COMPARATIVE ANALYSIS AND THE APPLICATION OF NON-CONTACT TEMPERATURE READING DEVICES IN THE CONTROL OF COVID-19 USING FUZZY PROMETHEE

A THESIS SUBMITTED TO THE INSTITUTE OF GRADUATE STUDIES
NEAR EAST UNIVERSITY

BY

DUWA, BASIL BARTH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN BIOMEDICAL ENGINEERING

NICOSIA, 2021

COMPARATIVE ANALYSIS AND THE APPLICATION OF NON-CONTACT TEMPERATURE READING DEVICES IN THE CONTROL OF COVID-19 USING FUZZY PROMETHEE

A THESIS SUBMITTED TO THE INSTITUTE OF GRADUATE STUDIES NEAR EAST UNIVERSITY

BY

DUWA, BASIL BARTH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

IN

BIOMEDICAL ENGINEERING

NICOSIA, 2021

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name:
Signature:
Date

ACKNOWLEDGEMENT

My appreciation to God almighty,who made it possible for me to complete this program successfully.

Besides my efforts, the success of this work depends hugely on the encouragements of many. I would like to use this medium to appreciate my indefatigable supervisor, Assoc. Dr.Dilber Ozsahin-Uzun for her tremendous supports and motivation throughout my programme; I genuinely don't take that for granted.

To my enthusiastic and focused co-supervisor, Dr.BernaUzun, who I couldn't have imagined working on this thesis without. Her, effortlessness in passing knowledge and intense interest on her students still dumbfound me. I sincerely appreciate you!

I would also like to show my greatest appreciation to my Head of department, Prof.Dr. Ayse GunayKibareer for her enormous support and interest in my academics, for her motherly guidance and advice. My special thanks to Prof.Dr.Mehmet Ozsoz for believing in me and giving me the opportunity to work on several projects with him, I remain grateful for this.I specially acknowledge the Dean faculty of Engineering Prof.Dr. Bulent Bilgehan.

To my dearest parents,Mr. Barth. Duwa and Christy Duwa and my maternal grandmother Mrs Regina Banki, who are my greatest pillars; their financial, spiritual and moral supports cannot be over emphasised.

I also acknowledge my course mates Sharmain Dube and Sabareela Moro, my senior colleague Mubarak Taiwo Mustapha, my housemate Prince George, friends and well-wishers.It would be indeed difficult to find a proper word to convey my appreciation.

ABSTRACT:

The spread of the COVID-19 pandemic around the globe made it necessary to apply simple methods to control and prevent the virus. A non-contact thermometer is used often in fever screening at different check-points. However, there is need to compare and obtain the best fever screening device. In this study, five fever screening thermometers namely, the handheld medical laser thermometer, Apollo in motion thermometer, Tytohome, Door access face recognition fever alarm device and the Delphi-pole mounted contact free fever detection were compared using the fuzzy-based MCDM methods.

The variables were assessed based on criteria such as the, cost, company reputation, age of the device, battery capacity, functions, advantage, disadvantage and accuracy of the device. The alternatives were evaluated based on the multi-criteria decision-making (MCDM) methods, the fuzzy preference ranking method for enrichment evaluation (fuzzy PROMETHEE). The handheld medical laser thermometer with the net flow 0.0061 showed to be the best followed by the Apollo in motion temperature device with net flow of 0.0051, respectively. The tytohome revealed to be the third with the net flow of -0.0027. The least effective were the Door access face recognition thermometer and the Delphi-pole mounted device.

In this study, the strengths and weaknesses of the non-contact temperature reading devices were shown. These could be important for the users and the experts for understanding the features of these devices. The results revealed that the handheld medical laser thermometer should be preferred in control-points of the COVID-19 because of its low cost, high accuracy and high functionality.

Keywords: COVID-19, temperature reading devices, fuzzy-PROMETHEE.

ÖZET

COVID-19 pandemisinin dünya geneline yayılması, virüsü kontrol altına almak ve önlemek için basit yöntemlerin uygulanmasını zorunlu hale getirdi. Farklı kontrol noktalarında ateş taramasında sıklıkla temassız bir termometre kullanılır. Bununla birlikte, en iyi ateş tarama cihazını karşılaştırmaya ve elde etmeye ihtiyaç vardır. Bu çalışmada, el tipi medikal lazer termometre, Apollo hareketli termometre, Tytohome, Kapı erişimli yüz tanımalı ateş alarm cihazı ve Delphi direğine monte temassız ateş tespiti olmak üzere beş ateş tarama termometresi, bulanık tabanlı MCDM yöntemleri kullanılarak karşılaştırılmıştır. Değişkenler, cihazın maliyeti, şirket itibarı, cihazın yaşı, pil kapasitesi, işlevleri, avantajı, dezavantajı ve doğruluğu gibi kriterlere göre değerlendirildi. Alternatifler, çok kriterli karar verme (MCDM) yöntemlerine, zenginleştirme değerlendirmesi için bulanık tercih sıralama yöntemine (bulanık PROMETHEE) dayalı olarak değerlendirildi. 0,0061 net akışa sahip eltipi tıbbi lazer termometresi, sırasıyla 0,0051 net akışa sahip Apollo hareketli sıcaklık cihazı tarafından takip edildi. Tytohome, -0.0027 net akışla üçüncü oldu. En az etkili olanlar, Kapı erişim yüzü tanıma termometresi ve Delphi direğine monte edilmiş cihazdı. Bu çalışmada temassız sıcaklık okuma cihazlarının güçlü ve zayıf yönleri gösterilmiştir.

Bunlar, bu cihazların özelliklerini anlamak için kullanıcılar ve uzmanlar için önemli olabilir. Sonuçlar, düşük maliyeti, yüksek doğruluğu ve yüksek işlevselliği nedeniyle COVID-19'un kontrol noktalarında el tipi tıbbi lazer termometrenin tercih edilmesi gerektiğini ortaya koydu.

Anahtar Kelimeler: COVID-19, sıcaklık okuma cihazları, bulanık-PROMETHEE.

TABLE OF CONTENTS

LIST OF FIGURES

List of Tables

CHAPTER 1

INTRODUCTION

Background of Study

The COVID-19 pandemic virus is an infectious disease, known for its recent scaryoutbreak recorded worldwide. This virus affects persons with symptoms such as that of the severe acute respiratory syndrome as referred to as the SARS-CoV. COVID-19, case was first recorded in China at the Wuhan province, in November 2019 and death was first recorded in December same year [1]. Thus, the virus is categorised under the sub-family of *Orthocorronavirinae* and the genus *Corona viridae*. It is a zoonotic disease which commonly spreads as a result of interaction among people carrying the virus, which may also include consumption of infected animals. The novel COVID-19 has recorded more than 80% related symptoms with that of the Severe Acute Respiratory Syndrome (SARS-CoV) because of the shared morphological features such as the recent strains. A report by the World Health Organisation in January, 2021 recorded global status of countries with high mortality, such as Malaysia with a total death of more than 474. Singapore recorded 29, Turkey with 15 UK variant, Ukraine 147 and the United States with over 20 million reported cases for the new UK variant [2].

Furthermore, the increased number in mortality of people infected with the COVID-19 is life threatening. Science and technology are engineered processes designed to protect people from getting infected, such as the application of artificial intelligence and in telemedicine, respectively. The COVID-19is classified as a single-strand RNA virus known as *Coronaviridae,* designed as spherical single-strand sized organism with a diameter of about 600-1400 A degree diameter. The name was coined based on the crown and spherical shape with a Spike-like feature.
Wikipedia reports that the Corona virus is the evolution of the current COVID-19 virus and was first recorded in the Guangdong province of China, which spreads to different countries. COVID-19 is characterised by symptoms such as, fever, pneumonia, tastelessness and lack of appetite. The common symptoms of COVID-19are represented in Table 1.

Table1: Common symptoms of COVID-19 [3]

Symptoms	**Percentage (%)**
Dyspnea	38.9
Fever	87.9
Anorexia	18.6
Dry cough	67.7
Myalgia	14.8
Nausea	5.0
Headache	13.6
Hemoptysis	0.9

CLINICAL FEATURES:

Individual infected with the novel COVID-19 could be clinically examined based on three major features: Asymptomatic state, multi organ dysfunction syndrome (MODS) and acute respiratory distress syndrome (ARDS). Furthermore, common clinical features of an infected person are highly examined by fever status. Features such as cold, anorexia, nausea, pneumonia, diarrheic, dyspnoea and high body temperature are experienced. The centres for disease control (CDC) reported that the aged are more likely to be infected with COVID-19. Similarly, people that are infected with other diseases such as asthma, diabetes, hypertension, are also at high risk of being infected [4].

MODE OF TRANSMISSION: The COVID-19 is transmitted in many different processes. These processesare reported by Charles Lito be from a host, which could be objects or animals to humans, vice-versa. Also, processes such as for more, aerosol, fecal oral route are also reported to be influential in the

spread of the virus. For instance, respiratory droplets, cough or sneezing from an infected person could spread to a distance of about

1.8 meter range. Researchers also reported that the virus could survive on plastic and steal surface for more than two days and survive on a wood for 24 hours and can survive on a copper for more than three days. Furthermore,

the virus is said to be transmissible through the nasal cavity, proceeding into the throat and subsequently to the rest of the body.

DIAGNOSIS: The COVID-19 virus is mainly diagnosed based on the World Health Organisation reverse transcriptase polymerase chain reaction (rRT-Pcr) process; which is regarded as the easiest and fastest method of diagnosis. This process is done using the nasopharyngeal swab method through the nasal opening. The sample has a mixture of the saliva/mucus collected from the upper respiratory tract through the nasal opening using along cotton swab. After vigorous study on the sample collected, the rRT-Pcr test is conducted to determine COVID-19 status of the patient (4). Also, the Nucleic Acid Amplification test is recommended by the World Health Organisation as one of the testing methods. Similarly, serological methods are amplified to detect the antibodies in the white blood cells to fight the antigen. However, the serological methods have elaborate features of detecting the small stage COVID-19.

In addition, the COVID-19 is diagnosed in different ways which include the common type Polymerase chain reaction-test, CRISPR technology, mammoth detection and Sherlock detection methods. The PCR based-COVID test is virtually adopted in every part of the globe; also referred to as a gold-standard method of diagnoses [5].

TREATMENT: The COVID-19 is reported to have no specific clinical cure for now. However, researches are done in many fields to develop potential treatment. Drugs and vaccines are also applicable as potential treatment for similar diseases. Companies, research institutes, hospitals and schools are also part of the collaboration in developing novel drugs to combat this virus. Drugs such as hydroxychloroquune and Remdesivir were tested as potential COVID-19 treatment. Vaccines such as Pfizer, Johnson and Johnson, Casino Ads-nCoV and Pittsburgh Pittcovacc are developed to treat and control the spread of COVID-19 [6].

PREVENTION: Many preventive measures were outlined by different researchers. These preventive measures are devised to curtail the spread of COVID-19. One important measure is cleanliness by applying hand sanitizer and soap. Social distancing is one of the most common preventive measures, which is done to curtail the spread of the virus and having contacts with an infected person or place. Similarly, face masks and hand gloves are also very important factors used in preventing the virus to spread. Furthermore, technology is out in place as another factor that assists in curtailing and preventing the spread of this vicious disease. Internet of things and internet of medical things (IOT and IOMT) is one of the technologies used in the internet connects and transfers data. Thus, IOT/IOMT is essential in collection and analyzing the patient's medical history to healthcare system and used in controlling the spread of the

virus.

Another prominent technology used in assisting health workers, especially during the COVID-19 pandemic is the telemedicine. This type of technology is an on-line based system of diagnosis and administration. It is recorded to be remarkably outstanding in prevention and control of the spread of COVID-19. Medical practitioners have used it in diagnosing patients that have fever related symptoms, which may likely to have been exposed to COVID-19 virus. In India, it was reported that, some parts of the country adopted the telemedicine system in curtailing the spread of COVID-19. It was recorded to be successful and reduces the work load on the medical workers and controls the spread of the virus. Also, in USA, the Rush University medical centres were reported to use telemedicine for medical consultation of COVID-19 patients. Phone apps and software are also developed to assist massively in managing the spread of the virus [7].

Thesis problem:

- In the recent time, COVID-19 has been unveiled as a global threat to human life. It has affected the normal human lifestyle, halting most social activities due to the pandemic.
- Worldometer (2021) (www.worldometers.info/coronavirus) reports the live cases of about 167,070,795 with 3,469,436 deaths and 148,011,966 recovery as of April 2021.
- Numerous alternatives were proposed on how to diagnose COVID-19 tentatively.
- However, high body temperature level is one of the noticeable symptoms on infected persons.
- There is a need to study different thermometers used to measure the temperature of persons.
- Five major novel temperature reading devices will be used based on multi-criteria decision making analysis.

Aims of the Study:

- To analyze the most effective non-contact device using the fuzzy-PROMETHEE technique.
- To determine the desirable technique based on the parameters used.
- To understand the most effective and least effective and partial effective and and feature of the device based on fuzzy-PROMETHEE analysis.

Significance of the study:

- The findings of this research will enable industries, schools, hospitals and any place of gathering to be informed on the effective option to be used for taking temperature.

- The findings of this research will enable people with the outright ranking of the devices based on the criteria used.

CHAPTER 2

LITERATURE REVIEW

Understanding the human body temperature is one of the recognizable factors used for diagnoses done to assess the patient's health status. This assists in diagnosing and subsequent treatment of the target disease. Meanwhile, a normal human body temperature is scientifically standardized from 36.5% to 37.5 % °C. However, increase in anything above the required temperature is a reflection of high body temperature relating to fever. Therefore, it is very important for health practitioners to use accurate, precise and standard body temperature measuring devices that will reflect the real body temperature. Various methods were devised to measure the main body temperature in many body parts such as temperature of the urinary bladder, nasopharynx and oesophagus. However, these processes of temperature measurements have limited advantages especially during any disease outbreak, as a result to the transmittable nature of the viruses especially the spread of Corona virus. Hence, novel methods to control and prevent the spread of the virus are devised such as the provision of non-contact temperature measuring devices [8].

Studies revealed that, the World Health Organisation (WHO) puts measures to control the spread of COVID-19 by a mandatory usage of body temperature screening for the identification of the novel COVID-19 infection. These measures are out in place in different points in a gathering, such as in super markets, schools and more. NON-CONTACT devices are not only easy to handle but are only easy to handle but are quick, cost efficient, reliable and efficient in temperature assessment. Another method is the indirect estimate of the core measurements of the temperature using the NON-CONTACT infrared thermometer (NCITs). The non-contact Infrared thermometers are regarded as portable tools with rapid measurements, which include the frontal bone and temporal artery measurements. Thus, one of the prominent efficiency of the NCITs is that it does not require sterilisation before use which makes it outstanding when compared with the rest of the devices applicable in measuring the body temperature. Furthermore, non-contact infrared thermometer is also advantageous over many body reading devices because of its wide range of object measurement without contacting the devices; thus, this process avoids the spread of the virus. In addition, the equipment is been inferred through capturing thermal radiation into a sensing element which is subsequently converted into electronic signal. This is digitally processed by presenting the temperature to the user. The history of the conversion of the thermal radiations to electrical signal was discovered in 1800s by Macedonia Mellon. After the discovery, many improvements have been done on it, making it look modern and simple to use [9].

Similar study by Khan S. et al (2020) was done on the comparative accuracy testing of some non-contact infrared thermometers and temporal artery thermometers among adult hospital setting. They compared the accuracy among non-contact infrared thermometers (NCIT).Another study conducted on comparison of forehead temperature screening with infrared thermometers was done by Carpene G and colleagues in 2021. Similar to this study, the scientists assessed the body temperature using thermal imaging scanners and non-contact infrared thermometers to screen people having the severe acute respiratory syndrome (SARS-CoV-2) symptoms [10]. The study population was 24 active healthcare workers, which consists of 16 women and 8 men and a mean age of 42+_14 years and range 19-65 years using a forehand scanning of temperature at a point of entry of the building in Italy. The authors compared HiKvisionDs-2 ID 1217 B-6/PA and Jumper JPD-FR300, repeating scanning 10 times on a subject using the same thermometer to determine the measuring accuracy and the mean of accuracy. However, the studies conducted by both Khan and Carpene teams have not accurately determine the effectiveness of the mentioned body reading devices to predict fever. Meanwhile, our study considers the major symptoms associated with Corona virus to be fever. The World Health Organisation (2020) assessed the common symptoms of COVID-19, with the body fever to be 87%, making it to be the highest noticeable symptoms when diagnosed. Furthermore, in this research, we consider to compare major body temperature reading devices, modernised to curtail the spread of the COVID -19 using the fuzzy based multi criteria decision analysis techniques [11].

Multi-criteria decision making

The multi-criteria decision making is regarded as a subgroup of decision making process, involved in a diverse relative measures that aim to serve an optimum alternative for decision problems. MCDM is defined as the process of surveying, arranging, selecting or prioritizing an independent group that serve as alternative based on disproportional criteria. For instance, Analytical Hierarchy process was first proposed by Saati Thomas as a computational process based on the parameters and goals of the research. This process also has the potentials of predicting, controlling and examining a particular process. Therefore, many researchers have implored the application of decision making using different approaches in terms of theoretical computational studies. For providing the optimum solution to multi criteria decision problems, many techniques are used, Analytic hierarchy process (AHP), technique for order of preference by similarity of ideal solution (TOPSIS), Elimination Et choixtraduisant la reality (ELECTRE), preference Ranking Organisation method for enrichment evaluation (PROMETHEE), Fuzzy logic based MCDM, Data envelopment analysis (DEA) and VIKOR method, in different fields [12].

Preference ranking organisation method for enrichment evaluation(promethee)

The PROMETHEE was developed in 1980s, considered as one of the refined computational methods. It's application is dynamic, which is widely used in virtually every fields of studies, such as in the legislative, transportation, teaching, business and in social insurance. Furthermore, the PROMETHEE and Gaia techniques assist in computing choices in a research without bias. It gives an equal mathematical analysis based on the given choice of study [13]. In other words, it allows partial and complete ranking of alternatives used in a research.

In addition, the history of PROMETHEE 1 can be traced to its evolution in 1982 by J.P Grains at Quebec University Laval, Canada. Hence, the creation of PROMETHEE 3 and 4 was possible a few years after aging by J.P Grains and B. Mareschal. Also, a virtual intuitive module named GAIA was proposed by the same individuals in 1988; the device assists in graphical support to the PROMETHEE. Again, in 1992 and 1994 , respectively Mareschal and Wheats also proposed another PROMETHEE V and PROMETHEE VI, which posses a human mind embedded. The PROMETHEE method has recorded some successes in many fields such as in water assessment, banking, medicine, labour setting, tourism, administration and many more [14].

The PROMETHEE and Gaia are applicable in many independent choices such as in decision making, prioritization, asset assignment, positioning and compromise. In addition, the PROMETHEE is considered practical and does not require assumption in selecting criteria and also has demerits of making it only revolving around its relegation of loads when computing [15].

Fuzzy logic based mcdm:

The fuzzy theory is traced to its existence for many years. In 2003 two people named Kaluarachchi and Khadam applied the use of this technique in their intention to undertake study that utilizes a choice of examination in cost-efficient products. They also investigated three potential products in an organized method in controlling hazard. Similarly, in 2011Balmat etal., proposed a better way to control geographical hazard by evaluating the impact of light in marine mishaps. This dynamic study, analyses the cause effect of this natural disaster using the fuzzy technique in analysing the cause of the hazard. Additionally, in 1992 some researchers named Guo, Esogbue and Theologidu used the fuzzy techniques to analyse many water assessment [16]. This however, is significant in choosing and assessing their choices made. In 2011, a study by Haley and Hamidi used a model to analyse the fuzzy technique to survey. Moreover, the fuzzy technique method deals in expansion of classical set of systems

which is related in solving many problems of a given uncertainty in data. This helps in evaluation of various issues with great difficulty. In addition, the fuzzy technique is developed for its application in fields such as in engineering, medicine, social sciences, environment, economics and many associated studies. Outlined problems, involved in using fuzzy method is that, they demand multiple simulation before use. Fuzzification is also a method that deals with the distribution of the mathematical involvement of platform to fuzzy inputs. In other words, the fuzzy assists in analyzing computation that involves numbers that range between 0 to 1. Furthermore, the fuzzy sets are characterized as a trapezoid-shaped with an expansion of the worth at a point of 1. Another major application of the fuzzy method was first done in Japan on a tram-train in Sendai. Since then, the fuzzy has been applied in various field such as to assist helicopters and in monitoring of fuel consumption in Vehicles. The fuzzy technique is also applicable in clinical and social insurance information with incredible potentials to profit [17].

Fuzzy logic: Fuzzy-based study is considered as a system that grades truth and false notions in a more fashioned way. In other words, vague cumulative variables are determined using the Fuzzy Logic technique that is based on other applications. Thus, the Fuzzy Logic is a part of soft computing method that ultimately tolerates imaginary variables by giving solutions.

The evolution of Fuzzy-based Logic could be traced to when it was introduced by Professor Lotfi A. Zadeh from computer science. Hence, this technique enables the characterization and evaluation by transitional values in testing variables using words such as true or false, high or low, yes or no e.t.c. Similarly, other ideas such as very high or relatively fast could be managed by the computer and polished using mathematical computation to embed human approach in programming the computer [19].

Furthermore, the sets of variables application could be traced to the ancient Greek method of approach that is in contrast to the Fuzzy based logic. Philosophers such as Aristotle were reported to have attempted to design a theory of logic, which was later named the “laws of thought”. This law was expressed using either a true or false approach. However other philosophers such as Plato and Heraclitus objected Parmenides suggestion to the interpretation of the laws of thought. Heraclitus emphasised on the adaptation of using either true or not true. However, Plato initiated establishment of the Fuzzy based logic frame work [20].

I. Advantage of Fuzzy Logic

The advantages of using the Fuzzy based logic technique could be summarized based on its simplified structure and easy to comprehend. It also has broad applications in both practical form and in commercial use. Also, it presents only acceptable reasoning. Vague problems in different fields of studies are solved. It does not require a

specific input in its application. In other words, variables could be modified and adjusted and give best solution to any complex problems [21].

II. Disadvantage of Fuzzy based logic

The Fuzzy based logic is advantageous in many applications such as in its inaccuracy in certain system that involves assumption in getting the final results. Similarly, the technique when compared to the machine learning lacks the full capacity. Other testing systems and hardware are basically required in validating and subsequently in the verification of system [22].

Fuzzy Sets.

The Fuzzy sets are the members that relate mutually by the expansion of sets which permits many members in a particular set. Elements of different sets are contained using standard values such as 0 or 1 and in range of [0,1].

Mathematical definition of the fuzzy sets.

The Fuzzy sets are defined using the mathematical equation below;

A fuzzy set $\tilde{A}$ in IR is a set of ordered pairs:

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \in IR\}$$

Where $\mu_{\tilde{A}}: IR \rightarrow [0,1]$ and $\mu_{\tilde{A}}(x)$ is called the membership function for the fuzzy set [23].

Representation of fuzzy sets

The fuzzy set is represented in a more discrete and continuous cases as shown in the equation below:

- *1st Case:*

“U” is represented as discrete and finite value as shown below:

$$\tilde{A} = \{\frac{\mu_A(x_1)}{x_1} + \frac{\mu_A(x_2)}{x_2} + \frac{\mu_A(x_3)}{x_3} + \cdots\} = \sum_{i=1}^{n} \frac{\mu_A(x_i)}{x_i}$$

- *2nd Case:*

"U" is represented as continuous and infinite as shown below:

$$\tilde{A} = \{\int \frac{\mu_{\tilde{A}}(x)}{x}\}$$

The above equations involve, the collection of individual element as represented by the summation of the symbols, where U is termed as the universe of information.

Basic Operations on Fuzzy Sets

Union, complement and intersection operation on fuzzy sets are represented below [24].

- **Union:**

$$\mu_{A \cup B}(x) = \mu_A \vee \mu_B; \qquad \forall x \in U$$

$\vee$ represents the maximum 'max' operation.

- **Intersection:**

$$\mu_{A \cap B}(x) = \mu_A \wedge \mu_B; \forall x \in U$$

$\wedge$ represents the minimum 'min' operation.

- **Complement:**

$$\mu_{\tilde{A}'}(x) = 1 - \mu_{\tilde{A}}(x)$$

$$\tilde{A} \cap \tilde{A'} \neq 0$$

Properties of Fuzzy Sets

Fuzzy set are characterised by properties as described;

- Commutative: such as fuzzy set $\tilde{A}$ and $\tilde{B}$, and is defined as:

$$\tilde{A} \cup \tilde{B} = \tilde{B} \cup \tilde{A}$$

$$\tilde{A} \cap \tilde{B} = \tilde{B} \cap \tilde{A}$$

[25]

- Associative Property: which involves fuzzy sets $\tilde{A}$, $\tilde{B}$ and $\tilde{C}$, and is defined as the following equation:

$$\tilde{A} \cup (\tilde{B} \cup \tilde{C}) = (\tilde{A} \cup \tilde{B}) \cup \tilde{C}$$

$$\tilde{A} \cap (\tilde{B} \cap \tilde{C}) = (\tilde{A} \cap \tilde{B}) \cap \tilde{C}$$

a) Distributive Property: this involves fuzzy sets $\tilde{A}$, $\tilde{B}$ and $\tilde{C}$, and states that:

$$\tilde{A} \cup (\tilde{B} \cap \tilde{C}) = (\tilde{A} \cup \tilde{B}) \cap (\tilde{A} \cup \tilde{C})$$

$$\tilde{A} \cap (\tilde{B} \cup \tilde{C}) = (\tilde{A} \cap \tilde{B}) \cup (\tilde{A} \cap \tilde{C})$$

- Idem potency Property: fuzzy set $\tilde{A}$ states:

$$\tilde{A} \cup \tilde{A} = \tilde{A}$$

$$\tilde{A} = \tilde{A} \cap \tilde{A}$$

- Identity: fuzzy set $\tilde{A}$ and universal set U, state: [26]

$$\tilde{A} = \tilde{A} \cup \square$$

$$\square = \tilde{A} \cap \square$$

$$A = \tilde{A} \cap U$$

$$U = \tilde{A} \cup U$$

- Transitive: fuzzy sets $\tilde{A}$, $\tilde{B}$ and $\tilde{C}$ state:

$$\text{If } \tilde{A} \square \tilde{B} \text{ and } \tilde{B} \square \tilde{C} \text{ then } \tilde{A} \square \tilde{C}$$

- Involution: fuzzy set $\tilde{A}$, states:

$$\overline{\overline{\tilde{A}}} = \tilde{A}$$

- De Morgan'sLaw: is a significant law that is vital in demonstrating level of redundancies and logical inconsistency as it states:

$$\overline{\tilde{A} \cap \tilde{B}} = \overline{\tilde{A}} \cup \overline{\tilde{B}}$$

$$\overline{\tilde{A} \cup \tilde{B}} = \overline{\tilde{A}} \cap \overline{\tilde{B}}$$

[27]

MembershipFunction:

This involves the demonstration of the fuzzy logic through rational logic that is used to describe fuzziness. In other words, the fuzziness characterized at its best through membership function.

The membership function is defined by Lofti A. in a pioneer research paper named “fuzzy sets”. Important membership function characteristics include the following:

- Membership functions distinguish fuzziness|
- The membership function resolves real-life problems based on occurrences rather than knowledge.|
- It is usually represented in a graph. [28]|

The membership functions involve the following features as shown below;

- **Core:** the equation below defines the core of the fuzzy set $\tilde{A}$ in the universe.

$$\mu_{\tilde{A}}(x) = 1$$

- **Support:** the equation below defines the support, core of the fuzzy set $\tilde{A}$ in the universe.

$$\mu_{\tilde{A}}(x) > 0$$

- **Boundary:** the equation below defines the boundary, core of the fuzzy set $\tilde{A}$ in the universe.

$$1 > \mu_{\tilde{A}}(x) > 0 \qquad [29]$$

Fuzzification

Fuzzification is defined as the process of converting of a fuzzy set. Thus, there are two major methods of fuzzification, which include:

- Support Fuzzification (s-fuzzification) technique:

$$\tilde{A} = \mu_1 Q(x_1) + \mu_2 Q(x_2) + \cdots + \mu_n Q(x_n)$$

$Q(x_i)$ called the Kernel of fuzzification.

- Grade Fuzzification (g-fuzzification) technique:

x_i Constant and μ_i is expressed as a fuzzy set. [30]

De-fuzzification

De-fuzzification process converts the fuzzy member into data. In other words, it can also be described as the process of reduction of a fuzzy set into a crisp set. Thus, Defuzzification of result is vital in engineeringapplications. The term de-fuzzification is also known as "rounding it off". Similarly, to de-fuzzify a result, the followingmethods could be applied:

- **Max-Membership Method:** This method is functional in peak output. It is also referred to as the height method. It is mathematically represented as:

$$\mu_A(x^*) > \mu_A(x), \qquad \forall x \in X$$

x^* is the de-fuzzified output.

Centroid Method: it determines the centre corresponding crisp value as represented:

$$x^* = \frac{\int \mu_A(x).\, x dx}{\int \mu_A(x).\, dx}$$

- **Weighted Average Method:** the membership function is weighted in this method, based on its maximum membership value as expressed:

$$x^{\square} = \frac{\sum \mu_A(x).(x)}{\sum \mu_A(x)}$$

- **Mean-Max Membership:** as represented:

$$x^{\square} = \frac{\sum_{i=1}^{n} \bar{x}}{n}$$

The algebraicoperationsforfuzzysets

Definitions on the operation of the fuzzy set theory.

- Algebraic Product: $\tilde{A}\tilde{B} \Leftrightarrow \mu_{AB} = \mu_A \mu_B$
- AlgebraicSum: $\tilde{A} + \tilde{B} \Leftrightarrow \mu_{A+B} = \mu_A + \mu_B - \mu_A \mu_B$
- Bounded-Sum: $\tilde{A} \square \tilde{B} \Leftrightarrow \mu_{A \square B} = 1 \wedge (\mu_A + \mu_B)$
- Bounded-Difference: $\tilde{A} \square \tilde{B} \Leftrightarrow \mu_{A \square B} = 0 \vee (\mu_A - \mu_B)$
- Bounded- Product: $\tilde{A} \square \tilde{B} \Leftrightarrow \mu_{A \square B} = 0 \vee (\mu_A + \mu_B - 1)$

Where, the operations of $\vee, \wedge, +, -$ denote the max, min, arithmetic sum and arithmetic difference, respectively.

[31]

DEFINITION OF CONCEPTS

The Multi-criteria decision making analysis (MCDA) and decision analysis (DA) have the following concepts and their respective meanings.

Multi (multiple): also similar to terms such as many, numerous and several.

Criteria: the **c**riteria detail the plural form of **c**riterion which may be **c**lassified as parameters to differentiatevariables.

Decision: defines basic approach to a process, especially in a resolution to **c**onsider or not a variable.

Analysis: is a process that involves a complex approach to simplify a decision in details.

Multi-Criteria Decision Making (MCDM): deals with decisions used for the selection of alternatives using the desired criteria for the studies.

Decision Analysis (DA): involves the systematic selection of alternatives using both the visual and quantitative approaches in decision making. Organizations, industries, individuals and groups apply this in makingstrategic decisions and in many applications [32].

Multiple Criteria Decision Analysis (MCDA)

This technique considers a theoretical approach in solving decision problems; which is concentrated in making decisions that involve solving problems of different kind.

The MCDA is used as an appropriate tool to inform, clarify, justify and analyze decisions to be successful.

In 1979, Stanley Zionts demonstrated in a publication work titled "If Not A Roman Numeral, Then What?. In the research, Stanley tried to fashion this technique to attract the readers to make use of the technique [33].

Important Steps to follow

The MCDM has the following important steps to consider and to follow in any analysis.

Step 1. Identify the problem

When a problem is identified, it does not necessarily mean it is solved; In this step, problem is identified, which is one of the important processes that make decision. However, the problem may not even be solved but rather became more complex as part of the MCDA requires the identification of the problem.

Step 2.3.1.2 Make objectives

After the problem is identified, the objectives must be defined. The objectives are the guide to having a result.

Step 3. Define criteria

Selecting the right criteria is important in MCDA. The criteria are in some way linked to the objectives in that they are our measure of success. With respect to the objectives, it is important to set meaningful criteria. Here, we

Step 4. Develop a list of options

List of options are required to be developed for proper analysis in this step.

Step 5. Evaluate options

Options are evaluated here simply through ranking. We could also be required to consider the consequences associated with each option or alternative. From the results that we would obtain, we can be confident that we are minimizing most of the attached risk. Each time we consider an option, we need to always remember the objective

of the experiment, if the risks exceed what we could potentially gain, as well as how easy or difficult it is to achieve the objective. In production systems, it is important to evaluate the cost of inputs, the process and the outputs.

Step 6. Calculation

In this step, it is important to know that we are using all the data mentioned above to calculate and then select the highest score which will be the option closest to the ideal. Also, in this step, we obtain the result by taking the product of the score of each criterion and its weight, then summing the scores of each criterion. To obtain the final score, we then add all the other scores. From the calculation, we would then have to choose the option with the highest scores.

Step 7. Documentation

When the desired results are obtained then, they are monitored and implemented for future application in decision making [34].

Advantages of Multiple Criteria Decision Analysis (MCDA)

The MCDM is having the following advantages;

- simple and clear
- easily adjusted criteria
- reliable
- They are used n numerous fields of study.
- They assist in decision making
- Data can be combined
- Agents can be compared [35]

PROMETHEE Process

The PROMETHEE process considers two types of information. The weights of the alternatives and the preference function for each criterion are paired with the alternatives. Furthermore, the preference function (P_j) is used in the evaluation (in scores) of the two alternatives represented a_t *and* $a_{t'}$ within the system into a preference degree

ranging from 0 to 1 for each specific criterion. Different types of preference function exist for the PROMETHEE method, which include the V-shape function, level function, usual function, U-shape function, linear function and Gaussian function.

2.4.1 The basic steps involved in the PROMETHEE method are as follows:

Step one. For an individual criterion represented as j, a specific preference function denoted as $p_j(d)$is determined

Step two. For a criterion, its weight is represented as $w_T = (w_1, w_2, \dots, w_k)$. If the relative importance of the criteria is equal, then the weights can be equal.

Step three. Outranking relation of any alternative are represented as $a_t \; and \; a_{t^F} \square A$ which are defined by π and can be calculated using the following formula

$$\pi(a_t, a_{t^F}) = \sum_{k=1}^{K} w_k . [p_k(f_k(a_t) - f_k(a_{t^F}))], \; AXA \rightarrow [0,1][36] \quad (1)$$

Here, $\pi(a, b)$ represent the preference index while k represents the selected criteria. The preference index indicates the intensity of preference in the MCDM for the alternative a_t in comparison to alternative a_{t^F} considering all criteria at the same time.

Step four. Determination of the leaving and entering outranking

- The Leaving or positive flow for the alternative a_t:

$$\Phi^{+}(a_t) = \frac{1}{n-1} \sum_{\substack{t^F=1 \\ t^F \neq t}}^{n} \pi(a_t, a_{t^F}) \quad (2)$$

- The Entering or negative flow for the alternative a_t:

$$\Phi^{-}(a_t) = \frac{1}{n-1} \sum_{\substack{t^F=1 \\ t^F \neq t}}^{n} \pi(a_{t^F}, a_t) \quad (3)$$

In the equation, the number of alternatives is represented by n. In other words, there is comparison made between the alternatives as (n-1) to other alternatives within the system. The leaving flow is denoted as $\Phi^{+}(a_t)$ that indicates the strength of every alternative which is shown as $a_t \square A$. However, the entering flow is presented as $\Phi^{-}(a_t)$ which represents the weakness of the alternatives $a_t \square A$. Furthermore, the strength of the alternative is measured via the negative and position outranking flows, respectively. The positive outranking flow is cumulatively outranked as sum of individual alternative compared to the rest of the criteria, while the negative flow shows the calculation of the weakened characters of the alternatives using all the criteria [37].

Step 5. partial order of the alternatives (determination)

The higher outranking flow and the lower negative outranking flow are considered as preferred. Equal negative outranking flow and higher positive outranking alternative are also preferred. Therefore, alternative a_t in PROMETHEE I is preferred over alternative a_{t^F} $(a_t P a_{t^F})$ when it satisfies the following conditions:

$(a_t P a_{t^F})$ if;

$$\begin{cases} \Phi^+(a_t) > \Phi^+(a_{t^F}) \text{ and } \Phi^-(a_t) \leq \Phi^-(a_{t^F}) \\ \Phi^+(a_t) = \Phi^+(a_{t^F}) \text{ and } \Phi^-(a_t) < \Phi^-(a_{t^F}) \end{cases} \quad (4)$$

$a_t$is indifferent to a_{t^F} ($a_t I a_{t^F}$) if both alternatives a_t and a_{t^F} have same entering and leaving flows, then:

$$(a_t I a_{t^F}) \text{if: } \Phi^+(a_t) = \Phi^+(a_{t^F}) \text{ and } \Phi^-(a_t) = \Phi^-(a_{t^F}) \quad (5)$$

If an alternative has higher positive outranking flow and higher negative outranking flow it will be difficult to compare all the alternatives. However, with the function below, such situations are defined as incomparable with PROMETHEE I.

$a_t$is incomparable to a_{t^F} $(a_t R a_{t^F})$ if

$$\begin{cases} \Phi^+(a_t) > \Phi^+(a_{t^F}) \text{ and } \Phi^-(a_t) > \Phi^-(a_{t^F}) \\ \Phi^+(a_t) < \Phi^+(a_{t^F}) \quad \text{and } \Phi^-(a_t) < \Phi^-(a_{t^F}) \end{cases} \quad (6)$$

To overcome this issue, PROMETHEE II was used, which gives a net outranking flow in incomparable situations in PROMETHEE I.

Step 6. Determination of the net outranking flow for each particular alternative by the formula represented below

$$\Phi^{net}(a_t) = \Phi^+(a_t) - \Phi^-(a_t) \quad (7)$$

A complete order determined via net flow can be obtained by PROMETHEE II, as shown below

$a_t$is preferred to a_{t^F} $(a_t P a_{t^F})$ if $\Phi^{net}(a_t) > \Phi^{net}(a_{t^F})$ (8)

$a_t$is indifferent to a_{t^F} ($a_t I a_{t^F}$) if $\Phi^{net}(a_t) = \Phi^{net}(a_{t^F})$. (9)

The higher the $\Phi^{net}(a_t)$ value, the better is the alternative. [38]

CHAPTER 3

MATERIALS AND METHODS

STUDY DESIGN:

A total of five (5) numbers of novels, modern and functional body temperature reading devices were collected randomly from different sources online. These devices were searched using electronic databases. Similar to the Shahrukh Khan and colleagues research, these devices were measured based on different parameters using multi-criteria decision making approach such as the fuzzy PROMETHEE-Gaia method to obtain the ranking results.

Sampling and eligibility criteria

This study used some modern temperature reading devices applicable in detecting the body temperature associated to COVID-19 suspected cases. Some devices were captured but lack credible qualities such as, the company reputation and the use on COVID-19 cases. However, these ineligible devices were discarded thereby replacing them with the five most reputable and modern thermometers used on COVID-19 suspected cases. Therefore, we analyzed them based on the criteria such as, cost, company reputation, life length battery life, functions, merits and demerits and accuracy when used. In other words, the devices were analysed based on their functional characters, advantages and disadvantages and the eight parameters, respectively. Also, the accuracy of the devices were analysed based on their individual characteristics such as, temperature reading, distance, cost of the device, efficiency and structure. This method was similarly used by Giovanni Carpene and colleagues research work, “comparison of forehand temperature screening with infrared thermometer and thermal imagine scanner” but lacks computing methods for result evaluation [39].

Sample size estimation

A total of five (5) reputable fever sensing devices, Tytocare, handheld medical laser thermometer, door access system face recognition fever alarm device with thermal camera, Apollo made fever detection thermal system and Delphi made body temperature detection system. Also, eight criteria were used in this research these include, the name of the company, functions, disadvantages, company reputation, accuracy, battery capacity (life), advantages, and cost of the device.

Instruments:

Tytocare, handheld medical laser thermometer, door access system face recognition fever alarm device with thermal camera, Apollo made fever detection thermal system and the Delphi made fever detection system were the five body temperature reading devices studied and evaluated using eight different parameters and mathematically computed using the fuzzy PROMETHEE-Gaia analysis. In this analysis the Gaussian preference functions has been applied for the PROMETHEE analysis. Furthermore the importance weights of the parameter have been defined using the linguistic fuzzy scale.

Tytohome:

Figure 1. Tytocare [40]

The TYTOHOME or tytocare medical diagnostic kit is an integrated telehealth kit that relatively eases patients and health professionals schedules through an easy video appointment and self-reading diagnoses incorporated as shown in figure 1. In a report presented by WIRED to review the new medical equipment, tytocare was highly placed above its contemporaries due to its fascinating features [41]. It was also reported that most diagnostic tests kits lack the clinical features, making it the first commercial-audiovisual assisted home diagnostic kit.

Furthermore, the audacious features of the TYTOHOME device make it outstanding in the period of the COVID-19 pandemic. It's body temperature reading feature is also unique, in such a way that it records the body temperature and sends to the physician for further diagnosis, when compared to other devices, the tytocare has features such as, a digital camera which is outstanding. The tytocare devices also charge through a 5-volt 2A port without a MicroUSB. In addition, the device contains a ring connector that can attach to different adaptors. In an online guide, the tytocare is reported to have an estimated cost of about 300 USD.

A comprehensive examination of the tytocare was done on the company's website. The device contains a kit package and App that includes devices for different medical problems, these includes for, ear, lungs, heart, throat, Heart rate, Temperature, skin, abdomen. Furthermore,tytocare is not relegated to solving one medial problem; rather its application extends to solving varieties of medical conditions for both the old and young.In a recent study, Israel is said to have adapted the use of tytocare to remedy the urgency in its medical outreach. With no iota of doubt, it is an established fact that whenever a population is increasing, there's need for urgent medical presence. Therefore, Israel took this advantage to introduce tytocare to its populace to enhanceand boost its healthcare services. Clalit health system is one of the biggest health services in Israel that leads in the digital health system. The tytocare device was introduced to the clalithealth which targeted children. [42]

HANDHELD MEDICAL LASER THERMOMETER:

Figure 2: handheld medical thermometer

[43]

A clinical thermometer is a body temperature measuring device used to determine the temperature of the body to assist in diagnosing a detected disease. The handheld medical laser thermometer is a device designed using sensor to read a person's body temperature from a far without touching the body. In addition, these types of thermometers are laser embedded electro-mechanical equipments that assist health practitioners to detect higher or lower temperature of the patient's body. Furthermore, in case of communicable diseases or viruses, the thermometer helps in predicting the disease by observing the "fever" observed in a patient. The spread of COVID-19 was reduced drastically through the assistance of the handheld medical laser thermometers. The non-contact thermometer is placed close to an individual'sforehead to measure the body temperature, thus, when the body temperature is high, the thermometer indicates through the help of a screen. The thermometer is basically recorded

to be innovative, easy to use, friendly and equipped with a memory that can store many data. Also, the thermometer is cheaper to acquire than the others and it is characterized by its touch less quality [44].

3.4.3. Door access system face recognition fever alarm device with thermalcamera:

Figure 3: Door access system face recognition fever alarm device with thermal camera [45]

Figure 3 shows the face recognition fever alarm device is a body temperature reading device that embedded qualities such as, the phone-like camera screen, processor, interface and a thermometer. In other words, this device detects fever of the patient and is connected to an alarming sensor which subsequently beeps to indicate the presence of an ill person. In addition, this device is more equipped than most of the temperature reading devices due to the characteristics embedded. The device is placed in front of a door before passage, especially used in the COVID-19 pandemic period.

The device is characterized by a camera resolution of about 2 million pixels, binocular wide dynamism with a focusing distance of about 50- 150 cm, an auto white balance and a photo flood light LED and infrared double. Furthermore, the screen is 8.0 wide and a touch optional support. It also processes using a CPU RK3288 quad core and a storage EMMC 8G. The door access face recognition fever alarm device with thermal camera is functional

through use of network such as, the internet and wireless (WiFi), supporting audio 2.5 w/4R and a USB. It supports other functions such as, face recognition, tracking many persons at the same time and body temperature detection. Stated features of the device include it's waterproof and dust proof design quality; gives accurate face recognition with face masks, captures dynamic body at night using the LED dual, also, it takes a very few seconds to automatic alarm [46].

The apollo in motion temperature/fever detection thermal camerasystem:

Figure 4: Apollo device

[47]

This device is a camera-temperature reading incorporated device with unique features such as, capturing moving object from a far and checking the human body temperature as shown in figure 4. This device is manufactured by the Apollo group, which makes it outstanding compared to its contemporaries of similar functions.

SCW's manufactured fever detection device is designed to detect only fever in the body. However, the device is not designed to diagnose body ailment or identify corona virus in the body. The device is a designed Apollo manufactured appliance with a thermal camera. The thermal camera uses parameters such as, environmental and installation to maintain perfectbody temperature.

The Apollo device detects high temperature (fever) on people in motion and in large gatherings such as airports, mosques, train stations, bus stations or large shopping malls. The temperature accuracy is revealed to be reliable.

In addition, the device also consists of an automatic temperature calibration and a dual spectrum video that spot persons by using both thermal and visible light. A blackbody is also included, which assists to calibrate thecamera in an accurate precision without temperature fluctuation [48].

The data was defined based on the triangular linguistic fuzzy scale as shown in Table 2. Also the importance weights of the parameters were equally very high.

Table 2. The linguistic fuzzy scale

Scale of evaluation	Fuzzy scale
Very High (VH)	(0.75, 1, 1)
High (H)	(0.50, 0.75, 1)
Medium (M)	(0.25, 0.50, 0.75)
Low (L)	(0, 0.25, 0.50)
Very Low (VL)	(0, 0, 0.25)

The Gaussian preference function was applied for every criterion. Similarly, the Yager index was equally applied for the defuzzification of the linguistic data. The values obtained after the defuzzification was also used for the PROMETHEE [49]. Table 2 shows the representation of the linguistic fuzzy scale, evaluating the alternatives based on the criteria. The scale of evaluation measures the variables as very high, high, medium, low or very low, while the classical scale measures using numbers.

Table 3. Decision matrix of the non-contact temperature reading devices

Importance Weights	VH	VH	VH	VH	VH	VH	VH	VH
Aim	Min	Max	Max	Max	Max	Max	Min	Max
Preference functions	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian
Alternatives/Criteria	Cost	Company Reputation	Age (year)	Battery capacity	Functions	Advantage	Disadvantage	Accuracy

Tytohome	H	VH	1	H	VH	H	L	VH
Handheld Medical laser thermometer	VH	M	2	M	H	H	M	H
Door Access Face recognition Fever alarm Device	H	VH	1	H	H	H	M	VH
The Apollo in motion temperature/fever detection thermal camera system	M	VH	2	M	H	M	L	VH
The Delphi-pole mounted contact free fever detection system	VH	VH	1	VH	H	VH	H	H

Table 3 details the decision matrix of the five non-contact temperature reading devices used in this study. Thus, they are characterised by their importance weights, aims, preference function and alternatives. The importance weights are measured by qualities such as, very high (VH), high (H), very low (VH), and low (L). Similarly, the aimis characterised by either, maximum (ma) and minimum (min). Preference functions are based on Gaussian. Alternatives or criteria are classified by their costs, company reputation, age (year),battery capacity functions, advantages, disadvantages and accuracy. Therefore each device is classified based on an individual quality of the decision matrix.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

Table 4.1 Ranking results of the thermometers Using F-PROMETHEE

Complete Ranking	Non-contact temperature reading Devices	RANK Φ^{net}	Φ^{+}	Φ^{-}
1	Handheld Medicallasertherm.	0,0061	0,0083	0,0022
2	The Apollo in motiontemperature/feverdet.	0,0051	0,0066	0,0015
3	Tytohome	-0,0027	0,0016	0,0044
4	Door Access Facerecog.	-0,0037	0,0009	0,0046
5	The Delphi-polemountedcont.	-0,0048	0,0015	0,0063

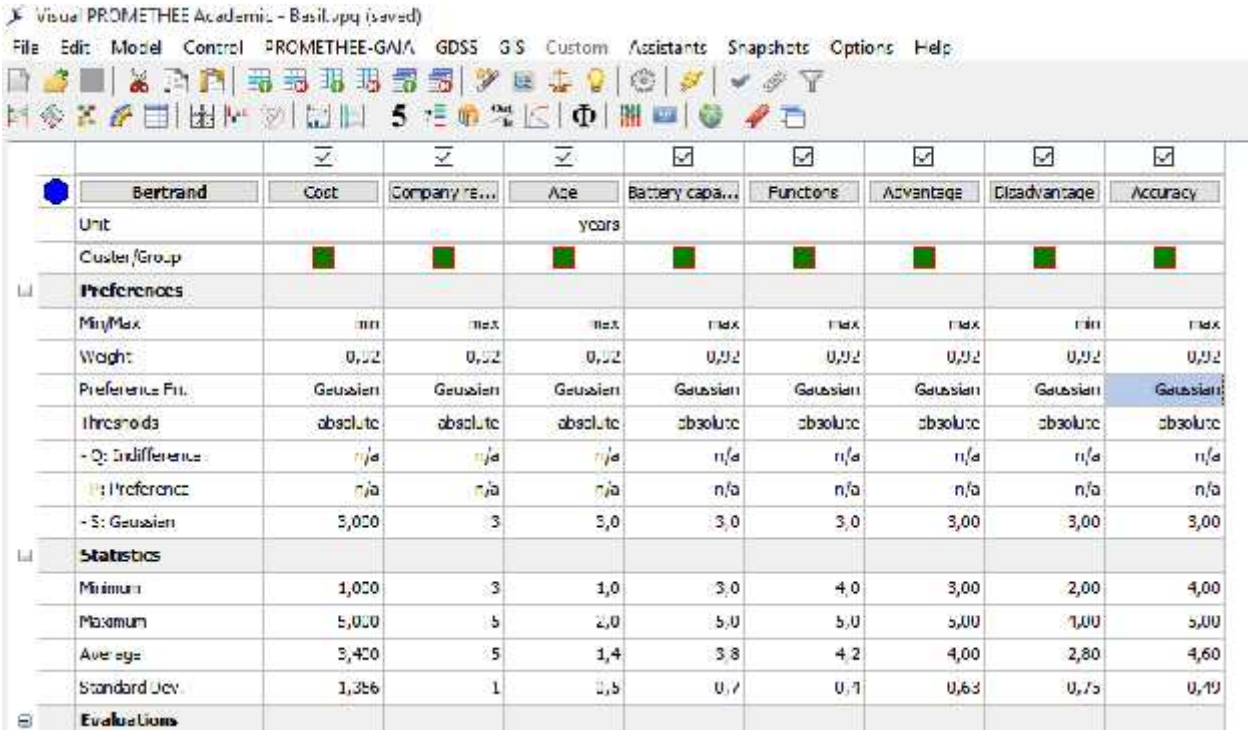
Table 3 gives a clear representation of the complete ranking results for the non-contact fever measuring devices with eachpair alternative compared numerically based on the outline criteria and weight importance. As shown in Table 3 the positive outranking flow represents numerically the power of the alternative, while weakened alternatives are represented as the negative outranking flow and the net flow indicates the net ranking results. In addition, the alternatives with the highest net flow are considered as the most effective. Therefore, as represented on our table of ranking results using the fuzzy-PROMETHEE, the handheld medical laser thermometer has the maximum positive outranking flow with a minimal negative outranking flow which makes it the best among the body temperature reading devices used in detecting high body temperature; then the Apollo in motion temperature/fever device. The Apollo device recorded lower negative outranking flow than the handheld medical laser thermometer. Therefore, the Apollo device is the second best amongst the devices with 0.0051 net flows and the Tytohome recorded the third with -0.0027 net flows. The last two devices, the Door access face recognition and Delphi-pole mounted device gave the least outputs with the net flow of -0.0037 and -0.0048 values, respectively. Furthermore, the strength and weakness of the respective devices are recorded as shown in figure 6. Also the parameters for each of the diagnostic devices are outline based on individual effective performance of the variables.

Similarly, if the parameters are in having advantage over the technique, they are represented above while, if the criteria arehaving disadvantage over the technique, it is represented at zero level. As represented in table 3, the preferred device for measuring the body temperature is the handheld medical laser thermometer with almost

all the parameters indicated highabove the threshold level, while the least effective device for measuring the human body temperature is the Delphi-pole mounted. Therefore, these experimental results will be highly valuable to different sectors such as in hospitals, research

institutions, governments and patients.

Figure 4.2: Visual representation of the Fuzzy-PROMETHEE



Bertrand	Cost	Company re...	Age	Battery capa...	Functions	Advantage	Disadvantage	Accuracy
Unit			years					
Cluster/Group								
Preferences								
Min/Max	min	max	max	max	max	max	min	max
Weight	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
Preference Fn.	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute
- Q: Indifference	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- P: Preference	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- S: Gaussian	3,000	3	3,0	3,0	3,0	3,00	3,00	3,00
Statistics								
Minimum	1,000	3	1,0	3,0	4,0	3,00	2,00	4,00
Maximum	5,000	5	2,0	5,0	5,0	5,00	4,00	5,00
Average	3,400	5	1,4	3,8	4,2	4,00	2,80	4,60
Standard Dev.	1,356	1	0,5	0,7	0,4	0,63	0,75	0,49
Evaluations								

Figure 4.2 represents the visual representation of the Fuzzy-PROMETHEE. This Data was analyed using the PROMETHEE-GAIA analysis after collecting the raw data from the source. It was evaluated based on the criteria exhibited on the figure 6. Giving the maximum/ minimum, weight, preference, thresholds, and standard deviation.

Figure 4.3 Tytocare result representation.

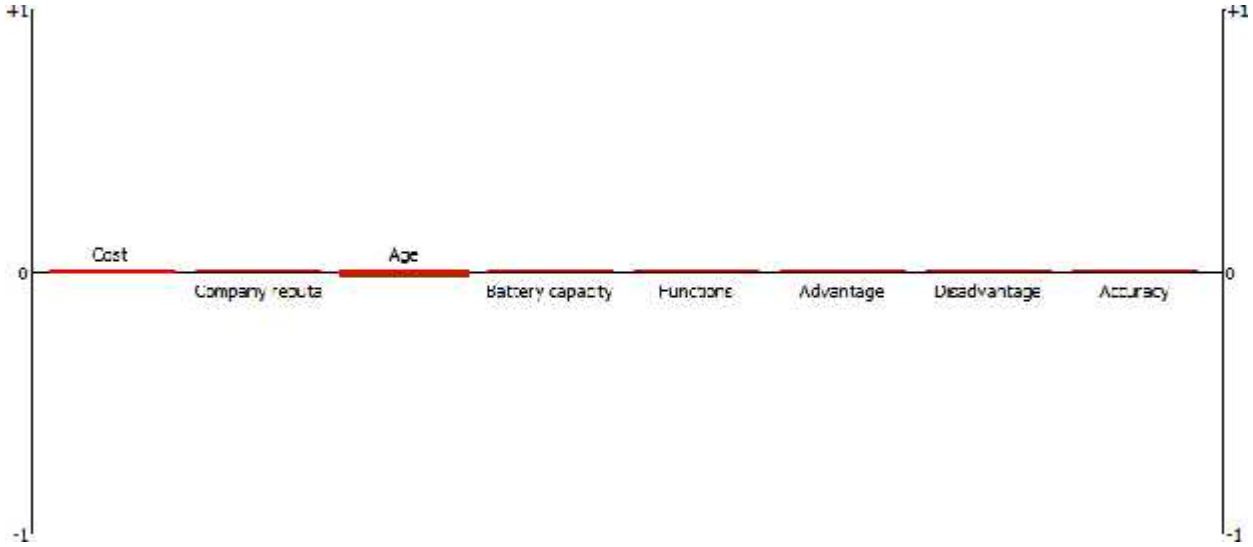
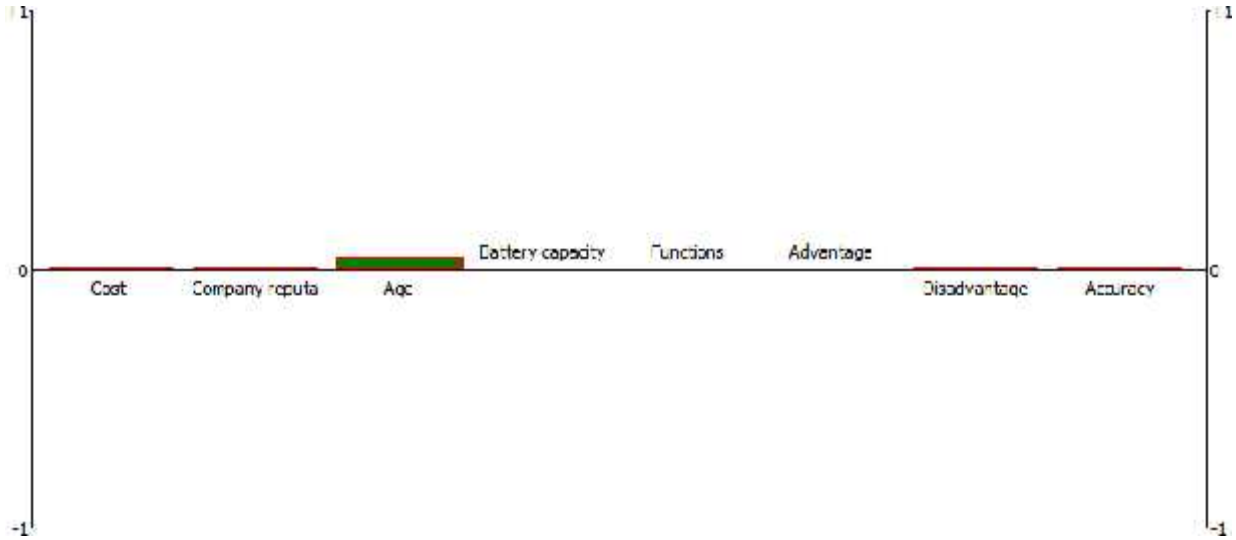


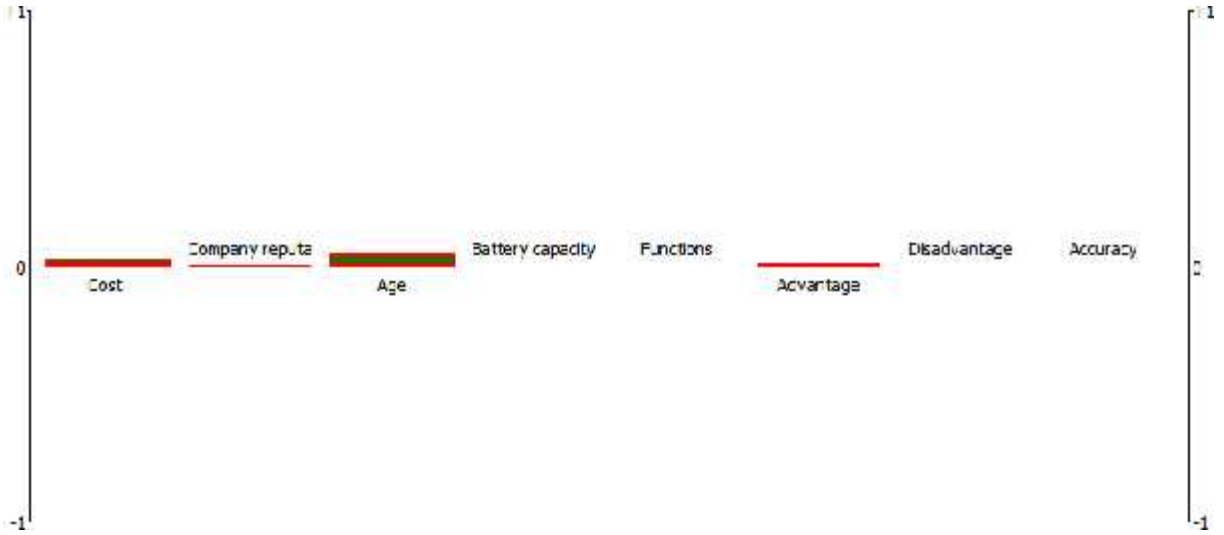
Figure 4.3 shows the representation of the result of tytocare using eight criteria after the fuzzy-PROMETHEE analysis. The cost showed a positive representation with an equal positive analysis in company reputation, the battery capacity, functions, advantage, disadvantage and accuracy. While the Age revealed the highest negativity as illustrated in figure 6.

Figure 4.4: Apollo in motion temperature/ fever measuring device:



The figure 4.4 represents the Apollo in motion temperature /fever measuring device. The analysis was done using the eight criteria as illustrated on figure 4.4. The analysis showed equal positive analysis in the cost, company reputation, disadvantage and accuracy. The battery capacity, functions and advantage showed no effect. While the Age showed the most positive criteria.

Figure 4.5: Handheld medical laser thermometer



The figure 8 represents the handheld medical laser thermometer with the most favourable result. The cost showed a partial positive result with the a little positive result in company reputation and the advantage, with no results in the battery capacity, functions, disadvantage and accuracy. The Age has the highest positive results.

Figure 4.6: Door access face recognition thermometer:

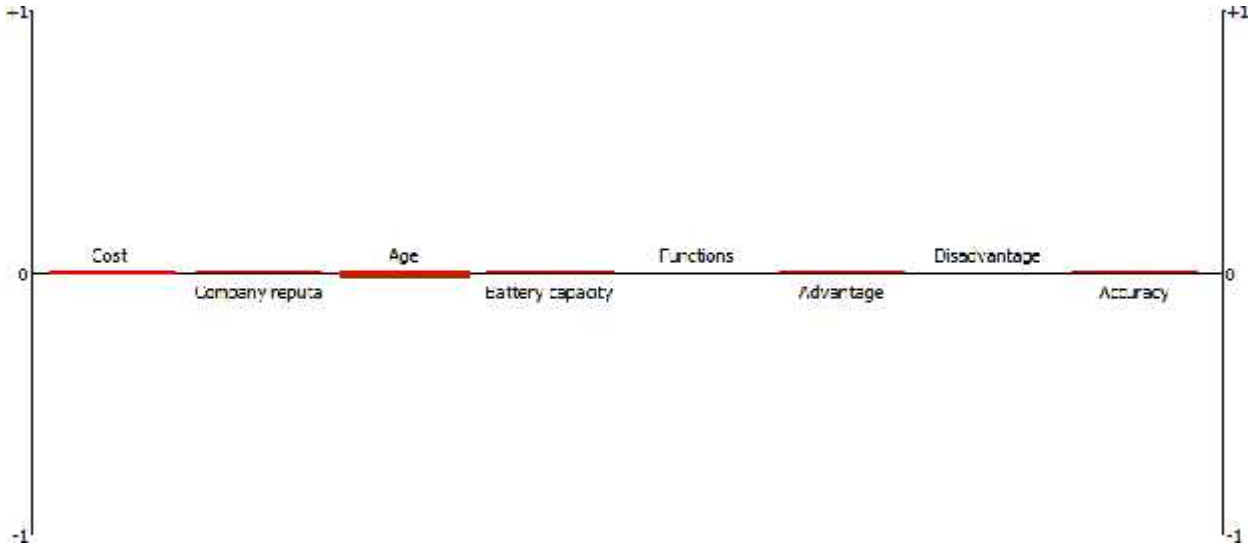
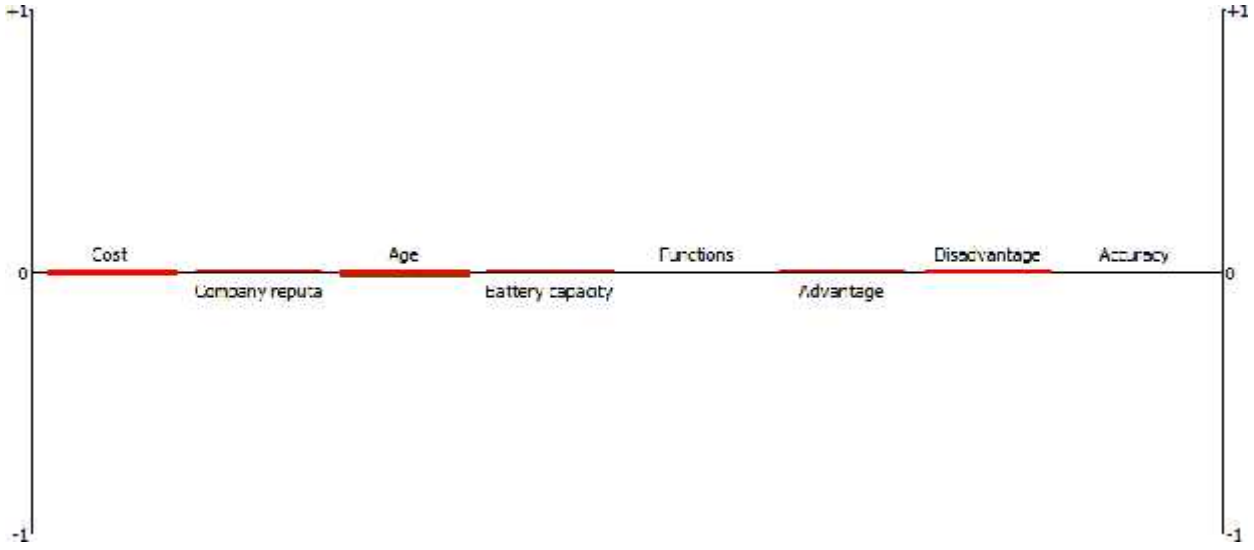


Figure 4.6 provides the result illustration of the door access face recognition devices. The result shows equal representation of the parameters, cost, battery capacity, advantage and accuracy and no result in the functions and disadvantage. While, the age exhibits high, negative results.

Figure 4.7: Delphi-pole mounted



The cost and age exhibited high negative results as shown in figure 4.7 . The company reputation, battery capacity and advantage revealed partial positive results. However, the negative is higher than the positive with the least results compared to the rest.

Figure 4.8: Result analysis using the required criteria

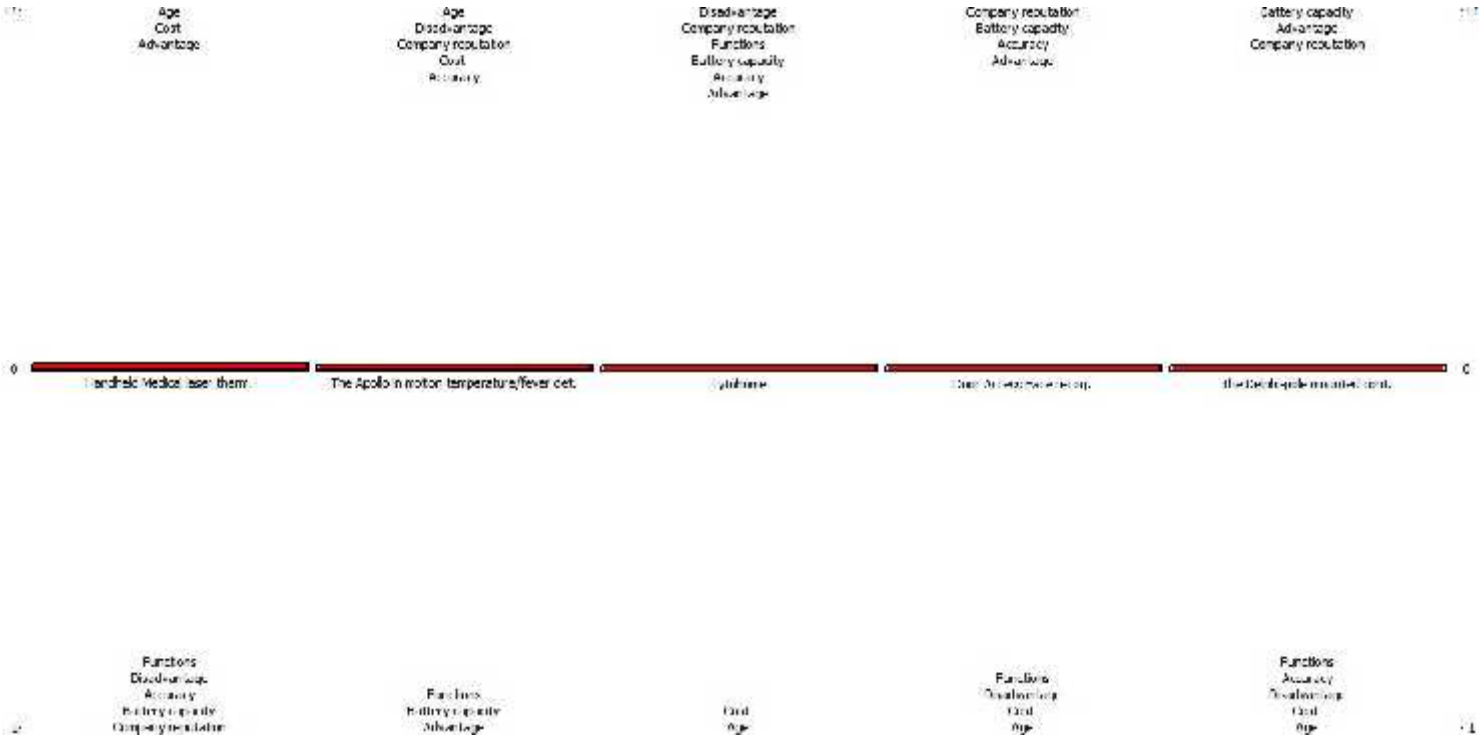


Figure 4.8 shows the final result after F-PROMETHEE analysis. The Handheld medical laser thermometer exhibits the highest positive results, followed by the Apollo in motion device, then the tytohome device. The least positive results were the door access face recognition device and the Delphi-pole mounted device with a very high negative results.

CHAPTER 5

5.0 Conclusion

In this study, five fever screening thermometers namely, the handheld medical laser thermometer, Apollo in motion thermometer ,Tytohome, Door access face recognition fever alarm device and the Delphi-pole mounted contact free feverdetection were compared using the fuzzy-based MCDM methods.

The MCDM method, fuzzy PROMETHEE was applied in this research to provide better alternative among the devices. The PROMETHEE technique provides a swift ranking for sets of alternatives separated by each parameter. Furthermore,in this study, similar to the M.Sayan et al methods, a linguistic fuzzy scale was used to define the important weights of each parameter with equality. In other words, the values were interchanged to triangular fuzzy variables and further introduced the Yager index for defuzzification. Also, the PROMETHEE decision and the Gaussian preference function were applied for the ranking results.

This researchfocused on analysing five selected fever detection novel thermometers used in detecting possible symptoms of COVID-19 using the fuzzy-based MCDM methods. The effective evaluations were made, guided by selected parameter. The result of the evaluation obtained, revealed that the handheld medical laser thermometer proved to be more effective.

Similarly the results indicated that the top most effective devices were Medical laser thermometer, Apollo in motion thermometer and the Tytohome. However, Door access face recognition fever device and the Delphi-pole mounted contactfree fever detection were recorded as least effective devices based on the selected criteria. The variables were assessed based on criteria such as the, cost, company reputation, age of the device, battery capacity, functions, advantage, disadvantage and accuracy of the device. The alternatives were evaluated based on the multi-criteria decision-making (MCDM) methods, the fuzzy preference ranking method for enrichment evaluation (fuzzy PROMETHEE). The results of this study will be beneficial for the experts having difficulty in selection of problems of the temperature devices.

Reference:

1. Wang, C., Horby, P. W., Hayden, F. G. &Gao, G. F. (2020) A novel coronavirusoutbreak of global healthconcern. *Lancet* **395**, 470–473

2. Kontis, Vasilis; Bennett, James E.; Rashid, Theo; Parks, Robbie M.; Pearson-Stuttard, Jonathan; Guillot, Michel; Asaria, Perviz; Zhou, Bin; Battaglini, Marco; Corsetti, Gianni; McKee, Martin; Di Cesare, Mariachiara; Mathers, Colin D.; Ezzati, Majid (2020). "Magnitude, demographics and dynamicsof the effect of the first wave of the COVID-19 pandemic on all-cause mortality in 21 industrialized countries". *Nature Medicine: 1–10. doi:10.1038/s41591-020-1112-0. ISSN 1546-170X. PMID 33057181. S2CID 222838346. Archived from the original on 4 November 2020. Retrieved 8 November 2020*

3. Woo PC, Huang Y, Lau SK, Yuen KY (2010). "Coronavirus genomics and bioinformatics analysis". Viruses. **2** (8): 1804–20. doi:10.3390/v2081803. *PMC 3185738. PMID 21994708. Coronaviruses possess the largest genomes [26.4 kb (ThCoV HKU12) to 31.7 kb (SW1)] among all known RNA viruses (Figure 1)[2,13,16]*.

4. Kruger, P. (2020). Compelled testing for the novel Corona Virus. *South African Medical Journal*, *110*(7), 0. doi: 10.7196/samj.2020.v110i7.14890

5. Al-Turjman, F. (2020). AI-Powered IoT for COVID-19 (1st ed.). CRC Press. https://doi.org/10.1201/9781003098881

6. Yildirim, F. S., Sayan, M., Sanlidag, T., Uzun, B., Ozsahin, D. U., &Ozsahin, I. (2021). Comparative Evaluation of the Treatment of COVID-19 with Multicriteria Decision-Making Techniques. *Journal of healthcare engineering*, *2021*, 8864522. https://doi.org/10.1155/2021/8864522

7. Escher, A., 2020. An Ounce of Prevention: Coronavirus (COVID-19) and Mass Gatherings. *Cureus*,.

8. Apa H, Gozmen S, Bayram N, et al. Clinical accuracy of tympanic thermometer andnon-contact infrared skin thermometer in pediatric practice: an alternative for axillarydigital thermometer. PediatrEmer Care. 2013;29:992–997

9. Franconi M, La Cerra C, Marucci AR, et al. Digital axillary and non-contact infraredthermometers for children. ClinNurs Res. 2018;27:180–190.

10. Khan, S., Saultry, B., Adams, S., Kouzani, A., Decker, K., Digby, R. and Bucknall, T., 2020. Comparative accuracy testing of non-contact infrared thermometers and temporal artery thermometers in an adulthospital setting. *American Journal of Infection Control*,.

11. Carpenè, G., Henry, B., Mattiuzzi, C. and Lippi, G., 2021. Comparison of forehead temperature screeningwith infra-red thermometer and thermal imaging scanner. *Journal of Hospital Infection*,.

12. Steuer, R.E. (1986). Multiple Criteria Optimization: Theory, Computation and Application. New York: John Wiley

13. Jordan-Yarmouk basin co-riparians according to the Helsinki and ILC rules. Water International,23(3): 164–173, 1998.

14. D. Al-Rashdan, B. Al-Kloub, A. Dean, and T.Al-Shemmeri. Environmental impact assessment and ranking the environmental projects in Jordan. European Journal of Operational Research, 118(1):30–45, 1999.

15. W. Yu, Z. Zhang, Q. Zhong, L. Sun Extended TODIM for multi-criteria group decision making based on unbalanced hesitant fuzzy linguistic term setsComputers and Industrial Engineering, 114 (2) (2017), pp. 316-328

16. Greene, R.; Devillers, R.; Luther, J.E.; Eddy, B.G. (2011). "GIS-based multi-criteria analysis". Geography Compass. 5/6 (6): 412–432. doi:10.1111/j.1749-8198.2011.00431.

17. Behzadian, M., Otaghsara, S., Yazdani, M., and Ignatius, J. (2012). A state-of-the-art survey of TOPSIS applications.Expert Systems with Applications, 39(17): 13051-13069

18. Dilber UzunOzsahin, Hüseyin Gökçekuş, Berna Uzun,James LaMoreaux (2021), “Application of Multi-Criteria Decision Analysis in Environmental and Civil” *springer Nature*ISBN: 978-3-030-64765-0

19. Ozsahin, I., Sekeroglu, B., Musa, M., Mustapha, M., &UzunOzsahin, D. (2020). Review on Diagnosis of COVID-19 from Chest CT Images Using Artificial Intelligence. Computational and Mathematical Methods in Medicine, 2020, 1-10. https://doi.org/10.1155/2020/9756518.

20. Sayan, M., SarigulYildirim, F., Sanlidag, T., Uzun, B., UzunOzsahin, D., &Ozsahin, I. (2020). Capacity Evaluation of Diagnostic Tests for COVID-19 Using Multicriteria Decision-Making Techniques. Computational and Mathematical Methods In Medicine, 2020, 1-8. https://doi.org/10.1155/2020/1560250.

21. Ozsahin, I., Mustapha, M., Albarwary, S., Sanlidag, B., Ozsahin, D., & Butler, T. (2021). An investigation to choose the proper therapy technique in the management ofautism spectrum disorder. Journal of Comparative Effectiveness Research.https://doi.org/10.2217/cer-2020-0162.
22. Goumas,M., &Lygerou,V. (2000). An extension of the PROMETHEE method for decision making in fuzzy environment:Ranking of Alternative Energy Exploitation Projects.*European Journal of Operational Research*, vol. 123, pp. 606–613.
23. Uzun. Ozsahin, D., Uzun, B., Syidanova, A., & Mustapha, M. (2021). Introduction to the Application of Multi-Criteria Decision Analysis in Environmental and CivilEngineering Professional Practice in Earth Sciences. In D. UzunOzsahin, H. Gökcekus, B. Uzun& J. LaMoreaux, Application of Multi-criteria Decision Analysis inEnvironmental and Civil Engineering (1st ed., pp. 1-6). Springer International Publishing.
24. Uzun, B., Mustapha, M., Syidanova, A., &Uzun. Ozsahin, D. (2021). The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). In D. UzunOzsahin, H. Gökcekus, B. Uzun& J. LaMoreaux, Application of Multi-criteria Decision Analysis in Environmental and Civil Engineering (1st ed., pp. 25-30). SpringerInternational Publishing.
25. Mustapha, M., Ozsahin, B., UzunOzsahin, D., &Ozsahin, I. (2021). A comparative study of X-ray based medical imaging devices. In I. Ozsahin, D. UzunOzsahin&B.Ozsahin, Applications of Multi-Criteria Decision-Making Theories in Healthcare and Biomedical Engineering (1st ed., pp. 163-180). Elsevier Inc.
26. Mustapha, M., UzunOzsahin, D., &Ozsahin, I. (2021). Comparative Evaluation of Point-of-care Glucometer Devices in the Management of Diabetes Mellitus. In I.Ozsahin, D. UzunOzsahin& B. Ozsahin, Applications of Multi-Criteria Decision-Making Theories in Healthcare and Biomedical Engineering (1st ed., pp. 117-136).Elsevier Inc.
27. Ozsahin, I., UzunOzsahin, D., Ozsahin, B., & Mustapha, M. (2021). Introduction to the Applications of Multi-Criteria Decision-Making Theories in Healthcare andBiomedical Engineering. In I. Ozsahin, D. UzunOzsahin& B. Ozsahin, Applications of Multi-Criteria Decision-Making Theories in Healthcare and BiomedicalEngineering (1st ed., pp. 117-136). Elsevier Inc.

28. Charnes A., W. W. Cooper and E. Rhodes (1978). “Measuring the Efficiency of Decision Making Units.” EJOR 2: 429-444.
29. 6. Ic, Y. (2012). An experimental design approach using TOPSIS method for the selection of computer-integrated manufacturing technologies. Robotics and Computer-Integrated Manufacturing, 28(2): 245-256
30. 7. Konidari, P., and Mavrakis, D. (2007). A multi-criteria evaluation method for climate change mitigation

policy instruments. Energy Policy, 35(12): 6235-6257

31. 8. Behzadian, M., Otaghsara, S., Yazdani, M., and Ignatius, J. (2012). A state-of-the-art survey of TOPSIS applications. Expert Systems with Applications, 39(17): 13051-13069.
32. 9. Lai, S. (1995). Preference-based interpretation of AHP. International Journal of Management Science, 23(4): 453-462.
33. 10. Podvezko, V. (2011). The comparative analysis of MCDA methods SAW and COPRAS. Inzinerine-Ekonomika-Engineering Economics, 22(2): 134-146.
34. 11. Zadeh, L. (1965). Fuzzy sets. Information and Control, 8(3): 338-353.
35. 12. Yu, P.L., 1973. A class of solutions for group decision problems. Management Science 19 (8), 936–946

36. Balmat, J., Lafont, F., Maifret, R., and Pessel, N. (2011). A decision-making system to maritime risk assessment. OceanEngineering, 38(1): 171-176

37. Geldermann, J., Spengler, T., &Rentz, O. (2000). Fuzzyoutrankingforenvironmentalassessment. Case study. *Ironand Steel MakingIndustry. FuzzySets Syst*,115(1), 45–65.

38. Hsiao SH, Chen TC, Chien HC, Yang CJ, Chen YH. Measurement of body temperature to prevent pandemic COVID-19 in hospitals in Taiwan: repeated measurement is necessary. J HospInfect 2020;105:360-1.

39. Ng DK, Chan CH, Chan EY, Kwok KL, Chow PY, Lau WF, et al. A brief report onthe normal range of forehead temperature as determined by noncontact, handheld, Infrared thermometer. Am J Infect Control 2005;33:227-9.

40. https://i.ytimg.com/vi/3AaUCs4R9ZM/maxresdefault.jpg

41. www.wired.com

42. https://tecnoimpex-tytocare.com

43. https://israelmedicalinnovation.com/wp-content/uploads/2019/06/Tyto-Care-Pic.jpg

44. Chiappini E, Sollai S, Longhi R, et al. Performance of non-contact infrared thermometer for detecting febrile children in hospital and ambulatory settings. J Clin Nurs. 2011;20:1311–1318.

45. http://china.org.ru/product/62582167493 Ali Epress. (2021)

46. https://www.aliexpress.com/i/1005001632968920.html

47. SCW 2021 https://www.getscw.com/the-apollo-in-motion-thermal-fever-detection-system.php

48. Abuzairi, T., ImaniatiSumantri, N., Irfan, A. and MaulanaMohamad, R., 2021. Infrared thermometer on the wall (iThermowall): An open source and 3-D print infrared thermometer for fever screening. *HardwareX*, 9, p.e00168.

49. Demir, K., McDonald, E., de L'Étoile-Morel, S., Schweitzer, L., Butler-Laporte, G., Cheng, M. and Lee, T., 2021. Handheld infrared thermometer to evaluate cellulitis: the HI-TEC study. *Clinical Microbiology and Infection*,.