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Finding the Nation with the Highest Rate of Deaths due to Cancer Using PROMETHEE

[1]S.Vaishnavi, [2]Keerthi Menon, [3]Chilkhe Ganesh Nagorao
Department of Mathematics and Computing[1,2]
School of Advanced Sciences, Vellore Instituteof Technology, Chennai, Tamil Nadu, India[1,2]
School of Social Languages, Vellore Institute of Technology, Chennai, TamilNadu, India[3]

Abstract: *Cancer is a growing problem in today's world. Cancer is considered to be the leading cause of death in many countries. The incidence rates for various cancer forms vary by nation and can depend on many factors such as the lifestyle of the people, obesity rates, exposure to certain chemicals, family history, and others. As preventing cancer is a significant public health challenge, it is important to identify which country is leading in death rates due to the disease. This study uses a Multi-criteria decision-making (MCDM) method named Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) to perform this test and rank the countries on this basis. The outcome of the decision-making process is to create awareness among people to reduce the effects caused by cancer in that particular country*

Keywords: Multi-criteria, Cancer, ranking, countries, decision-making

I. INTRODUCTION

Cancer is a deadly disease in which some cells from a particular part of the body uncontrollably grow and may spread to all parts if not diagnosed early, resulting in a tumour. One distinguishing characteristic of cancer is the quick development of aberrant cells that spread outside of their normal borders, infiltrate other body components, and eventually metastasize to other organs. The main reason why cancer patients die is because of widespread metastases [1].Due to variations in healthcare systems, some nations may have greater cancer rates than others. People may have different standards of care or fewer treatment alternatives in other nations. Some cancers are genetic; therefore if a community has a higher incidence of a particular disease, it can also appear in future generations at a higher incidence rate. Environmental factors may also contribute to some cancers [18]. There are more than 200 types of cancer. In this study, we have taken the 5 most commonly occurring types of cancer and ranked 5 different countries in Asia namely, Bangladesh, Iran, Vietnam, Turkey, and the Philippines based on the maximum number of deaths caused due tothese types of Cancer. The countries were chosen based on their population, which lies between 80 billion and 200 billion. The attributes that were taken into consideration when choosing the country with leading death rates due to cancer in the years 2000-2019: number of deaths due to liver cancer(5th most common cancer worldwide), number of deaths due to kidney cancer(14th most common cancer worldwide), number of deaths due to brain and Central Nervous System (CNS) cancer(10th most common death cause cancer worldwide), number of deaths due to pancreatic cancer(12th most common cancer worldwide) and number of deaths due to thyroid cancer(7th most common cancer in women).

Cancer is a major cause of death in every nation in the world and a major barrier to raising life expectancy. In 112 of 183 nations, cancer is the primary or second major cause of death before the age of 70, and it ranks third or fourth in another 23 countries, according to estimates from the World Health Organisation (WHO) in 2019 [9]. Since the dawn of time, mankind has been aware of cancer. Some of the earliest evidence of cancer can be found in the form of fossilized bone tumours in ancient Egyptian human mummies. Old literature has also made references to the disease [12]. Greek physician Hippocrates (460–370 BC) named the illness "cancer" for the first time. He is considered the "Father of Medicine". Hippocrates used the words carcinomas and carcinoma to refer to tumours that do not cause ulcers and those that do. This is the Greek word for crab [12]. The Greek word for crab was translated into the Latin word cancer by the later Roman physician Celsus (28–50 BC). Galen, a Roman physician (130-200 AD), was the first

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to utilize the Greek word for swelling, Oncos, to describe tumours. Oncology, or the study of cancers, has the root word Oncos. In 1761, Giovanni Morgagni of Padua formalized autopsies to determine the origin of diseases. This also established the framework for the research of cancer. Through the ages, there have been numerous theories on the cause of cancer. German surgeon Karl Thiersch demonstrated in the 1860s that tumours spread through the division of malignant cells, not through a liquid.

Trauma was once assumed to be the root of cancers until the 1920s [13].

One in six deaths, or around 10 million deaths, was predicted to be due to cancer in 2020, making it the top cause of death globally [7]. The leading causes of cancer-related deaths are tobacco use, high body mass index, alcohol consumption, inadequate intake of fruits and vegetables, unhealthy diet, air pollution, and lack of physical activity, which account for approximately one-third of fatalities. In low- and lower-middle-income nations, cancer- causing infections including the human papillomavirus (HPV) and hepatitis are thought to bethe cause of 30% of cancer cases [7].

Types of cancer	New cases in 2020 (% of all types)		Deaths in 2020 (% of all types)	
Liver	905,677	(4.7)	830,180	(8.3)
Kidney	431,288	(2.2)	179,368	(1.8)
Brain and cns	308,102	(1.6)	251,329	(2.5)
Pancreatic	495,773	(2.6)	466,003	(4.7)
Thyroid	586,202	(3.0)	43,646	(0.4)

Table 1: New Cases and Deaths for 5 Types of Cancers Worldwide in 2020.

Globally, the incidence and death from cancer are increasing rapidly, this is due to the population's aging and expansion as well as changes in the prevalence and distribution of thekey risk factors for cancer, many of which are linked to socio-economic development [1].

According to predictions, half of all cancer diagnoses and 58.3% of all cancer fatalities for both sexes will occur in Asia in 2020, which is home to 59.5% of the world's population [16]. Ensuring radiation is used in healthcare (for diagnostic and therapeutic reasons) safely and suitably, limiting exposure to Ultraviolet light, consuming a balanced diet that includes fruit and vegetables, engaging in regular exercise, and avoiding or limiting alcohol consumption. Cancers can be prevented in 30 to 50% of cases by avoiding risk factors and applying evidence-based preventative measures. If detected early and treated effectively, many cancershave a high chance of recovery.

Multiple criterion decision-making (MCDM), a subfield of operational research, is concerned with identifying the optimum outcomes in situations when there are several indications, competing aims, and competing criteria. This technology is becoming more and more popularacross all industries because it allows decision-makers the ability to make choices while simultaneously taking all the criteria and objectives into account [2]. The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) family of outranking techniques, consists of PROMETHEE I for partial ranking of the alternatives and PROMETHEE II for complete ranking of the alternatives [3]. We have used the (PROMETHEE II) method to perform this test. The rationale for choosing this method is that it is considered to be a superior method for ranking and choosing from a limited number of alternatives among the Multi-criteria decision-making (MCDM) methods. It is well suited to decision-making issues when a limited number of options must be ranked according to several competing criteria. To express the decision-maker's choice between pairs of alternatives for each criterion, the PROMETHEE approach provides a preference function [5].PROMETHEE II method presumes that the weights of the criteria are known beforehand.

The preference indices are exclusively computed concerning the best criteria, which are initially determined by this method [6].

This study aims at ranking countries in Asia to create awareness about the increase in cancerrates in the region and the need for action for the same. Countries are ranked to analyze and compare the number of deaths.

II. LITERATURE REVIEW

According to the official databases of the World Health Organization and American Cancer Society, ischemic heart disease is the leading cause of mortality (8.97 million fatalities) and a lethal non-communicable disease, but cancer will most certainly overtake it by 2060 (18.63 million fatalities). The overall chance of dying from cancer between

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the ages of 0 and 74 is 10.6% (12.7% in males and 8.7% in women, respectively); the risk of malignancy is highest for the lung, liver, and stomach in men and for the breast, lung, and cervix in women [19]. The most important source of data on cancer is cancer registries, which are used to plan patient treatment and cancer control initiatives as well as to understand the scope, patterns, and trends throughout time [20]. Mainly due to population growth and aging, the worldwide burden of cancer is anticipated to rise to 27.5 million new cases and 16.3 million cancer deaths by 2040[21]. The world's cancer mortality rates are highly varied[22]. This is crucial in low- and middle-income countries (LMIC), which are going through an economic transition that involves growing mechanization of labour and transportation, cultural changes in the roles of women, and increased exposure and access to global markets. In comparison to high- Human Development Index (HDI) countries, lower- and medium-Human Development Index (HDI) countries had about a 3-fold higher rate of cancers linked to infection. The third UnitedNations High-Level Meeting on Non-Communicable Diseases in 2018 and the United Nations High-Level Meeting on Universal Health Coverage in 2019 both emphasized the significance of prevention and control of cancer [23]. As a result, many of the lifestyle risk factors that are currently prevalent in high-income countries (HIC), such as tobacco use, physical inactivity, excess body weight, and reproductive patterns, are also becoming more frequent in low- and middle-income countries (LMICs)[26].Men are assumed to have a higherrisk of most cancer types because of greater exposure to carcinogenic environmental and behavioral variables, such as smoking, while a new study reveals that other characteristics like height, endogenous hormone exposure, and immunological function also have a significant impact[27,28]. The WHO South-East Asia Region recorded 1.4 million cancer- related fatalities and an estimated 2.2 million new cases, accounting for more than one in ten deaths in the region. Conclusions therefore backed the cancer prevention recommendations that encourage a healthy body weight (defined by the World Health Organisation as between 18.5 and 24.9 kg/m2) and proper energy balance throughout a person's lifetime.

III. PROMETHEE METHOD

The preference function-based outranking method is a special type of MCDM tool that can provide a ranking ordering of the decision options. The PROMETHEE (preference ranking organization method for enrichment evaluation) method was developed by Brans and first presented in 1982 at a conference at the University Laval in Laval, Quebec, Canada, which was organized by Nadeau and Landry and was further extended by Vincke and Brans. [31].The PROMETHEE I method can provide the partial ordering of the decision alternatives, whereas, the PROMETHEE II method can derive the full ranking of the alternatives. In this paper, the PROMETHEE II method is employed to obtain the full rankingof the alternative locations for a given industrial application.

The dataset for this study was obtained from the Web [35]

https://www.kaggle.com/datasets/bahadirumutiscimen/cancer-death-rates-in-the-world- 19902019

Country name	Liver Cancer (2000-2019)	Kidney Cancer (2000-2019)	Brain and CNS Cancer (2000-2019)	Pancreatic Cancer (2000-2019)	Thyroid Cancer (2000-2019)
Bangladesh	2506.35	491.75	2084.35	1536.65	472.35
Iran	1672.8	590.4	2531.55	1876.9	222.9
Vietnam	2246.15	559.5	1289.25	2414.95	869.75
Turkey	1971.6	1247.35	3082.8	4485.85	376.3
Philippines	4092	724.05	1596.65	2083.25	743.35

Table 2: Dataset from Kaggle

The procedural steps involved in the PROMETHEE II method are listed below:

Step 1: Determine the criteria (j=1,2,…,k) and the set of possible alternatives in a decisionproblem.

Let A_i where i=1,2,3,4,5 represent the alternatives, A1 represents Bangladesh, A2 represents Iran, A3 represents Vietnam, A4 represents Turkey, and A5 represents the Philippines. Let y1, y2, y3, y4, and y5 represent the criteria

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for choosing the country with the most number of deaths caused due to cancer be Liver cancer, Kidney cancer, Brain and CNS(Central NervousSystem) cancer, Pancreatic cancer, Thyroid cancer.

Step 2: Determine the weight w_j of each criterion such that

$$\sum_{j=1}^{k} w_j = 1$$

		Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
	Weightage	20%	20%	20%	20%	20%
	Countryname	Liver Cancer (2000-2019)	KidneyCancer (2000-2019)	Brain andCNS Cancer(2000-2019)	Pancreatic Cancer (2000-2019)	ThyroidCancer (2000-2019)
Alternative1	Bangladesh	2506.35	491.75	2084.35	1536.65	472.35
Alternative2	Iran	1672.8	590.4	2531.55	1876.9	222.9
Alternative3	Vietnam	2246.15	559.5	1289.25	2414.95	869.75
Alternative4	Turkey	1971.6	1247.35	3082.8	4485.85	376.3
Alternative5	Philippines	4092	724.05	1596.65	2083.25	743.35

Table 3: Weights for each criteria

Step 3: Normalize the decision matrix using the following equation:Beneficial criteria:

$$R_{ij} = \frac{[y_{ij} - \min(y_{ij})]}{[\max(y_{ij}) - \min(y_{ij})]} (i=1,2,..,n; j=1,2,..,m) \qquad (1)$$

	y1	y2	y3	y4	y5
A1	0.344556	0	0.443311	0	0.385638
A2	0	0.130558	0.692649	0.11537	0
A3	0.237	0.089664	0	0.29781	1
A4	0.123512	1	1	1	0.237149
A5	1	0.307438	0.171392	0.185338	0.804591

Table 4: Using the beneficial formula

For non-beneficial criteria, Eqn. (1) can be rewritten as follows:

$$R_{ij} = \frac{[\max(y_{ij}) - y_{ij}]}{[\max(y_{ij}) - \min(y_{ij})]} (i=1,2,..,m; j=1,2,..,n) \qquad (2)$$

According to our requirement, we have used beneficial criteria to rank the country with themost number of deaths.

Step 4: Determine of deviation by pair-wise comparison.

$d_j(a,b) = g_j(a) - g_j(b)$ (3)

Where a and b represent the alternatives.

$d_j(a,b)$ denotes the difference between the evaluations of a and b on each criterion

	y1	y2	y3	y4	y5
A12	0.344556	-0.13056	-0.24934	-0.11537	0.385638
A13	0.107556	-0.08966	0.443311	-0.29781	-0.61436
A14	0.221044	-1	-0.55669	-1	0.148489
A15	-0.65544	-0.30744	0.271919	-0.18534	-0.41895
A21	-0.34456	0.130558	0.249338	0.11537	-0.38564
A23	-0.237	0.040895	0.692649	-0.18244	-1
A24	-0.12351	-0.86944	-0.30735	-0.88463	-0.23715
A25	-1	-0.17688	0.521257	-0.06997	-0.80459
A31	-0.10756	0.089664	-0.44331	0.29781	0.614362

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A32	0.237	-0.04089	-0.69265	0.182439	1
A34	0.113488	-0.91034	-1	-0.70219	0.762851
A35	-0.763	-0.21777	-0.17139	0.112471	0.195409
A41	-0.22104	1	0.556689	1	-0.14849
A42	0.123512	0.869442	0.307351	0.88463	0.237149
A43	-0.11349	0.910336	1	0.70219	-0.76285
A45	-0.87649	0.692562	0.828608	0.814662	-0.56744
A51	0.655444	0.307438	-0.27192	0.185338	0.418953
A52	1	0.176879	-0.52126	0.069968	0.804591
A53	0.763	0.217774	0.171392	-0.11247	-0.19541
A54	0.876488	-0.69256	-0.82861	-0.81466	0.567442

Table 5: Pairwise comparison

Step 5: Determine the preference function,

$P_j(a, b)=F_j[d_j(a,b)]$

Where $P_j(a,b)$ represents the function of the difference between the evaluations of alternative a regarding alternative b on each criterion into a degree ranging from 0 to 1. Thesmaller number of the functions denotes the indifference of the decision maker. On the contrary, a close to 1 indicates greater preference.

Step6: Determine the multi-criteria preference index

$$(a, b) = \sum^{k}{}_{j=1} (a, b)w_j \qquad (5)$$

where $w_j>0$ are the weights associated with each criterion. The symbol (a, b)shows that thedegree of a is preferred to b over all the criteria.

	y1	y2	y3	y4	y5	
	20%	20%	20%	20%	20%	
A12	0.068911	0	0	0	0.077128	0.146039
A13	0.021511	0	0.088662	0	0	0.110173
A14	0.044209	0	0	0	0.029698	0.073907
A15	0	0	0.054384	0	0	0.054384
A21	0	0.026112	0.049868	0.023074	0	0.099053
A23	0	0.008179	0.13853	0	0	0.146709
A24	0	0	0	0	0	0
A25	0	0	0.104251	0	0	0.104251
A31	0	0.017933	0	0.059562	0.122872	0.200367
A32	0.0474	0	0	0.036488	0.2	0.283888
A34	0.022698	0	0	0	0.15257	0.175268
A35	0	0	0	0.022494	0.039082	0.061576
A41	0	0.2	0.111338	0.2	0	0.511338
A42	0.024702	0.173888	0.06147	0.176926	0.04743	0.484417
A43	0	0.182067	0.2	0.140438	0	0.522505
A45	0	0.138512	0.165722	0.162932	0	0.467166
A51	0.131089	0.061488	0	0.037068	0.083791	0.313435
A52	0.2	0.035376	0	0.013994	0.160918	0.410288
A53	0.1526	0.043555	0.034278	0	0	0.230433
A54	0.175298	0	0	0	0.113488	0.288786

Table 6: Preference function and multi-criteria preference index

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	A1	A2	A3	A4	A5		
A1	0	0.146039	0.110173	0.073907	0.054384	0.384503	0.096126
A2	0.099053	0	0.146709	0	0.104251	0.350013	0.087503
A3	0.200367	0.283888	0	0.175268	0.061576	0.721099	0.180275
A4	0.511338	0.484417	0.522505	0	0.467166	1.985426	0.496357
A5	0.313435	0.410288	0.230433	0.288786	0	1.242942	0.310736
	1.124193	1.324632	1.00982	0.537961	0.687377		
	0.281048	0.331158	0.252455	0.13449	0.171844		

Table 7: Comparison matrix of one alternative over another alternative

Step7: Determine the leaving and the entering outranking flows as follows:Leaving (or positive) flow:

$$\varphi^{+}(a) = \frac{1}{n-1} \sum_{y \in A} (a, y) \qquad (6)$$

Entering (or negative) flow:

$$\varphi^{-}(a) = \frac{1}{n-1} \qquad (7)$$

where n is the number of alternatives, $\varphi^{+}(a)$ represents positive outranking flow or is knownas leaving flow(how a dominates all the other alternatives), $\varphi^{-}(a)$ represents the negative outranking flow or is known as entering flow (how a dominates by all the other alternatives). The alternative with a higher value of $\varphi^{+}(a)$ and the lower value of $\varphi^{-}(a)$ is the best alternative. Here, each alternative faces (n – 1) a number of other alternatives. The leaving flow expresses how much an alternative dominates the other alternatives, while the entering flow denotes how much an alternative is dominated by the other alternatives. Based on these outranking flows the PROMETHEE II method can give the complete preorder by using a net flow, though it loses much information on preference relations.

	Positive flow ($\varphi^{+}(a)$)	Negative flow($\varphi^{-}(a)$)
A1	0.096126	0.281048
A2	0.087503	0.331158
A3	0.180275	0.252455
A4	0.496357	0.13449
A5	0.310736	0.171844

Table 8: Leaving (or positive) flow and Entering (or negative) flow

Step 8: Calculate the net outranking flow for each alternative and rank accordingly:

$$(a) = \varphi^{+}(a) - \varphi^{-}(a) \qquad (8)$$

Determine the ranking of all the considered alternatives depending onthe values of(a). Thehigher value of (a), the better the alternative. Thus, the best alternative is the one having the highest(a)value [33,34].

	Net flow($\varphi(a)$)	Rank
A1	-0.18492	**4**
A2	-0.24365	**5**
A3	-0.07218	**3**
A4	0.361866	**1**
A5	0.138891	**2**

Table 9: Net outranking flow and rank

In comparison to the other possible countries selected in this example, A4, or Turkey, has thegreatest net flow value and, as a result, has the most deaths in Asia.

Table 9 shows the ranks for each alternative that is, each country.

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IV. CONCLUSION

This method has helped to find the country that has the most number of deaths in the given scenario. Cancer is the second leading cause of death in Turkey. Identification and ranking of the countries aids in raising awareness and need for action to prevent the increase in mortalityrates due to cancer in the upcoming years. The PROMETHEE II technique is an interactive multi-criteria decision-making strategy created to handle both discrete choices and quantitative criteria. In comparison to other MCDM approaches, the PROMETHEE method provides several advantages as this technique can categorize those options that are difficult to compare as non-comparable alternatives due to the accommodative relationship of assessment standards.

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