctors to find the better treatment. Different specialist work together in a multidisciplinary team, which helps them to find overall treatment of patient that combines different levels of treatment.

**Table 3. Symptoms and treatment**

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>The size, type, and grade of tumor</td>
<td>Surgery (for low grade tumor)</td>
</tr>
<tr>
<td>Status of tumor on vital parts of brain</td>
<td>Surgery and Radiation therapy</td>
</tr>
<tr>
<td>Spread ratio of tumor in other parts of body</td>
<td>Surgery, Radiation therapy, and chemotherapy</td>
</tr>
<tr>
<td>Possible side effects</td>
<td>Radiation therapy can damage healthy tissue</td>
</tr>
<tr>
<td>Patients overall health</td>
<td>Treatment often cause side effects</td>
</tr>
</tbody>
</table>
3 Data Description

In our approach, all the information and data have been collected from different medical research centre and cancer hospital. RGCIRC is a project of Indraprastha Cancer Society and Research Centre, a not-for-profit public society. It is one of the largest medical centers for cancer treatment in Asia. Dr. Pervez Ahmed Khan is a Consultant - Neurosurgery at Batra Hospital, New Delhi. Once, I discussed with Dr. Perwez regarding mathematical approach of cost optimization of brain tumor treatment. He accepted my proposal and provided valuable information and data of diagnosis and its respective details for the set of diagnosis to implement my approach. Diagnosis which result for similar symptom have been grouped together as Gj with per unit cost, for all j. We have proposed a methodology of optimality to optimize the cost of brain tumor treatment. The expertise of medical science people like, doctor, and health care team may use my proposed approach to get an optimal solution. In table 1, the different diagnoses are described, and in figure 3, diagnoses have been categorized as a group with the similar result and it’s per unit cost.

4 Methods

If the objective function is f(X) and XЄS, where s is the set of all feasible values of X. then X*Є S and f*(X) ≤ f(X) for all XЄS, where X* is a minimizer of “f” on S.

The concepts of Linear programming (LP) have been implemented to find the least expensive way to meet the requirements. To minimize the cost of different set of diagnosis (S1 to Si) and their group categories which result a similar symptom (G1 to Gj), where i and j are the number of set of diagnosis and the number of group categories. Per unit cost of diagnosis are defined in a table i.e. Cij. Let us assume that
the variables $X_i$ are the non-negative variables denoting the number of diagnosis of different sets which are used to meet the requirement $j = 1, 2 \ldots n$ and $i = 1, 2 \ldots m$ which are corresponding name of diagnosis and sets of diagnosis. One unit of test $j$ contributes $a_{ij}$ unit of set $i$, where $C_j$ is per unit cost of diagnosis $j$. The objective is to determine the variable $X_j$ to minimize the total cost of diagnosis.

4.1 Balanced Transportation Problem (BTP): Representation of supply - demand diagnosis tableau

<table>
<thead>
<tr>
<th>$G_1$</th>
<th>$G_2$</th>
<th>...</th>
<th>$G_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_1$</td>
<td>$C_{11}$</td>
<td>...</td>
<td>$C_{1j}$</td>
</tr>
<tr>
<td></td>
<td>$X_{11}$</td>
<td>...</td>
<td>$X_{1j}$</td>
</tr>
<tr>
<td>$S_2$</td>
<td>$C_{21}$</td>
<td>...</td>
<td>$C_{2j}$</td>
</tr>
<tr>
<td></td>
<td>$X_{21}$</td>
<td>...</td>
<td>$X_{2j}$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$S_i$</td>
<td>$C_{i1}$</td>
<td>...</td>
<td>$C_{ij}$</td>
</tr>
<tr>
<td></td>
<td>$X_{i1}$</td>
<td>...</td>
<td>$X_{ij}$</td>
</tr>
<tr>
<td>$b_1$</td>
<td>$b_2$</td>
<td>...</td>
<td>$b_i$</td>
</tr>
</tbody>
</table>

$$(S, G; C_{ij}) \rightarrow \text{Set of supply and demand with per unit cost}$$

$X_{ij} \rightarrow \text{Quantity transported from supply point } i \text{ to demand point } j.$

Supply $\rightarrow$ Set of diagnosis

\[
(S_i)_{i=1} \rightarrow C_{1j} \\
(S_i)_{i=2} \rightarrow C_{2j} \\
\vdots \\
(S_i)_{i=m} \rightarrow C_{ij}
\]

Demand $\rightarrow$ Which result similar symptoms

\[
(G_j)_{j=1} \rightarrow C_{i1} \\
(G_j)_{j=2} \rightarrow C_{i2} \\
\vdots \\
(G_j)_{j=n} \rightarrow C_{ij}
\]

Minimize $\sum_{j=1}^{n} C_j X_j$

\[\text{Minimize } \sum_{j=1}^{n} C_j X_j\]
Subject to $\sum_{j=1}^{n} a_{ij} x_j \geq b_j$, for all $j$

$x_j \geq 0$, for all $j$

To enhance the probability, constraints might be used, in which the model can be modified as lower and upper bonds on the amount of individual diagnosis in the treatments.

**Random test: Worst case**

**Random test-1 (RT-1)**

Minimize $\sum_{j=1}^{n} C_j x_j$

\[
\begin{align*}
(G_j)_{j=1} &\rightarrow [\Sigma C_j \Sigma X_j \rightarrow b_j] \rightarrow \left[\left\{(C_{i1})_{i=1, 1} + \{(C_{i1})_{i=2, 2}\}\right] + \{(C_{i2})_{i=3, 1}\}\right] + \{(C_{i3})_{i=4, 3}\}\right] \\
(G_j)_{j=2} &\rightarrow [\Sigma C_j \Sigma X_j \rightarrow b_j] \rightarrow \left[\left\{(C_{i1})_{i=1, 2} + \{(C_{i2})_{i=2, 2}\}\right] + \{(C_{i3})_{i=3, 1}\}\right] + \{(C_{i4})_{i=4, 3}\}\right] \\
(G_j)_{j=3} &\rightarrow [\Sigma C_j \Sigma X_j \rightarrow b_j] \rightarrow \left[\left\{(C_{i2})_{i=1, 1} + \{(C_{i3})_{i=2, 2}\}\right] + \{(C_{i4})_{i=3, 1}\}\right] + \{(C_{i5})_{i=4, 3}\}\right] \\
(G_j)_{j=4} &\rightarrow [\Sigma C_j \Sigma X_j \rightarrow b_j] \rightarrow \left[\left\{(C_{i3})_{i=1, 1} + \{(C_{i4})_{i=2, 2}\}\right] + \{(C_{i5})_{i=3, 1}\}\right] + \{(C_{i6})_{i=4, 3}\}\right] \\
\end{align*}
\]

$= \$826$

**Random test-2 (RT-2)**

Minimize $\sum_{j=1}^{n} C_j x_j$

\[
\begin{align*}
(G_j)_{j=1} &\rightarrow [\Sigma C_j \Sigma X_j \rightarrow b_j] \rightarrow \left[\left\{(C_{i1})_{i=2, 1} + \{(C_{i2})_{i=4, 1}\}\right] + \{(C_{i3})_{i=5, 3}\}\right] \\
(G_j)_{j=2} &\rightarrow [\Sigma C_j \Sigma X_j \rightarrow b_j] \rightarrow \left[\left\{(C_{i1})_{i=3, 1} + \{(C_{i2})_{i=4, 1}\}\right] + \{(C_{i3})_{i=5, 3}\}\right] \\
(G_j)_{j=3} &\rightarrow [\Sigma C_j \Sigma X_j \rightarrow b_j] \rightarrow \left[\left\{(C_{i2})_{i=3, 1} + \{(C_{i3})_{i=4, 1}\}\right] + \{(C_{i5})_{i=5, 3}\}\right] \\
(G_j)_{j=4} &\rightarrow [\Sigma C_j \Sigma X_j \rightarrow b_j] \rightarrow \left[\left\{(C_{i3})_{i=3, 1} + \{(C_{i4})_{i=4, 1}\}\right] + \{(C_{i5})_{i=5, 3}\}\right] \\
\end{align*}
\]

$= \$783$

**Random test-3 (RT-3)**

Minimize $\sum_{j=1}^{n} C_j x_j$
4.2 Solution stages

The solution to a TP has two stages; first stage to identify IBFS, and the second to get the optimal solution (OS). There are three standard methods of identifying IBFS (North-west corner cell method (NCCM), Minimum cost cell method (MCCM), and Vogel’s approximation method (VAM)). We can choose either of these methods, out of which we are considering North-west corner cell method to find the IBFS and two standard methods of getting optimal solution (Stepping stone method, and Modified distribution method (MODI)/U-V Method). After getting the IBFS, we may apply either Stepping stone method or Modified distribution method to find out the optimal solution. Here, we have applied stepping stone method to find the optimal solution.

User of our methodology (either doctor or healthcare team who have expertise in medical science) may provide better treatment in minimum cost. As per the symptoms of the disease in patients, user prescribe some diagnosis to identify the actual disease, which help him to provide better treatment. Our proposed methodology will help the patients to get their diagnosis in optimal cost.

As per the requirement of number of diagnosis, User may ask random number of different set of supply (a1 to a4), but supply should not get exceed or reduced the demand. Our proposed methodology may work for balanced transportation problem in which, total number of supplies are equal to total number of demand.

It is Microsoft Excel based application, which need to fill the required data in proposed transportation tableau to get the feasible and optimal result. The user need to fill per unit cost of different diagnosis in proposed transportation tableau with their similar property in given set of groups (G1, G2, ..., Gj), and put the demand from the diagnosis center to fulfil the requirements of diagnosis, which makes the supply and demand in balanced.

\[
S_i: (a_i)_{j=1 \text{ to } 4} \rightarrow (3, 6, 2, 4) \\
G_j: (b_j)_{j=1 \text{ to } 4} \rightarrow (6, 6, 2, 4)
\]

**Demand → Which result similar symptoms**

\[
\begin{align*}
(G_j)_{j=1} &\rightarrow (C_{i1})=1, (C_{i1})=2, (C_{i1})=3, (C_{i1})=4; (S_{42}, S_{40}, S_{41}, S_{43}) \\
(G_j)_{j=2} &\rightarrow (C_{i2})=1, (C_{i2})=2, (C_{i2})=3, (C_{i2})=4; (S_{63}, S_{65}, S_{62}, S_{61}) \\
(G_j)_{j=3} &\rightarrow (C_{i3})=1, (C_{i3})=2, (C_{i3})=3; (C_{i3})=4; (S_{30}, S_{32}, S_{31}, S_{34}) \\
(G_j)_{j=4} &\rightarrow (C_{i4})=1, (C_{i4})=2, (C_{i4})=3; (C_{i4})=4; (S_{54}, S_{50}, S_{53}, S_{52}) \\
\end{align*}
\]

\[\Sigma(G_j)_{j=1\text{ to } 4} = 788\]
Stage 1: To identify Initial Basic Feasible Solution (IBFS): Average Case: The TP talks about the diagnosis, a diagnosis from a given set of requirements. The given set of diagnosis i as ai and the requirement in diagnosis j is bj and the problem is one of finding a least cost treatment from the sets to the required diagnosis, where Cij is the per unit cost of diagnosis.

The problem is finalized as Xij, the quantity of diagnosis given from sets i to required diagnosis j. The objective function is to minimize the total cost of treatment CijXij subject to sets constraints.

For every set, ai is the quantity available in sets i and as far as every requirement parts are concerned.

\[ \sum ai = \text{Total availability, and } \sum bj = \text{Total requirements.} \]

If \( \sum ai \geq \sum bj \) and \( Cij \geq 0 \): Total availability is more than the requirements (possible to fulfill all requirements of different set of diagnosis)

If \( \sum ai < \sum bj \) and \( Cij \geq 0 \): Total availability is less than the requirements (then obviously all the requirements cannot be met).

North-West Corner Cell Method (NCCM):

**Step 1:** Begin in the upper left corner of the transportation table.

**Step 2:** Set \( X11, X11 = \min \{a1, b1\} \).

**Step 3:** if \( X11 = a1 \), cross out row 1, no more basic variables will come from row 1 and set \( b1 = b1 - a1 \).

**Step 4:** if \( X11 = b1 \), cross out the column 1, no more basic variables will come from column 1 and set \( a1 = a1 - b1 \).

**Step 5:** if \( X11 = a1 - b1 \), cross out either row 1 or column 1, but not both. Set \( b1 = 0 \), when cross out row 1. Otherwise set \( a1 = 0 \), when cross out column 1.

**Step 6:** Continue to apply this procedure to the most north-west corner cell in the table that does not lie in a crossed-out row or column. Finally there will be only one cell that can be assigned a value (Assign this cell a value equal to its row or column demand, and cross out both the cells row and column).

**Step 7:** Now, IBFS has been obtained

\[
\text{Minimize } \sum_{j=1}^{n} CjX_j
\]

Minimum Cost Cell Method (MCCM):

**Step 1:** Find cell with smallest \( \{Cij\} \).

**Step 2:** Set \( Xij, Xij = \min \{ai, bj\} \) to cell of step 1.

If \( Xij = ai \), cross out row i, no more basic variables will come from row i and set \( bj = bj - ai \).

If \( Xij = bj \), cross out the column j, no more basic variables will come from column j and set \( ai = ai - bj \).

If \( Xij = ai-bj = 0 \), cross out either row i or column j, but not both. Set \( bj = 0 \), when cross out row i. Otherwise set \( ai = 0 \), when cross out column j.
Step 3: Continue to apply step 1 and step 2 with rest of the per unit cost element of transportation cost matrix. Finally there will be only one cell that can be assigned a value (Assign this cell a value equal to its row or column demand, and cross out both the cells row and column).

\[
\text{Minimize } \sum_{j=1}^{n} c_jx_j
\]

\[
(G_j)_{j=1} \rightarrow \sum c_j \sum x_j \rightarrow b_j \rightarrow [(C_{11})_{i=2}, 3] \\
(G_j)_{j=2} \rightarrow \sum c_j \sum x_j \rightarrow b_j \rightarrow [(C_{12})_{i=1, 2} + ((C_{12})_{i=3}, 4)] \\
(G_j)_{j=3} \rightarrow \sum c_j \sum x_j \rightarrow b_j \rightarrow [(C_{13})_{i=1, 2}] \\
(G_j)_{j=4} \rightarrow \sum c_j \sum x_j \rightarrow b_j \rightarrow [(C_{14})_{i=1, 2} + ((C_{14})_{i=3}, 4)]
\]  

\[
\sum (G_j)_{j=1to4} = 763
\]

**Vogel’s Approximation Method (VAM):**

**Step 1.** Find penalty by subtracting smallest per unit cost from next to smallest per unit cost in same row or column.

Allocate the variable to least possible per unit cost of largest penalty row or column, if penalty are ties then select arbitrarily. Adjust supply or demand as following: **Step 2.**

Set \(x_{ij} = \min \{a_i, b_j\}\).

If \(x_{ij} = a_i\), cross out row \(i\), no more basic variables will come from row \(i\) and set \(b_j = b_j - a_i\).

If \(x_{ij} = b_j\), cross out the column \(j\), no more basic variables will come from column \(j\) and set \(a_i = a_i - b_j\).

If \(x_{ij} = a_i - b_j = 0\), cross out either row \(i\) or column \(j\), but not both. Set \(b_j = 0\), when cross out row \(i\). Otherwise set \(a_i = 0\), when cross out column \(j\).

**Step 3:** Continue to apply this procedure. Finally there will be only one cell that can be assigned a value (Assign this cell a value equal to its row or column demand, and cross out both the cells row and column).

\[
\text{Minimize } \sum_{j=1}^{n} c_jx_j
\]

\[
(G_j)_{j=1} \rightarrow \sum c_j \sum x_j \rightarrow b_j \rightarrow [(C_{1k})_{i=1}, 3] + [(C_{1k})_{i=2}, 1]] \\
(G_j)_{j=2} \rightarrow \sum c_j \sum x_j \rightarrow b_j \rightarrow [(C_{12})_{i=1, 3} + ((C_{12})_{i=4}, 4)] \\
(G_j)_{j=3} \rightarrow \sum c_j \sum x_j \rightarrow b_j \rightarrow [(C_{13})_{i=1, 2}] \\
(G_j)_{j=4} \rightarrow \sum c_j \sum x_j \rightarrow b_j \rightarrow [(C_{14})_{i=1, 2} + ((C_{14})_{i=3}, 4)]
\]  

\[
= 763
\]
Stage 2: To identify Optimal Solution (OS): Best Case

Stepping stone method – to get the optimal solution (OS): The steps are involved to check the optimality of the initial basic feasible solution using the stepping stone method:

Step 1: Condition to solve for the optimality is to ensure that the number of allocated cells is exactly equal to m+n-1, where ‘m’ is the number of rows, while ‘n’ is equal to the number of columns, if this condition fail, means the allocated cells are less than m+n-1 (degenerate feasible solution exist).

Step 2: When degenerate feasible solution exist, consider ε to make the condition BFS, choose the position in which it should retain the fact that these m+n-1 positions are independent and assume ε=0 as an allocation.

Step 3: Select unallocated cell, move with allocated cell, either horizontally or vertically and returns to the same unallocated cell, called as a “closed loop”. Such that, no three consecutive allocated cells either be in the same row or column.

Step 4: Once the loop is created, assign “+” or “-” sign alternatively on each corner cell of the loop, but begin with the “+” sign for the unallocated cell.

Step 5: Repeat these steps again until all the unallocated cells get evaluated. If all the computed changes are ≥0, then the optimal solution has been reached.

Step 6: But in case, if any value comes to be negative, then there is a scope to reduce the transportation cost further. Then, select that unallocated cell which has the most negative change and assign as many units as possible. Subtract the unit that added to the unallocated cell from the other cells with a negative sign in a loop, to balance the demand and supply requirements.

Net cost (Increased/Decreased): In table 5, Applying step1 to step5 of stepping stone method to check the computed changes are either < or ≥0, if all computed changes are ≥0, then the optimal solution has been reached, but the net cost have decreased, next step(step 6) is require to check the optimality condition. When net cost increased, means optimality condition reached.

The Stepping stone method, to check the net cost by putting +1 one by one in per unit cost cell to all unallocated cell. Start from this unallocated cell with +1 and move to other allocated cell with alternate sign to form a loop. Continue this process one by one with all unallocated cell. The sign of the net cost will show that either net cost is increasing or decreasing.

<table>
<thead>
<tr>
<th>Unallocated cell</th>
<th>Loop of per unit cost cell</th>
<th>Net cost ↑</th>
<th>Net cost ↓</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_11</td>
<td>C_{11}C_{21}+C_{31}C_{41}</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>X_14</td>
<td>C_{14}C_{24}+C_{34}C_{44}</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X_{21}</td>
<td>C_{21}C_{31}+C_{41}C_{11}</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>X_{23}</td>
<td>C_{23}C_{33}+C_{43}C_{13}</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>X_{42}</td>
<td>C_{42}C_{12}+C_{32}C_{42}</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>X_{13}</td>
<td>C_{13}C_{23}+C_{33}C_{43}</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X_{24}</td>
<td>C_{24}C_{34}+C_{44}C_{14}</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>X_{32}</td>
<td>C_{32}C_{42}+C_{12}C_{42}</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>X_{43}</td>
<td>C_{43}C_{23}+C_{33}C_{43}</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>
In table 6, applying Step 6 of stepping stone method, because net cost has decreased, then there is a scope to reduce the transportation cost further. Then, select that unallocated cell which has the most negative change and assign as many units as possible. Subtract the unit that added to the unallocated cell from the other cells with a negative sign in a loop, to balance the demand and supply requirements.

<table>
<thead>
<tr>
<th>Unallocated cell</th>
<th>Loop of per unit cost</th>
<th>Net cost ↑</th>
<th>Net cost ↓</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_{11}$</td>
<td>$C_{11}+C_{12}+C_{24}$</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>$X_{21}$</td>
<td>$C_{22}+C_{23}+C_{34}$</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>$X_{12}$</td>
<td>$C_{22}+C_{23}+C_{34}$</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>$X_{22}$</td>
<td>$C_{22}+C_{23}+C_{34}$</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>$X_{31}$</td>
<td>$C_{31}+C_{32}+C_{44}$</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>$X_{41}$</td>
<td>$C_{41}+C_{42}+C_{24}$</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>$X_{33}$</td>
<td>$C_{33}+C_{34}+C_{11}$</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>$X_{34}$</td>
<td>$C_{34}+C_{31}+C_{12}$</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

All the computed changes are ≥0, and then the optimal solution has been reached.

Optimal solution (OS) = (Per unit cost of allocated cell)*(Quantity of allocated cell which are transported from supply point i to demand point j)

$\text{Minimize } \sum_{j=1}^{n} C_jx_j$

$\begin{align*}
(G_j)_{j=1} & \rightarrow \left[ \sum C_j \sum X_j \rightarrow b_j \right] \rightarrow \left[ \left( C_{11} \right)_{i=1}, 1 \right] + \left( C_{12} \right)_{i=2}, 2] \\
(G_j)_{j=2} & \rightarrow \left[ \sum C_j \sum X_j \rightarrow b_j \right] \rightarrow \left[ \left( C_{11} \right)_{i=1}, 1 \right] + \left( C_{12} \right)_{i=3}, 5] \\
(G_j)_{j=3} & \rightarrow \left[ \sum C_j \sum X_j \rightarrow b_j \right] \rightarrow \left[ \left( C_{11} \right)_{i=1}, 2 \right] \\
(G_j)_{j=4} & \rightarrow \left[ \sum C_j \sum X_j \rightarrow b_j \right] \rightarrow \left[ \left( C_{11} \right)_{i=2}, 1 \right] + \left( C_{12} \right)_{i=3}, 3] \\
\end{align*}$

$= \$761$

5 Experiment and Results

5.1 Experiment

In this work, considering the number of supplied diagnosis from supply point i and requirements of diagnosis at demand point j. In order to obtain the optimal solution, a stepping stone method was applied to evaluate the performance of our proposed approach. Specifically, the input dataset was taken from some of Indian diagnosis center that have shown in figure 3. The cost of individual diagnosis have converted from Indian currency to dollar. Diagnosis which result for similar symptom have grouped together as Gj for all j. Since we aimed to solve three different cases of problems, the measurement of optimality, stepping stone method was used to
optimize the treatment cost of brain tumor patients. We also evaluated the different cases to compare the performance of our proposed approach.

**Comparison between Allocated cells of supply-demand diagnosis tableau:**

Worst, average and best cases

- **Worst case:** RT’s (Random test-1, Random test-2, Random test-3)
- **Average case:** IBFS (NCCM, MCCM, VAM)
- **Best case:** OS (Stepping stone method (SSM), Modified distribution method (MODI)/U-V Method)

\[
C_{ij}X_{ij} \rightarrow \text{Set of constraints}
\]

\[
\Phi_{ij} \rightarrow S_i G_j \text{ Cells for i & j}
\]

The objective of our work is to minimize the total cost of treatment with

\[
\text{Quantity of diagnosis supplied from supply point I to demand point j with per unit cost } C_{ij}
\]

**5.2 Result**

**Cost comparison between worst, average and best cases**

- **Worst case:** RT’s (Random test-1, Random test-2, Random test-3)
- **Average case:** IBFS (NCCM, MCCM, VAM)
- **Best case:** OS (Stepping stone method (SSM), Modified distribution method (MODI)/U-V Method)
Table 7. Cost comparison between different processes

<table>
<thead>
<tr>
<th>Cases</th>
<th>Method</th>
<th>Total Cost (in $)</th>
<th>Cost Diff. (with OS)</th>
<th>Extra cost in $</th>
<th>Extra cost (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBFS (Avg. case)</td>
<td>MCCM</td>
<td>763</td>
<td>763-761</td>
<td>2</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>VAM</td>
<td>763</td>
<td>763-761</td>
<td>2</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>NCCM</td>
<td>779</td>
<td>779-761</td>
<td>18</td>
<td>2.31</td>
</tr>
<tr>
<td>OS (Best case)</td>
<td>SSM/MODI</td>
<td>761</td>
<td>761-761</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RT (Worst case)</td>
<td>RT-1</td>
<td>826</td>
<td>826-761</td>
<td>65</td>
<td>7.87</td>
</tr>
<tr>
<td></td>
<td>RT-2</td>
<td>783</td>
<td>783-761</td>
<td>22</td>
<td>2.81</td>
</tr>
<tr>
<td></td>
<td>RT-3</td>
<td>788</td>
<td>788-761</td>
<td>27</td>
<td>3.43</td>
</tr>
</tbody>
</table>

In the graphs (figures 5 & 6), it is simple to see the difference between three different process (IBFS, OS, and RT). The SSM/MODI method to optimize the cost of diagnosis. Left to optimal solution, IBFS exit, and right to optimal solution, RT’s are exist. Sometimes, we may find the solution through the IBFS to minimize the cost of diagnosis, but the optimality is the best process to achieve optimal solution, which will reduce the cost of group of diagnosis with similar symptoms that help the patient to get the diagnosis in minimum cost. Figure 3 is the collection of required data, group of similar diagnosis, and per unit cost of different diagnosis, and the process, which are collecting number of diagnosis accordingly to result performs. Figure 3 is showing the cost of diagnosis of groups from supply point i to demand point j.

![Cost comparison between IBFS, OS, and RT](image)

**Fig. 5.** Cost comparison between different process (in $)
Discussion

In this study, we aimed to detect the optimal result by using stepping stone method of LPP. To our knowledge, this is the first approach to investigate the effective approach to minimize the diagnosis cost in healthcare. Using optimization approach of LPP, optimized solution were detected with excellent performance (all the cases–best, average, and worst cases) have been discussed. The performance of IBFS’s are near about OS, but RT’s are the worst case to implement for optimizing the result. Multiple sets of diagnosis are supplied from supply point i to demand point j, out of which, the diagnosis that result similar symptoms are grouped. This is illustrated in figure 3 that compares all the cases of different methods. It can be clearly seen that our objective is meeting the requirements. The proposed methodology is cost effective. The treatment cost of brain-tumor is expensive. In addition to treatment cost, many people find unplanned extra expenses related to their care. For some people, the cost becomes reason for them to get their complete treatment. It can create an issue that make their health at risk and may lead to higher cost in future. A cost effective methodology have proposed for patients to get their treatment in optimal cost. The concept of optimality of OR has been implemented to optimize the cost of brain tumor treatment. The optimal solution is a set of optimization and feasible solution, which minimize the cost of treatment in healthcare. A set of choices that result in the condition being satisfied is called feasible solution. The objective of this paper is to give a methodology of optimality, which provides the optimal cost solution of brain tumor treatment. There are two steps to reach up to the optimal result. First step to get the feasible solution by applying either of these three standard methods (North-west corner cell method, Minimum cost cell method, or Vogel’s approximation method) of transportation problem, then Stepping stone method or
Modified distribution methods of OR are used to get the optimal solution, which resulted in minimum cost of brain tumor treatment.

7 Conclusion

The main objective of this paper is to provide a cost effective methodology that help the healthcare team and doctors to choose the selective diagnosis, which minimize the cost and side effects of treatment. The scientist and doctors are trying to get the better solution of the treatment of brain tumor in minimum cost with minimum side effects. Treatment of brain tumor is expensive. In addition to treatment cost, many people find unplanned extra expenses related to their care. For some people, the cost becomes reason for them to get their complete treatment. It can create an issue, which makes their health at risk and may lead to higher costs in future. Our proposed approach will help them to get their treatment in optimal cost. The optimization detection using stepping stone method achieved excellent performance for minimizing the treatment cost of brain tumor followed by IBFS’s. We provide excellent approach for detecting OS. In future research, we recommend the following useful approach that should improve the concept in healthcare to minimize the cost of diagnosis as well as in different respect to optimize the difficulties and provide useful results towards development in healthcare.

8 References


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