Descriptive Decision-making of Lung Cancer Treatment Using a DM Model with Dempster-Shafer Theory and Prospect Theory

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Abstract— This paper explains a descriptive decision-making framework under uncertainty elucidating different decision attitudes of a newly-diagnosed lung cancer patient regarding treatment decision. The problem of treatment decision making of a lung cancer patient has been defined as Evidential Decision-making Problem (EDMP) at first. Belief function of Dempster-Shafer theory is exploited to explain uncertainty of EDMP and Prospect theory is applied to accomplish a descriptive decision-making framework. The goal of this paper is to find what decisions regarding treatments are made by a lung cancer victim when attitudes towards uncertainty are different.

Keywords— Dempster-Shafer Theory; Prospect theory; decision-making; uncertainty; lung cancer; decision attitude.

I. INTRODUCTION

Medical science involves decision-making either under certainty or uncertainty. Traditionally, medical practitioners played a paternalistic role in treatment decisions and the patients mostly abided by the decisions. But there has been revolutionary change in medical fields since few decades and the patients are being more and more encouraged to get involved in treatment decisions. The patient’s preference is especially more important when there are several alternatives of treatment and each alternative has its own trade-offs and each patient has his/her own viewpoint of judging the trade-offs [1]. For example: a patient with rheumatoid arthritis may face three anti-tumor necrosis factor-alpha (TNF-alpha) therapy options: etanercept (Enbrel), adalimumab (Humira) and infliximab (Remicade). Reference [2] expresses how the therapy decisions vary depending on various factors. Researches on patient decision-making have an extensive history. In early 1980s, researchers started experiments in the field of urology involving advanced technology. Multiple studies have shown that the combination of physicians’ knowledge and patient’s participation improved patient satisfaction and physician's time [3]. Although the traditional school of thought argued that involving patients in choosing treatment can make them burdened or can be unfavorable for them, yet no such evidence exists to support this issue [4]. In fact there have been evidences that patients feel more active when being included in health-care decisions [5].

Decision-making (DM) is critical to human life in case of treatment and other aspects as well. Theoretically, Decision-making models can be classified into two groups: Normative or prescriptive and Descriptive decision models. This paper describes a descriptive decision-making model under uncertainty in brief and elucidates its application in decision-making of patients who have recently been diagnosed with lung cancer, but have not yet undergone treatment. The motivation behind the choice of this topic is the rate of mortality from lung cancer every year according to the statistics of American Cancer Society [6]. Apart from the physician’s advice of treatment procedures, a patient has his/her own freedom to decide from an array of alternatives considering the trade-offs. It has been suggested that behavioral as well as demographic influences are observed in treatment choice preferences.

In this paper, we have considered a patient’s attitude toward uncertainty which is reflected in decision-making regarding treatment. At first we have modeled a DM problem under uncertainty as the Evidential DM Problem (EDMP) and converted it into DM problem under risk [7]. We approximate probabilities using the basic belief assignment (bba) of Dempster-Shafer Theory (DST) [8] associated to the subsets of the states of nature taking into account, the decision-makers’ attitude towards uncertainty. Prospect Theory (PT) [9] is then used to explain how a decision maker formulates decision in different attitudes. We have named the framework as Nusrat-Yamada-Descriptive Decision-Making (NY-DDM) framework. The goal of this paper is to: 1) illustrate a descriptive decision-making framework under uncertainty which is reflected in decision-making regarding treatment and other aspects as well. Theoretically, Decision-making models can be classified into two groups: Normative or prescriptive and Descriptive decision models. This paper describes a descriptive decision-making model under uncertainty in brief and elucidates its application in decision-making of patients who have recently been diagnosed with lung cancer, but have not yet undergone treatment. The motivation behind the choice of this topic is the rate of mortality from lung cancer every year according to the statistics of American Cancer Society [6]. Apart from the physician’s advice of treatment procedures, a patient has his/her own freedom to decide from an array of alternatives considering the trade-offs. It has been suggested that behavioral as well as demographic influences are observed in treatment choice preferences.

II. RELATED WORKS ON DECISION-MAKING UNDER UNCERTAINTY

One of the early DM models under uncertainty is proposed by Schmeidler [10] where rank-dependent utility [11] model is utilized and uncertainty is represented by a probability distribution over a partition of states of nature. In [10], the author introduces functional representation of a preference
relations derived from axioms and this functional representations are sums of products of probability
interpretation and utility interpretation. This kind of
presentation was primarily initiated in [11].

A more general description of uncertainty is introduced in
generalized expected utility (GEU) [12, 13] model where basic
belief assignment (bba) of DST has been used to represent
uncertainty. GEU can be explained by the following equation:

\[ U_{geu}(a_i) = \sum_k m(S_k) \bullet V(a_i, S_k), \]  

(1)

where \( m(S_k) \) is a basic belief assignment and \( S_k \) is a focal
element representing a set of states of nature. \( V(a_i, S_k) \) is a
utility evaluation depending on the alternative \( a_i \) and \( S_k \), and
can be given by a parametric function called OWA operator
[13, 14], whose parameters could be determined by the attitude
(equative, pessimistic, optimistic, etc.) of the decision-maker to
non-specificity or ignorance of the states in \( S_k \).

One DM model under uncertainty called Cautious OWA
with Evidential Reasoning (COWA-ER) is introduced in [15]
as an extension of [13]. The authors of [15] have considered the
results of two extreme attitudes (pessimistic and optimistic) of [13]
jointly and develop a four-step process in order to select an
alternative regardless of any specific attitude. At first, the
expected payoffs (bounded by extreme pessimistic and
optimistic) are normalized in [0, 1]; each imprecise value is
converted to bba. Later on, the bba's are combined by a
combination rule named Proportional Conflict Redistribution
rule no. 5 (PCR5) [15]. The last step is the decision making
from these resulting bba.

It is relevant to mention Cumulative prospect theory (CPT)
in this section that falls under the category of descriptive
DM model under uncertainty. CPT is an extension of prospect
theory incorporating rank-dependent utility theory for
transforming probabilities. Noticeably, uncertainty in CPT is
represented by a probability distribution on a partition of states
of nature and it transforms the entire cumulative distribution
function instead of transforming each probability separately.
Another descriptive DM model under uncertainty is proposed
by Tamura et al.[17-20] as an extension of PT. A limitation of
this model is that it cannot implement various decision attitudes
other than the typical three; equate, pessimistic and optimistic.
For example, it does not explain the median approach as well as 2nd pessimistic/optimistic. Next, Tamura et al. model lacks in consideration about the difference between
the weighting function of probability and the one of bba.

The key differences between our proposed model, NY-
DDM and the above mentioned models can be summarized as follows:
1) uncertainty by bba is more general than a probability distribution on a partition, and can represent all
realms of DM, 2) it can deal with various decision attitudes to
non-specificity or ignorance thanks to the capability for
converting any uncertainty model with OWA operator to a risk
model, 3) The incorporation of PT has given NY-DDM the
characteristics of a descriptive DM model.

III. NY-DDM FRAMEWORK

NY-DDM initiates with an Evidential Decision Making
Problem (EDMP). EDMP has similarity to the conventional
definition of decision making in different literature where \( A = \{ a_i \}_{i=1,...,N} \) is the set of alternatives, \( S = \{ s_j \}_{j=1,...,M} \) is the
states of nature and the outcome set \( O = \{ o_y \}_{y=1,...,Y} \)
and the utility function \( u_y = u(a_{ij}) \) . The uncertainty is defined
on the states of nature \( S : m(B) \) where \( B \subset S \). \( m(B) \) represents
the basic belief assignment (bba). We chose the Dempster-
Shafer Theory (DST) of Evidence due to its capability of
expressing more than one type of uncertainty. Decision-making
is practically performed under the realm of certainty, risk,
uncertainty and/or ignorance [21]. Our definition of EDM satisfies all of these realms by giving an appropriate bba. The
approach we have considered to solve a DM problem under
uncertainty is the probability approximation and we have approximated the bba to probability. In our model, a DM
problem with uncertainty is approximated by one of DM with
risk, depending on the attitudes to non-specificity or ignorance.

A seemingly standard way of approximation from bba to
probability is the one by equidistribution [22] where the mass
is equally distributed over the states of the focal element:

\[ P_{appr}(s_j) = \sum_{s_j \in S_k} \frac{m(S_k)}{|S_k|}. \]  

(2)

When the mass function is defined on a total ordered set,
or a set whose elements have a numerical attribute as in this
case, we could assign probability distributions of the worst
case and the best case which are consistent with the mass function;
the best case assigns the whole mass of \( S_k \) namely \( m(S_k) \), to
the largest/best element(s) \( s^{(k)}_{best} \in S_k \), and the worst case to the
smallest/worst element(s) \( s^{(k)}_{worst} \in S_k \). Note that \( s^{(k)}_{best} \) and
\( s^{(k)}_{worst} \) depend on alternative \( a_i \), because utility is a function of
a pair of \( a_i \) and \( s_j \). Therefore, \( P_{pes}(s_j | a_i) \), \( P_{app}(s_j | a_i) \) is
the probability distribution in the case where we assume that
\( s^{(k)}_{worst} \) (\( s^{(k)}_{best} \) ) happens with a probability equal to \( m(S_k) \),
when the decision-maker chooses \( a_i \) and thus the name Pessimistic (Optimistic) probability distribution respectively.
The equations of Pessimistic and Optimistic distribution are as
follows:

\[ P_{pes}(s_j | a_i) = \sum_k m_{pes}(s_j, S_k | a_i), \]  

(3)

\[ P_{app}(s_j | a_i) = \sum_k m_{appr}(s_j, S_k | a_i), \]  

(4)
where \( N_{pec} \) and \( N_{opt} \) are numbers of \( s_j \in S_k \) satisfying

\[
u(o_j) = \min_{s_j \in S_k} u(o_{ih})
\]

and satisfying

\[
u(o_j) = \max_{s_j \in S_k} u(o_{ih})
\]

respectively. Moreover, it is also possible to show that any GEU model with OWA operator can be transformed into a DM under risk. This fact lets us discuss descriptive model of DM under uncertainty in the framework of DM under risk. (Please refer to [7, 23] for detailed explanation and proof). We can infer from the above discussion that a DM problem under uncertainty with GEU and OWA operator could be transformed into a DM problem under risk equivalent to the original one.

By approximating uncertainty to probability, the EDMP is converted into three different problems of DM under risk (We could convert it to many other DM problems under risk depending on the attitude of the decision maker). At this point, applying PT will lead us to a descriptive model of DM under risk corresponding to DM under uncertainty with OWA operator. In PT, the choice of alternatives is determined by the combination of two very important functions: the value function and the weighting function [9]. In value function \( v(x) \), \( x \) is either gain or loss. If the value \( x \) is greater (less) than a neutral reference point, then the outcome has a gain (loss). According to PT, people value gains or loss differently and therefore \( v(x) \) reflects the subjective value of that outcome. The value function in original PT is:

\[
\begin{align*}
v(x) &= \begin{cases} 
  x^a, & \text{if } x \geq 0 \\
  -\lambda(-x)^a, & \text{if } x < 0.
\end{cases}
\end{align*}
\]

For \( a < 1 \), the value function exhibits risk aversion over gains and risk seeking over losses. Furthermore, if \( \lambda \) (loss-aversion coefficient) is greater than one, individuals are more sensitive to losses than gains. Furthermore, the weighting function \( \pi(p) \) used in this paper is as follows:

\[
\pi(p) = \frac{p^\gamma}{(1 - p)^{1/\gamma}}, \quad 0 \leq y \leq 1
\]

As we mentioned in Section II, NY-DDM has the advantage of deriving various attitudes including the 2nd optimistic/pessimistic, half-semi-quarter optimistic and pessimistic attitudes and median approaches [23], [24] which were unexplained by the previous descriptive DM models under uncertainty. Furthermore, this model removes the problem of considering the difference between weighting function of probability and the one of bba since we have converted the EDMP into a probabilistic decision-making problem.

IV. LUNG CANCER: FEW FACTS, DIAGNOSIS, STAGING AND TREATMENT ALTERNATIVES

A. Few Facts

Lung cancer is one of the three most common cancers diagnosed each year both in UK and USA. Around 41,400 people are diagnosed with Lung cancer in the UK [25] each year whereas in USA, the estimated number of new cases of lung cancer for 2012 is 226,160 with the estimated death of 160,340 people which is the highest among all common cancers according to [6]. Smoking is the most important cause of lung cancer though there are many other factors that increase risks such as: exposure to radon gas, exposure to certain chemicals, air pollution, previous lung diseases, past cancer treatment etc. Although screening tests are helpful to find and treat lung cancer early, unfortunately there is no generally accepted screening test for lung cancer. There are several different types of lung cancer that can be divided into two main types: 1) Small cell lung cancer (SCLC): About 13% lung cancers are small cell lung cancer. This tends to spread quickly. 2) Non small cell lung cancer (NSCLC): About 87% are of this type that spreads slowly than small cell lung cancer.

These are diagnosed based on how the cells look under a microscope. In this paper, we have dealt with NSCLC type of lung cancer. All of the stages, alternatives and outcomes mentioned here are given based on this type.

B. Diagnosis

According to visible symptoms, physical exams are asked to check for general signs of health, Chest X-ray to find tumors or abnormal fluid, CT scan or spiral CT scan that can show a tumor, abnormal fluid or swollen lymph nodes. The only sure way to know if lung cancer is present is by pathological tests by collecting samples of cells or tissue. The necessary tests to collect samples are: Sputum cytology, Thoracentesis, Bronchoscopy, Fine-needle aspiration, Thoracoscopy etc. .

C. Staging

The stage of cancer implies how big it is and how far it has spread. In order to plan the best treatment as well as analyze the prognosis, staging of cancer is very important. The tests and scans are required to get some information about the stage. Sometimes it is not possible to be certain about a stage of a cancer until after surgery. Both number staging system and the TNM system are being used in staging lung cancer. The stages of non small cell lung cancer can be explained as follows [26]:

Occult Stage: Lung cancer cells are found in sputum or in a sample of water collected, but a tumor cannot be seen in the lung.

Stage 0: Cancer cells found only in the innermost lining of the lung and the tumor has not grown through this lining.

Stage 0 tumor is also called carcinomata in situ.
Stage IA: Tumor has grown through the innermost lining of the lung into deeper lung tissue. The tumor is no more than 3 cm across, surrounded by normal tissue and tumor does not invade the bronchus. Cancer cells are not found in nearby lymph nodes.

Stage IB: The tumor is more than 3 cm across or it has grown into the main bronchus or it has grown through the lung into the pleura.

Stage IIA: The lung tumor is more than 3cm but cancer cells are found in nearby lymph nodes.

Stage IIB: Cancer cells are not found in nearby lymph nodes but tumor has invaded the chest wall. OR the tumor is more than 3 cm across or it has grown into the main bronchus or it has grown through the lung into pleura.

Stage IIIA: The tumor may be of any size. Cancer cells are found in the lymph nodes near the lungs and bronchi but on the same side of the chest as the tumor.

Stage IIIB: The tumor may be of any size. Cancer cells are found on the opposite side of the chest from the lung tumor or in the neck, sometimes in the pleural fluid.

Stage IV: Malignant growth may be found in more than one lobe of the same lung or in the other. OR cancer cells may be found in other parts of the body, such as brain, liver or bone.

D. Treatments

The treatment is planned taking into account of several issues such as the type of cancer, the position of the cancer within the lung, general health of the patient, the stage of cancer and results of blood tests and scans. Usually, non small cell lung cancer can be treated with surgery, chemotherapy, radiotherapy or a combination of these or sometimes with targeted therapies. New combinations of treatments are being studied in clinical trials and patients can also take part in clinical trials by choice.

Occult NSCLC can be cured by surgery. Stage 0 NSCLC is also treated with surgery or sometimes photodynamic therapy, electrocautery or laser surgery. Treatment of Stage I include surgery, external radiation therapy, and clinical trial of chemotherapy or radiation therapy following surgery, clinical trial of surgery followed by chemoprevention. Treatment of stage II NSCLC includes surgery, Chemotherapy followed by surgery, surgery followed by Chemotherapy, external radiation therapy and clinical trials. Treatment of Stage III NSCLC that can be removed with surgery may include surgery followed by chemotherapy, Chemo followed by surgery, surgery followed by chemotherapy combined with radiation therapy, surgery followed by radiation therapy. In some cases, radiation therapy, surgery or combination of these two are also applied. Treatment of Stage IV NSCLC include combination chemotherapy, combination chemotherapy and targeted therapy with a monoclonal antibody, targeted therapy with a tyrosine kinase inhibitor, maintenance therapy with anticancer drug, laser therapy etc [26].

It is important to state that, almost all of these treatment methods have moderate to severe side effects along with slim chance of complete recovery. In addition, the cost of the treatment is also very high in any country of the world. Therefore, a patient might have different mind-set regarding the treatment alternatives they are usually offered by the physicians. The intention of this paper is to analyze how a patient can choose a treatment among many alternatives based on three decision attitude: equative, pessimistic and optimistic. The next section describes the problem formulation step by step.

V. TREATMENT DECISION OF A LUNG CANCER PATIENT

Lung cancer is indeed life threatening and untreated lung cancer surely leads to death. Studies show that several factors such as external recommendation, intrinsic treatment characteristics, patients’ and their supporters’ own impressions and economic considerations are the most common factors of treatment decisions for non-malignant diseases whereas treatment efficiency (from the viewpoint of physician as well as patient) gets the top-most priority in case of life threatening diseases such as a disease like cancer [5]. We are dealing with a problem where the patient has recently been diagnosed with cancer and the stage of cancer is yet to be diagnosed. So, the correct stage of cancer is still uncertain to the patient. Cancer staging requires a couple of diagnosis both physical tests and pathological findings. Yet there can be uncertainties regarding staging. We assume that the patient is not completely aware of cancer stage thereby indicating the uncertainty of the problem which is represented in our constructed EDMP.

A. Problem Formulation

An EDMP includes the set of states of nature $S$, set of alternatives $A$ and the set of outcomes $O$ for each state and alternative pair $(a, s)$ and utility values for each outcome.

B. States of Nature

In this DM problem, the states of nature are the cancer stages being considered in real-life treatment process. There can be 9 different stages of non small state lung cancer depending on the position, tumor size and metastasis. Therefore, the set of states include 9 element; $S = \{s_1, s_2, ...s_9\}$ where $s_1$: Occult stage, $s_2$: Stage 0, $s_3$: Stage 1A, $s_4$: Stage IB, $s_5$: Stage IIA, $s_6$: Stage IIB, $s_7$: Stage IIIA, $s_8$: Stage IIIB, $s_9$: Stage IV.

C. Basic Belief Assignment

We assume that the stages of cancer are yet unknown to the patient. Therefore from the available evidences such as X-rays, CT, bronchoscopy, sputum cytology, meta-analyses, systematic reviews of RCT’s, cohort studies, expert opinion, it is possible to obtain the bba about what stage of cancer the patient belongs to. Here, the assumed bba value in Table I indicates that the patient belongs to any one of the stages in the focal element.

D. Alternatives

The set of alternatives consists of various treatment options offered to a lung cancer patient. Surgery, Chemotherapy, Radiation therapy, Targeted Therapy and Clinical Therapy are the standard treatments used by most of the oncologists. There are also variety and/or combination of these treatments
depending on the stage of cancer and obviously on patient's overall health condition. Therefore, we have also considered four types of each of the mentioned treatments. Table II illustrates 20 alternatives we have considered in this paper.

### E. Outcomes and Utility Values

In this DM problem, the consideration of outcome set for treatment decision depends on 4 factors: cost or expense of treatment (C), treatment efficiency (T), 5-year survival rate (S) and side effects (E) and the outcome set can be given by a quadruplet of O. The outcomes can be defined by the Cartesian product of the following sets: \( O = O_x \times O_T \times O_S \times O_E \) where \( O_x = \{
\begin{array}{ll}
\text{Very Expensive: 0, Expensive: 1, Moderately Expensive: 2, Inexpensive: 3}\}
\end{array}\), \( O_T = \{\text{No Recovery: 0, Slow Recovery: 1, Moderate Recovery: 2, Fast Recovery: 3}\}, \ O_S = \{10\% \text{ or less: 0, 20-40\%: 1, 40-50\%: 2, 60-80\% or more: 3}\}, \ O_E = \{\text{Long term side effects: 0, Severe Short term side effects: 1, Moderate Side effects: 2, Ignorable effects: 3}\}. \) Therefore, the set \( O \) has 256 outcomes in total. Table III partly shows the outcome table with corresponding utilities. Utility considered here is a relative representation of preferences over a set of outcomes. It is essentially subjective and personal. However, we assume the patient gives the utility by a multiple regression equation according to his/her intuition. The utility formula that has been used in this paper is: \((T^*64 + S^*16+ (E+T+4)^*4+C+I)\), where \( T, S, E, C \) represent treatment efficiency, 5-year survival rate, side effects and cost or expense of treatment respectively. All variables take values from 0 to 3 in an order of betterment. We obtained the utility values by iterating the variables from the lowest utility to the highest utility incrementing one variable at a time. According to the formula of utility generation, outcome \( o_1 \) equals 17. From the belief structure, we can now approximate the probabilities in three different attitudes of a decision-maker: namely Equative, Pessimistic and Optimistic and proceed to apply PT for overall value of each alternative. The mentioned attitudes are not the only attitudes that can be expressed by NY-DDM framework; many other attitudes can be expressed by changing the parameters of OWA operator. In case of PT application, it requires us to set a reference point (the point or value in the outcome list for which a decision-maker possesses a neutral feeling).

For this specific problem, we have taken the median value of all of the outcomes as a reference point assuming that the ordinary patients choose it as a reference to judge if the result is a success or failure. The next important part is to apply value function and weighting function to acquire and analyze decisions in different attitudes. The value function \( v(x) \) uses \( \alpha \), explaining risk attitude and \( \lambda \), called the loss aversion coefficient. It is widely known in different literature that \( \alpha \) to be less than 1 whereas \( \lambda > 1 \) resembles loss aversion [9, 27]. In this paper, we have used 48 combinations of \((\lambda, \alpha, \gamma)\) in evaluating the overall values of the alternatives to find a feasible decision of this problem.

### VI. RESULT AND DISCUSSION

Evaluation of 20 alternatives with 48 combinations of 3 coefficient provides a quite interesting result. For each combination representing a different attitude toward risk, we have generated overall values of all of 20 alternatives using the following equation:

\[
U_{prs}(a_i) = \sum_{j} \pi(p_j) \cdot v(x_{ij}),
\]

<table>
<thead>
<tr>
<th>Outcome Number</th>
<th>Description</th>
<th>Utility Value ((T^*64 + S^*16+ (E+T+4)^*4+C+I))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( o_1 )</td>
<td>Very Expensive, No recovery, 10% or less, Long term Side Effects</td>
<td>17</td>
</tr>
<tr>
<td>( o_2 )</td>
<td>Very Expensive, No recovery, 10% or less, Severe Short term effects</td>
<td>21</td>
</tr>
<tr>
<td>( o_{255} )</td>
<td>Inexpensive, Fast recovery, 60-80% or more, Moderate Effects</td>
<td>268</td>
</tr>
<tr>
<td>( o_{256} )</td>
<td>Inexpensive, Fast recovery, 60-80% or more, Ignorable Effects</td>
<td>272</td>
</tr>
</tbody>
</table>

TABLE I. BBA TABLE

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Sub-types</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery</td>
<td>L1</td>
<td>Video-assisted thoracic surgery (VATS): early stage cancers</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>Segmentectomy or wedge resection: Part of the lobe is removed</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>Lobectomy: A section of the lung is removed</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>Pneumonectomy: An entire lung is removed</td>
</tr>
<tr>
<td>Chemotherapy</td>
<td>L1</td>
<td>Neoadjuvant therapy: Chemo with radiation before surgery</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>Adjuvant therapy: Along with radiation after surgery</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>Chemo as a main treatment</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>Second-line treatment with a single drug for advanced stage cancer</td>
</tr>
<tr>
<td>Radiation Therapy</td>
<td>L1</td>
<td>Stereotactic Radiation: Early stage cancer</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>Intensity Modulated Radiation Therapy (IMRT)</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>3D-CRT</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>Internal Radiation Therapy</td>
</tr>
<tr>
<td>Targeted Therapies</td>
<td>L1</td>
<td>Drugs that target tumor blood vessel growth (Angiogenesis)</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>Drugs that target EGFR (Epidermal Growth Factor Receptor)</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>Drugs that target ALK gene</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>Complementary and alternative therapy</td>
</tr>
<tr>
<td>Clinical Trials</td>
<td>L1</td>
<td>Trials on Physical and Behavioral therapy: Trial on supportive care</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>Pre- and Post-surgery trials</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>Biomarker/Laboratory/Diagnostic Trials</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>Trials on Treatment</td>
</tr>
</tbody>
</table>
After that, an alternative with the highest value in the set is selected as a decision. In this way, we obtained the highest valued alternative for each combination and counted the number of times the alternatives received highest value among the 48 combinations. Table IV shows the decisions. The results show us which alternative the different attitudes to ignorance (equative, pessimistic, or optimistic) tend to choose regardless of attitudes to risk (risk-seeking or risk-averse). According to our model, a patient with equative attitude mostly chooses Surgery: L1 or Surgery L2 since among the result of 48 combinations, the overall values of Surgery: L1 and Surgery: L2 become equal for 44 combinations. A pessimist chooses Surgery: L2 because it always takes the highest value. An optimist chooses radiation therapy in all of the cases which is less invasive than most of the surgery options. We can infer that an optimist thinks that the best is to happen which makes aggression to get cured as much as possible. We can also infer that patients with equative and pessimistic attitude are being less aggressive in decision-making regarding treatment than patients with equative and optimistic attitude.

Surgery: L2 because it always takes the highest value. An optimist chooses radiation therapy in all of the cases which is less invasive than most of the surgery options. We can infer that an optimist thinks that the best is to happen which makes aggression to get cured as much as possible. We can also infer that patients with equative and pessimistic attitude are being less aggressive in decision-making regarding treatment whereas an optimist chooses an alternative that shows his aggression to get cured as much as possible. We can also infer that an optimist thinks that the best is to happen which makes him choose radiation therapies which may even incur moderate to major side effects.

<table>
<thead>
<tr>
<th>Decision Attitude</th>
<th>Alternative</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equative</td>
<td>Surgery: L1, Surgery L2</td>
<td>Surgery:L1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>=Surgery:L2 For 44 combinations; In 4 cases, L2 is negligibly larger than L1.</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>Surgery: L2</td>
<td>Highest in all combinations</td>
</tr>
<tr>
<td>Optimistic</td>
<td>Radiation Therapy: L1, Radiation Therapy: L3</td>
<td>Radiation Therapy: L1 has the highest value: 25 times</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radiation Therapy: L3 has the highest value: 23 times.</td>
</tr>
</tbody>
</table>

This research might be helpful for the researches of similar domain in a way that does not need to have a time-consuming survey. Our way of explaining attitudes as well as decisions based on human attitudes towards uncertainty might be helpful in other domains such as medicine sales forecasting or any other commodity. In this paper, we have assumed the belief assignments based on literature related to lung cancer. Our next target is to generate belief assignments for the mentioned DM problem from the available evidences using further enhancement of Dempster-Shafer’s rule of combination with a view of implementing an expert system of decision-making.

REFERENCES