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Fuzzy Sets in Multi Criteria Decision Making

Manan Jayesh Mehta Dr. Anjali Naithani
Department of Mathematics, Amity Institute of Applied Sciences, AMITY University, Uttar Pradesh

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Covid19,
decision making

Abstract

In this paper we will go through many things such we will see basic introduction of fuzzy set theory. Then we will go for fuzzy logic and real-life application of fuzzy logic, advantages and disadvantages of fuzzy logic and need of fuzzy logic. After that we study about fuzzy numbers and entropy of fuzzy sets. At last, we will do application to fuzzy decision-making approach and application example. We have introduced decision-making method in fuzzy decision-making approach. We also took the data of a hospital on Covid19 of age group 30-50 and solved it using our decision making method.

Introduction

Fuzzy is a branch of mathematics and fuzzy comes under pure AI (artificial intelligence) or sometimes we also call it as “soft computing methods”.

- Soft Computing: don’t have instructions.

Examples - AI: ANN, GA, Fuzzy, SVM

- Hard Computing: Write a program for any function/formula.

Have instructions one by one.

Examples - C, mat lab, C++

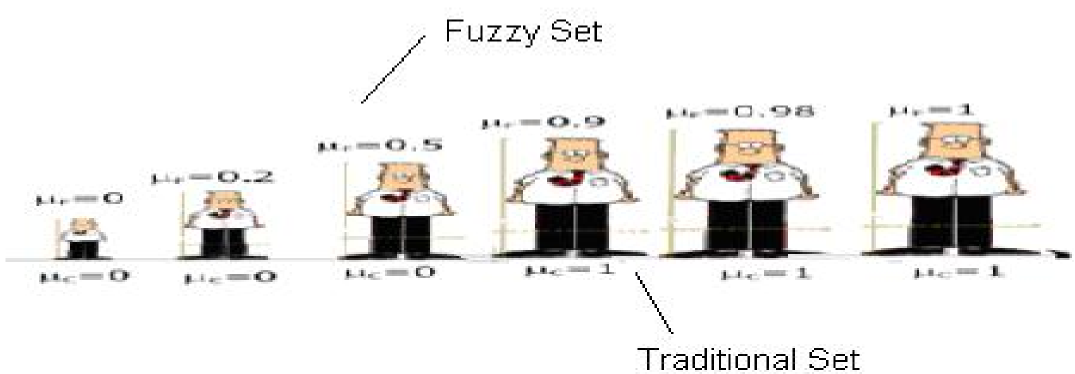
The fuzzy set theory is constructed on the central idea of "set" of which an individual is either a part or not a part. A sharp, crisp, and unambiguous differentiation exists between a member and a non-member for any well-defined "set" of entities in this theory, and there is an extremely exact and clear limit to demonstrate if an entity has a area with the set. "The probability for this entity to be an individual from that set is 90%," the ultimate result (i.e., end) is still possibly "it is" or "it is not" an individual from the set. The possibility for one to make a right expectation as "it is an individual from the set" is 90%, which does not imply that it has 90% membership in the set and meanwhile it has 10% non-membership.

Fuzzy logic - Logic alludes to the investigation of techniques and standards of human thinking. Classical logic, as regular practice, manages suggestions (e.g., ends or choices) that are either obvious or bogus. Each suggestion has an inverse. Classical logic, hence, manages mixes of factors that address suggestions. As every factor represents a speculative suggestion, any mix of them at last expects a reality esteem (by the same token valid or bogus), yet never is in the middle or both (i.e., is not correct and bogus at the same time).

Fuzzification is a significant idea in the fuzzy logic theory. Fuzzification is the interaction where the crisp amounts are changed over to fuzzy (crisp to fuzzy). By distinguishing a portion of the vulnerabilities present in the crisp values, we structure the fuzzy values. The transformation of fuzzy values is addressed by the participation capacities. In any down to earth applications in enterprises, estimation of voltage, current, temperature, and so on, there may be an unimportant mistake. This causes imprecision in the information. This imprecision can be addressed by the participation capacities. Hence fuzzification is performed.

Hence, fuzzification interaction may include appointing participation esteems for the given crisp quantities.

Figure 1 – distinction between Fuzzy Set and Traditional Set



FUZZY SET

Let x be a universal set. A fuzzy set A in x is a set of ordered pairs.

$A = \{(x, \mu_A (x)): x \varepsilon X\}$

Where $\mu_A (x)$ is the membership grade of x in A; $\mu_A: X \rightarrow [0,1]$ and each pair $(x, \mu_A (x))$ is called singleton.

$X = \{x_1, x_2, ...\}$ (X is discrete)

$A = \sum_{x \varepsilon X} \frac{\mu A\ (x)}{x}$

X = continuous

$A = \int_X \frac{\mu A\ (x)}{x}$

Let take some examples:

Ex. 1.) X = {1,2,3,4,5} (discrete)
$\mu_A(x) = 1/1+x^x$
Sol.
$\mu_A(1) = 1/1+1 = ½$
$\mu_A(2) = 1/1+4 = 1/5$
$\mu_A(3) = 1/10$
$\mu_A(4) = 1/17$
$\mu_A(5) = 1/26$

Ex. 2.) $\mu_A(x) = \begin{cases} 0, x < 0 \\ x/5, 0 \leq x < 5 \\ 10 - x/5, 5 \leq x < 10 \end{cases}$ (continuous)

Find membership at x = -2, 3, 6, 5, 9, 12.
Sol.
$\mu_A(-2) = 0$
$\mu_A(3) = 3/5$
$\mu_A(5) = 1$
$\mu_A(9) = 1/5$
$\mu_A(6) = 4/5$
$\mu_A(12) = 0$

CARDINALITY OF A FUZZY SET

1. Scalar Cardinality:

Scalar cardinality in a fuzzy set A issum of membership degree of the grade for all x Ɛ X, X is world of dissertation for the fuzzy set A

Sc(A) = | A | = $\sum_{x \varepsilon X} \mu A(x)$ (discrete)

Sc(A) = | A | = $\int_{x \varepsilon X} \mu A(x)$ (continuous)

Note→ 1. Relative cardinality is calculated only for discrete.

2. Relative cardinality = $\frac{|A|}{|X|}$

3. Fuzzy cardinality: Suppose A is a fuzzy set in X which has finite support. Then fuzzy cardinality of A is a fuzzy set represented by |Ã| or $F_c(A)$.
|Ã| or $F_c(A) = \{(|{}^{\alpha}A|, \alpha): \alpha \varepsilon \wedge (A)\}$

OPERATIONS OF FUZZY SETS

There are 4 basic operations on fuzzy sets:

- Union
- Intersection
- Compliment
- Difference

1. UNION:

To solve the union of 2 fuzzy sets B_1 and B_2, the formula is:

$$B_1 \cup B_2 = \max [\mu_A(x), \mu_B(x)]$$

This means we need to compare the membership of the upper values in the fuzzy sets and take the maximum out of it. We can only compare two elements with the same lower limit values. We cannot compare two components with different lower limit values.

Example) $B_1 = \{\frac{1}{1.0} + \frac{0.75}{1.5} + \frac{0.3}{2.0} + \frac{0.15}{2.5} + \frac{0}{3.0}\}$

$B_2 = \{\frac{1}{1.0} + \frac{0.6}{1.5} + \frac{0.2}{2.0} + \frac{0.1}{2.5} + \frac{0}{3.0}\}$

B1 U B2 = max $[\mu_A(x), \mu_B(x)]$

B1 U B2 = $\{\frac{1}{1.0} + \frac{0.75}{1.5} + \frac{0.3}{2.0} + \frac{0.15}{2.5} + \frac{0}{3.0}\}$

Note: Denominator need not be changed during the union of 2 fuzzy sets, all the operations are to be performed on the upper value or the degree value.

2. INTERSECTION:

To solve the intersection of 2 fuzzy sets B_1 and B_2 , the formula is:

$$B_1 \cap B_2 = \min [\mu_A(x), \mu_B(x)]$$

This means we need to compare the numerator in the fuzzy sets and take the minimum out of it. Two elements can only be compared with similar lower limit values

Example) $B_1 = \{\frac{1}{1.0} + \frac{0.15}{1.5} + \frac{0.3}{2.0} + \frac{0.15}{2.5} + \frac{0}{3.0}\}$

$B_2 = \{\frac{1}{1.0} + \frac{0.6}{1.5} + \frac{0.2}{2.0} + \frac{0.1}{2.5} + \frac{0}{3.0}\}$

$B_1 \cap B_2 = \min [\mu_A(x), \mu_B(x)]$

$B_1 \cap B_2 = \{\frac{1}{1.0} + \frac{0.15}{1.5} + \frac{0.2}{2.0} + \frac{0.1}{2.5} + \frac{0}{3.0}\}$

Note: All the operations are to be performed on the upper value only.

3. COMPLIMENT:

To find the compliment of set of a fuzzyB_1, we just have to subtract each of the degree value of the set from 1.

$$\overline{B} = 1 - \mu_B(x)$$

Example) B= $\{\frac{1}{1.0} + \frac{0.15}{1.5} + \frac{0.3}{2.0} + \frac{0.15}{2.5} + \frac{0}{3.0}\}$

$\bar{B}$= 1- $\mu_B(x)$

$\bar{B} = \{\frac{1-1}{1.0} + \frac{1-0.15}{1.5} + \frac{1-0.3}{2.0} + \frac{1-0.15}{2.5} + \frac{1-0}{3.0}\}$

$\bar{B} = \{\frac{1}{1.0} + \frac{0.85}{1.5} + \frac{0.7}{2.0} + \frac{0.85}{2.5} + \frac{1}{3.0}\}$

Note: We have to keep the lower limit value unchanged. All the operations are to be performed on the upper limit value.

4. DIFFERENCE:

The difference of two fuzzy sets can be found in B_1 and B_2, we have to solve the intersection between first fuzzy set B_1 and compliment of second fuzzy set B_2.

$$\mathbf{B_1|B_2= B_1 \cap \bar{B}_2}$$

OR

$$\mathbf{B_2|B_1= B_2 \cap \bar{B}_1}$$

Example) $B_1 = \{\frac{1}{1.0} + \frac{0.15}{1.5} + \frac{0.3}{2.0} + \frac{0.15}{2.5} + \frac{0}{3.0}\}$

$B_2 = \{\frac{1}{1.0} + \frac{0.6}{1.5} + \frac{0.2}{2.0} + \frac{0.1}{2.5} + \frac{0}{3.0}\}$

$\overline{\mathbf{B_2}} = \{\frac{0}{1.0} + \frac{0.4}{1.5} + \frac{0.8}{2.0} + \frac{0.9}{2.5} + \frac{1}{3.0}\}$

$B_1|B_2= B_1 \cap \overline{\mathbf{B_2}}$

$B_1|\ B_2 = \{\frac{0}{1.0} + \frac{0.15}{1.5} + \frac{0.3}{2.0} + \frac{0.15}{2.5} + \frac{0}{3.0}\}$

SOME OTHER OPERATIONS ON FUZZY SETS:

Algebric Sum:

Suppose there are 2 fuzzy sets P & Q then the algebric sum of these 2 fuzzy sets will be:

$$\mathbf{M_{P+Q}(x) = [\ \mu_P(x) + \mu_Q(x)\ ] - [\mu_P(x).\mu_Q(x)\ ]}$$

Algebric Product:

Suppose there are 2 fuzzy sets P &Q , then the algebric product of these 2 sets will be:

$$\mathbf{M_{P.Q} = \mu_P(x)\ .\ \mu_Q(x)}$$

Bounded Sum:

To track down the limited amount of 2 arrangements of fuzzy P and Q, we need to initially take the expansion of the numerator and afterward we need to contrast it with 1, then we need to remove the base worth from the two, i.e.

BOUNDED SUM: $\mu_{P \oplus Q} = \min [\, 1, (\mu_P + \mu_Q) \,]$

Bounded Difference:

To track down the limited distinction of 2 fuzzy sets P and Q, we need to initially take the contrast between the numerator and afterward we need to contrast it with 0, then, at that point, we need to remove the most extreme worth from the two.

BOUNDED DIFFERENCE: $\mu_{P \ominus Q} = \max [\, 1, (\mu_P - \mu_Q) \,]$

PROPERTIES OF FUZZY SET

i. Fuzzy set can be considered as a set of ordered pairs as
$\bar{A} = \{(X, \mu_A(X)) \,|x \,Ɛ\, U\}$ where $\mu_A(X)$ is the degree of membership of x in Ã.
ii. The degree of membership indicates the degree or confidence that x belongs to Ã.
iii. The degree of membership assumes values in the interval [0,1] i.e. $\mu_A(X)$ Ɛ [1,0].
iv. A classical or crisp set is written as $S = \{x_1, x_2, \ldots\}$.
v. A fuzzy set Ã is empty if degree of membership $\mu_A(X)$ is 0 for all x Ɛ U.
vi. The complement of a fuzzy set Ã written as Ã' is given as $\mu_{\tilde{A}'}(X) = 1 - \mu_{\tilde{A}}(X)$ for all x Ɛ U.
vii. Any fuzzy set Ã on universe U is the subset of universe U.

FUZZY LOGIC

The start of logic in fuzzy is to permit truth esteems to be any number in the interval [0, 1]. On the off chance that p is an atomic suggestion, we will currently let tv(p) mean the reality of p. In this way, tv(p) E [0, 1] for any recommendation in fuzzy logic. tv(p) = 1 implies that p is totally evident, tv(p) = 0 is that p is totally bogus and tv(p) = 0.65 simply implies that the reality of p is 0.65. Fuzzy logic is an endless esteemed logic in that reality esteems can go from zero to one. Fuzzy logic is worried about the reality of suggestions. However, in real world recommendations are frequently just incompletely evident. It is hard to describe the reality of "John is old" as unambiguously evident or bogus if John is 60 years of age. In certain regards he is old, being qualified for senior resident advantages at numerous foundations, yet in different regards he is not old since he isn't qualified for federal retirement aide. Along these lines, in fuzzy logic we would permit television (John is old) to take on different qualities in the span [0, 1] other than only zero what's more, one.

ADVANTAGES OF FUZZY LOGIC

The structure of Fuzzy Logic Systems is simple and reasonable.

fuzzy Logic is comprehensively used for business and utilitarian purposes.

It encourages you to control machines and purchaser items.

It may not offer precise thinking, however the solitary adequate thinking.

It causes you to manage the vulnerability in designing.

DISADVANTAGES OF FUZZY LOGIC

Fuzzy logic is not generally exact, so the outcomes are seen dependent on presumption, so it may not be broadly acknowledged.

Approval and Verification of a fuzzy information-based system needs broad testing with equipment. Setting accurate, fuzzy principles and, membership functions is a difficult task.

Some fuzzy time logic is mistaken for probability theory and the terms.

SOME REAL-LIFE APPLICATIONS IN FUZZY LOGIC

1. Self-focusing cameras.
2. Mycin medical expert system.
3. Automobile engine controls.
4. Anti-lock braking systems.
5. Colour film developing systems.
6. Subway control systems.

NEED FOR FUUZY LOGIC

1. It is based on intuition and judgement.
2. There is no requirement for the need in a mathematical model.
3. It is relatively simple, fast, and adaptive.
4. It is less sensitive to system fluctuations.
5. It could be used to implement design objectives, difficult to express mathematically, in linguistic or descriptive rules.

SOME APPLICATIONS OF FUZZY SETS:-

Fuzzy sets are very helpful in many industries. Mostly it is valuable to people who are involved with Research and Development. This includes Mathematicians, Medical Researchers, Engineers (like Mechanical Engi neers, Civil Engi neers, Computer Eng ineers, Aerospace Eng ineers, Agricultural Eng ineers, Geological Eng ineers, Industrial Eng ineers, Software Engi neers), scientists who deal with nature such as (Biological Scientists, Physical Scientists, Chemical Scientists, Earth Science), and it also helps Business Analyzers and Policy Analyzers.

➢ Applications on Fuzzy sets can be seen in many scientific and engineering works. There are many applications of fuzzy sets; for example washing machines, systems used for transmission, facial recognition, unmanned helicopters, systems used for forecasting of weather, health diagnosis and their treatments plans, stock marketing. Fuzzy sets are successfully useful in automation of industries, electronics, processing of images and robotics.

❖ Descriptive view of some applications insets of fuzzy or fuzzy logic:

1. Business –

Support systems used for decision making.
Staff evaluation in a big company.

2. Aerospace –

Control in altitude of a space shuttle.
Altitude control of a satellite.

3. Electronics –

Measuring humidity in a clean room.
Video camera's automatic exposure.
Microwave ovens.
Timings in washing machine.
Vacuum cleaners.

4. Automotive –

Control in traffic.
Intelligent systems of highways.

5. Defense –

Automatic target recognition underwater.
Hypervelocity interceptor control.

6. Finance –

Control of transfer of Banknotes.
Prediction in stock marketing.
Management of funds

7. Manufacturing –

Optimization of production of Butter.
Optimization of production of Milk.

8. Medical –

Diagnosis of medical support systems.
Diagnosis of Radiology.

9. Transportation –

Stopping and breaking.
Control of train schedule.
Acceleration of rails.
Automatic operations of trains underground.

10. Psychology –

Investigation of criminals and their prevention.
Analysis of behavior of humans.

APPLICATION TO FUZZY DECISION-MAKING APPROACH

Use of fuzzy sets inside the field of decision-making, generally, comprised of fuzzifications of the traditional speculations of decision-making. While decision-making under states of danger have been demonstrated by probabilistic choice hypotheses and game speculations. Fuzzy decision theories endeavor to manage the dubiousness and non-explicitness natural in human detailing of inclinations, limitations, and objectives. In this examination I have outlined the utilizations of fuzzy set hypothesis to the principal classes of decision-making problems. Classical decision-making for the most part manages a bunch of elective conditions of nature (results, results), a bunch of elective activities that are accessible to the decision maker, a connection showing the state or result not out of the ordinary from every elective activity lastly a utility or target work which arranges the results as indicated by their attractive quality. A decision is supposed to be made under states of assurance when the result for each activity can be resolved and requested absolutely. For this situation, the elective that prompts the result yielding the most elevated utility is picked. That is, the decision-making issue turns into an improvement issue, the issue of boosting the utility capacity. A decision is made under states of danger, then again, when the lone free information concerning the results comprises of their contingent likelihood appropriations, one for each activity. For this situation, the decision-making problem turns into an optimization problem of maximizing the expected utility. At the point when probabilities of the results are not known, or may not be significant, and results for each activity are portrayed just roughly, we say that decisions are made under uncertainty or vulnerability. In 1961, the British Economist Shackle portrayed that decision-making under uncertainty or vulnerability is maybe the main classification of dynamic issues. This is the excellent area for fuzzy decision-making. A few classes of decision-making problems are normally perceived. As indicated by one model, decision problem is named those including a solitary chief and those, which include a few decision makers. These issue classes are alluded to as individual decision-making and multiperson decision-making, respectively. As per another measure, choice issues are recognized that include a simple optimization of a utility capacity, a streamlining under requirements or an improvement under different goal rules. Besides, decision-making should be possible in one phase, or it tends to be done iteratively in a few phases. For all intents and purposes any control framework can be displaced with a fluffy rationale based control framework. This may be unnecessary abundance in various spots at any rate it enhances the arrangement of much more jumbled cases. So fluffy rationale isn't the reaction to everything, it ought to be used when legitimate to give better control. In case a clear shut circle or PID controller works fine then there is no necessity for a fluffy regulator. There are various circumstances while tuning a PID regulator or arranging a control framework for a tangled framework is overwhelming, this is where fluffy framework gets its chance to succeed. Perhaps the most acclaimed uses of fluffy rationale is that of the Sendai Subway framework in Sendai, Japan. This control of the Nanboku line, made by Hitachi, used a fluffy regulator to run the train the entire day. This made the line one of the smoothest running tram framework on earth and extended adequacy similarly as ending time. This is furthermore a delineation of the earlier affirmation of fluffy rationale in the east since the cable car went into movement in 1988.Fuzzy logic likewise discovers applications in numerous different systems. For instance, the MASSIVE 3D activity system for producing swarms utilizes fuzzy logic for man-made reasoning. This program was utilized extensively in the formation of the Lord of the Rings set of three just as The Lion, The Witch, and the Wardrobe films.

As a last illustration of fuzzy logic, it very well may be utilized in zones other than just control. Fuzzy logic can be utilized in any decision-making interaction like sign preparing or information investigation. An illustration of this is a logic system of fuzzy that dissects a force system and analyses any consonant aggravation issues. The system dissects the basic voltage, just as third, fifth and seventh music just as the temperature to decide whether there is cause for worry in the activity of the system.

Development designing and the board research has seen critical development in fuzzy logic applications to tackle various problems. Fuzzy logic has remained applied to display emotional vulnerability in development and address the absence of far-reaching informational indexes accessible for demonstrating. In the development area, fuzz logic has been joined with different procedures, like reproduction, hereditary calculations, furthermore, counterfeit neural organizations to make cross breed system. This meeting will zero in on ongoing uses of fuzzy logic and fuzzy hybrid strategies for applications identified with arranging and planning, assessing also, offering, efficiency, project control, organizing projects, measure improvement, hazard examination, and others. Specifically, moves identified with applying fuzzy logic in the development area will be examined and thoughts created on the best way to adjust fuzzy logic and fuzzy hybrid methods to even more likely suit development applications. The expanding accessibility of tremendous picture assortments on the Web is squeezing need for the improvement of productive methods for the handling, the investigation, the ordering, and the recovery of picture information. Genuinely merged outcomes were gotten nearby content-based image retrieval targeting ordering pictures with low-level substance-based highlights. Anyway, content-based image retrieval pertinence is hampered by the known issue of semantic hole, which is the hole between the low-level depiction of pictures and their semantic understanding given by people. Momentum research on picture preparing and recovery is committed to explore how to fill the semantic hole, which presents numerous difficulties and open issues. Among these, the trouble of clients to communicate their solicitations as all around characterized inquiries, the need of viable strategies for the extraction of significant also succinct highlights from pictures, the meaning of adaptable likeness measures for object coordinating, the programmed comment of visual substance with semantic ideas. Every one of these difficulties can be tended to with the assistance of fuzzy techniques, which may give proficient apparatuses to picture preparing just as advantageous instruments for both content-based and concept-based picture recovery.

Decision-making Problem with inclination data on options will be researched. Another methodology has been proposed to take care of the numerous property decision-making issues where the decision maker gives his inclination on options in a fuzzy connection. To mirror the decision maker's inclination data, a streamlining model is built to survey the ascribed loads and afterward to choose the best other options. Also, I will consider a staggered straight programming issue, furthermore, apply Fuzzy Mathematical Programming way to deal with get the arrangement of the system.

TOPSIS Method

TOPSIS, known as the **Technique for Order of Preference by Similarity to Ideal Solution,** is a multidisciplinary decision-making method. It compares a set of alternatives based on the aforementioned subject. The method is used commercially in all different industries, whenever we need to make an analysis decision based on the data collected.

TOPSIS showed up during the 1980s as a multi-layered dynamic framework. TOPSIS chooses the option in contrast to the most brief Euclidean separation from the best arrangement and the biggest separation from the most horrendously terrible arrangement.To make this definition easier, let's say you want to buy a cell phone, go to the store and analyze 5 cell phones based on RAM, memory, display size, battery, and price. Finally, you get confused after seeing so many things and you don't know how to decide which phone to buy. TOPSIS is a method of allocating ranks on the basis of weight and impact of a given item.

Weights mean how much a given factor should be taken into consideration (default weight = 1 for all factors). like you want RAM to have weighed more than other factors, so the weight of RAM can be 2, while others can have 1.

Impact means that a given factor has a positive or negative impact. Like you want Battery to be large as possible but the price of the mobile to be less as possible, so you'll assign '+' weight to the battery and '-' weight to the price.

This technique could be applied to machine learning model models based on various factors such as addition, R ^ 2, accuracy, Root mean square error, etc. Now that we have heard what TOPSIS is, and where we can use this. Let's see what is the process of using TOPSIS in a given database, which includes multiple rows (like different cell phones) and multiple columns (as various objects).

What does it really mean?

How about we consider what is happening in which we need to look at a few organizations and figure out which one has the most cash. These companies are some of our preferred methods. In order to put them together and determine which ones are the strongest, we need to use some reliable metrics. In such a case we may use certain indicators taken from financial statements such as ROA (return on equity), ROE (return on equity), DR (credit ratio), or CG (capital gearing). These guidelines will set our goals.

TOPSIS's equivocal comprehension depends with the understanding that the favored strategy ought to have a more limited mathematical separation from the best arrangement and the longest mathematical separation from the most obviously awful arrangement. It's quite simple huh?Such an approach allows for the acquisition of transactions between terms of which the negative performance of one can be canceled for the performance of the other condition. This provides an excellent model for modeling because we do not include other solutions based on the predefined limitations.

Problem Given m choices (options) Ai, every one of which relies upon n boundaries (standards) xj whose values are communicated with positive genuine numbers xij. The most ideal choice ought to be chosen. ***Mathematical model of the problem***

Originally, the constraint principles x_{ij} should be composed according to the technique of standardization. Suppose that a_{ij} are the standardized constraint values. Then each option A_i is articulated as the point

$A_i(a_{1i},...,a_{in})$ R^n. Selecting the most optimal value a_j^* $\{a_{1j}^*,...,a_{mj}^*\}$ for every parameter x_j, we determine the positive ideal solution $A^* = (a_1^*,....,a_n^*)$. The inverse is the negative ideal arrangement $Ao= (a_{10},....,a_{no})$.The positive and negative ideal arrangement are additionally indicated by A+ and A-. The choice on the request for choices is made regarding the request for numbers

$$D_i^* = \frac{d(A,Ao)}{d(A,A*)+d(A,Ao)} = = \frac{1}{\frac{d(A,A*)}{d(A,Ao)}+1}$$

The option A_{i1} is the finest solution if $\max\{D_1^*, D_2^*,..., D_n^*\}= D_{i1}^*$, & the choice A_{i2} is the foulest explanation if $\min \{D_1^*, D_2^*,..., D_n^*\}= D_{i2}^*$. The other options are between these two extremes. The maximum distance $D^* = \max_{i=1,...,m} D_i^*$ is usually called TOPSIS metric.

TOPSIS algorithm

Generally, the whole TOPSIS process can be encapsulated in 7 steps:

1. Create a matrix containing of M replacements and N criteria. This matrix is usually called an "evaluation matrix".

$$(a_{ij})_{M \times N}$$

As an example: M will be the number of our companies, while N, the number of metrics (ROA, ROE, DR, CG).

2. Normalize evaluation matrix:

$$\phi_{ij} = \frac{aij}{\sqrt{\sum_{i=1}^{M}(aij)^2}}$$

Each metric j for each company i is normalized to be in amid 0 and 1. The higher its worth the improved the metric.

3. Calculate the weighted normalized decision matrix. It is important to note that each criterion should have its own weight so that all of them will sum up to 1. The weights can be derived randomly (not recommended) or based on expert knowledge (industry standard).

$$X_{ij} = \phi_{ij} * W_j$$

$$W_j = \sum_{j=1}^{N} Wj$$

$$\sum_{j=1}^{N} Wj = 1$$

After we assign a weight to each financial metric, we need to normalize those so that these sum up to 1. Then we need to multiply each normalized metric from step 2 by corresponding normalized weight.

4. Determine the best and the worst alternative for each criterion:

$$X_j^b = max_{i=1}^{M} X_{ij}$$

$$X_j^w = min_{i=1}^{M} X_{ij}$$

We need to discover the maximum and minimum value of each financial metric among all companies.

5. Compute the Euclidean distance between the target alternative and the best/worst alternative:

6.

$$d_i^b = \sqrt{\sum_{j=1}^{N}(x_{ij} - x_j^b)^2}$$

$$d_i^w = \sqrt{\sum_{j=1}^{N}(x_{ij} - x_j^w)^2}$$

This is a calculation of the geometric distance between the value of each financial metric for a given company i and the best/worst value of such a metric among all companies.

7. For each other calculate the comparation

8. to the worst alternative. The results are our TOPSIS scores.

$$s_i = \frac{d_i^w}{d_i^w + d_i^b}$$

We compute a score for each company that is based on distances obtained in a step before.

9. Rank alternatives according to the TOPSIS score by descending order.

The company with metrics closest to the best will obtain the highest score and therefore will be at the top of our ranking.

And… that's all. We obtained a ranked set of alternatives based on specified criteria!

Application of TOPSIS Method in Multi Criteria Decision Making

***Problem* –**To determine which patient is most likely to be Covid19 Positive based on the Vaccination, Symptoms and Co morbidities.

We collected the data from a Hospital on Covid19 and ran a sample through the TOPSIS method on Microsoft Excel to determine which patient is likely to be Covid19 positive based on 3 criteria i.e. Vaccination, Symptoms and Co morbidities.

We collected the data of 100 patients of a Hospital and organised it into the Excel sheet as shown below:

There are 8 Possible Symptoms – Cough, Diarrhoea, Vomiting, Fever, Breathlessness, Nausea, Body Ache and Sore Throat.
&
There are 4 possible Co morbidities – Heart Disease, Chronic Lung Disease, Chronic Liver Disease and Diabetes.
&
There might be 3 possibilities for a person to be vaccinated or not – Fully Vaccinated i.e. both doses, Partially Vaccinated i.e. Only one dose and Not Vaccinated i.e. zero doses

1	Serial Number	Patient's Name	Gender	Cough	Diarrhea	Vomiting	Fever	Breathlessness	Nausea	Body ache	Sore throat	H
2												
3	1	Diksha Bhardwaj	Female	Yes	No	Yes	Yes	No	No	Yes	Yes	N
4	2	Ritika Goel	Female	Yes	No	No	No	No	No	No	No	N
5	3	Rakesh Kumar	Male	Yes	No	Yes	Yes	Yes	No	Yes	Yes	N
6	4	Rahul	Male	Yes	No	No	No	No	No	Yes	No	N
7	5	Naresh Kumar	Male	Yes	No	No	No	No	No	Yes	Yes	N
8	6	Jayesh Mehta	Male	No	No	Yes	Yes	Yes	No	Yes	Yes	N
9	7	Vibha agrawal	Female	No	No	No	Yes	No	Yes	Yes	No	N
10	8	Vipul Shah	Male	Yes	No	No	Yes	Yes	No	Yes	Yes	N
11	9	Jeeya Gupta	Female	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N
12	10	Anil	Male	No	No	No	No	No	No	Yes	No	N
13	11	Ramsharan Yadav	Male	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Y
14	12	Anjali Sharma	Female	No	No	No	Yes	Yes	No	Yes	No	Y
15	13	Sagar sharma	Male	No	No	No	No	No	No	No	No	N
16	14	Preeti Gupta	Female	No	No	No	Yes	Yes	No	Yes	Yes	N
17	15	Manav Jain	Male	Yes	Yes	Yes	Yes	No	No	Yes	Yes	N
18	16	Dhavesh Kaushik	Male	No	No	No	Yes	No	No	Yes	Yes	N
19	17	Arjun Sharma	Male	Yes	No	No	Yes	Yes	No	Yes	No	N
20	18	Seeva Bhardwaj	Female	No	No	No	Yes	Yes	No	Yes	Yes	N
21	19	Mansi Singh	Female	Yes	No	Yes	Yes	No	No	Yes	Yes	N
22	20	Harsh Adhyaru	Female	No	Yes	Yes	No	Yes	No	No	No	N
23	21	Kirti Mehta	Male	No	No	No	Yes	Yes	No	Yes	Yes	Y
24	22	Ritika Goel	Female	No	No	No	Yes	Yes	No	Yes	No	N
25	23	Naman Saxena	Male	No	No	No	Yes	Yes	No	Yes	Yes	Y
26	24	Lalita Chaturvedi	Female	Yes	Yes	Yes	Yes	No	No	Yes	Yes	N

1	Breathlessness	Nausea	Body ache	Sore throat	Heart disease	Chronic lung disease	Chronic liver disease	Diabetes	Covid19 Positive	If covid19 positive, w	Vaccinated
78	No	No	No	No	No	No	No	No	No	No	Not Vaccinated
79	No	No	No	No	Yes	No	No	No	No	Yes	Fully Vaccinated (both d
80	No	No	No	No	No	No	No	No	No	No	Not Vaccinated
81	No	No	No	No	No	No	No	No	No	No	Not Vaccinated
82	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not Vaccinated
83	No	Yes	Yes	No	No	No	No	No	No	No	Fully Vaccinated (both d
84	No	Yes	Yes	No	No	No	No	No	No	No	Fully Vaccinated (both d
85	No	Yes	Yes	Yes	No	No	No	No	No	No	Fully Vaccinated (both d
86	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Only 1st Dose
87	No	No	Yes	Yes	No	No	No	No	No	No	Fully Vaccinated (both d
88	No	Yes	Yes	No	No	No	No	No	No	No	Fully Vaccinated (both d
89	No	No	Yes	Yes	No	No	No	No	No	No	Fully Vaccinated (both d
90	No	Yes	Yes	No	No	No	No	No	No	No	Only 1st Dose
91	Yes	No	No	Yes	No	No	Yes	No	Yes	Yes	Not Vaccinated
92	No	Yes	No	No	No	No	No	Yes	No	No	Fully Vaccinated (both d
93	No	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Not Vaccinated
94	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Fully Vaccinated (both d
95	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Only 1st Dose
96	Yes	No	Yes	No	No	No	No	No	No	No	Only 1st Dose
97	No	No	No	No	No	No	No	No	No	No	Fully Vaccinated (both d
98	No	Yes	No	No	No	No	No	No	No	No	Fully Vaccinated (both d
99	No	No	Yes	No	No	No	No	No	Yes	Yes	Fully Vaccinated (both d
100	No	No	Yes	Yes	No	No	No	No	No	No	Fully Vaccinated (both d
101	Yes	Yes	Yes	No	No	No	No	Yes	No	No	Only 1st Dose
102	No	No	Yes	Yes	No	No	No	No	Yes	Yes	Only 1st Dose

Step1 Took a sample of 20 patients and divided the above data into three criteria and gave weightage to every criteria:

First is ***Vaccination*** which is **Non Beneficiary** for a person to be covid19 positive and the weightage of vaccination is 25%.

Second is Symptoms which is **Beneficiary** for a person to be covid19 positive and the weightage of Symptoms is 50%.

Third is Co morbidities which is **Beneficiary** for a person to be covid19 positive and the weightage of Co morbidities is 25%.

	B	C	D	E	F	G
1			Non-Benf.	Benf.	Benf.	
2						
3		Weightage	0.25	0.5	0.25	
4	**S.No.**	**Name**	**Vaccination**	**Symptoms**	**Comorbidities**	
5						
6	1	**Diksha Bhardwaj**	2	5	0	
7	2	**Ritka Goel**	2	1	0	
8	3	**Rakesh Kumar**	1	6	1	
9	4	**Rahul**	2	1	0	
10	5	**Naresh Kumar**	2	3	1	
11	6	**Jayesh Mehta**	2	5	0	
12	7	**Vibha agrawal**	2	3	0	
13	8	**Vipul Shah**	2	5	2	
14	9	**Jeeya Gupta**	2	7	2	
15	10	**Anil**	2	1	1	
16	11	**Ramsharan Yadav**	2	7	1	
17	12	**Anjali Sharma**	1	3	2	
18	13	**Sagar sharma**	2	0	0	
19	14	**Preeti Gupta**	1	4	2	
20	15	**Manav Jain**	2	6	2	
21	16	**Bhavesh Kaushik**	2	3	1	
22	17	**Arjun Sharma**	2	4	0	
23	18	**Seeya Bhardwaj**	1	4	2	
24	19	**Mansi Singh**	2	5	1	
25	20	**Harsh Adhyaru**	2	3	1	
26						
27						

Step2 Normalized evaluation matrix by applying the given formula

$$\phi_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M}(a_{ij})^2}}$$

	S.No.	Name	Vaccination	Symptoms	Comorbidities
29	S.No.	Name	Vaccination	Symptoms	Comorbidities
30					
31	1	Diksha Bhardwaj	0.25	0.2707652	0
32	2	Ritka Goel	0.25	0.054153	0
33	3	Rakesh Kumar	0.125	0.3249182	0.179605302
34	4	Rahul	0.25	0.054153	0
35	5	Naresh Kumar	0.25	0.1624591	0.179605302
36	6	Jayesh Mehta	0.25	0.2707652	0
37	7	Vibha agrawal	0.25	0.1624591	0
38	8	Vipul Shah	0.25	0.2707652	0.359210604
39	9	Jeeya Gupta	0.25	0.3790713	0.359210604
40	10	Anil	0.25	0.054153	0.179605302
41	11	Ramsharan Yadav	0.25	0.3790713	0.179605302
42	12	Anjali Sharma	0.125	0.1624591	0.359210604
43	13	Sagar sharma	0.25	0	0
44	14	Preeti Gupta	0.125	0.2166121	0.359210604
45	15	Manav Jain	0.25	0.3249182	0.359210604
46	16	Bhavesh Kaushik	0.25	0.1624591	0.179605302
47	17	Arjun Sharma	0.25	0.2166121	0
48	18	Seeya Bhardwaj	0.125	0.2166121	0.359210604
49	19	Mansi Singh	0.25	0.2707652	0.179605302
50	20	Harsh Adhyaru	0.25	0.1624591	0.179605302

Step 3 Calculated the weighted normalized matrix by using the formula:

$X_{ij} = \phi_{ij} * W_j$

	S.No.	Name	Vaccination	Symptoms	Comorbidities
54	S.No.	Name	Vaccination	Symptoms	Comorbidities
55					
56	1	Diksha Bhardwaj	0.0625	0.1353826	0
57	2	Ritka Goel	0.0625	0.0270765	0
58	3	Rakesh Kumar	0.03125	0.1624591	0.044901326
59	4	Rahul	0.0625	0.0270765	0
60	5	Naresh Kumar	0.0625	0.0812296	0.044901326
61	6	Jayesh Mehta	0.0625	0.1353826	0
62	7	Vibha agrawal	0.0625	0.0812296	0
63	8	Vipul Shah	0.0625	0.1353826	0.089802651
64	9	Jeeya Gupta	0.0625	0.1895356	0.089802651
65	10	Anil	0.0625	0.0270765	0.044901326
66	11	Ramsharan Yadav	0.0625	0.1895356	0.044901326
67	12	Anjali Sharma	0.03125	0.0812296	0.089802651
68	13	Sagar sharma	0.0625	0	0
69	14	Preeti Gupta	0.03125	0.1083061	0.089802651
70	15	Manav Jain	0.0625	0.1624591	0.089802651
71	16	Bhavesh Kaushik	0.0625	0.0812296	0.044901326
72	17	Arjun Sharma	0.0625	0.1083061	0
73	18	Seeya Bhardwaj	0.03125	0.1083061	0.089802651
74	19	Mansi Singh	0.0625	0.1353826	0.044901326
75	20	Harsh Adhyaru	0.0625	0.0812296	0.044901326

Step4 Determined the best and the worst alternative for each criterion using the formulas:

$$X_j^b = max_{i=1}^{M} X_{ij}$$

$$X_j^w = min_{i=1}^{M} X_{ij}$$

NOTE – The formulas are reversed in the case of Non-Beneficiary criteria.

78		Vaccination	Symptoms	Comorbidities
79	V+(Ideal Best)	0.03125	0.18953563	0.089802651
80	V-(ideal Worst)	0.0625	0	0

Step5 Calculated the Euclidean distance between the target alternative and the best/worst alternative using the formulas:

$$d_i^b = \sqrt{\sum_{j=1}^{N}(x_{ij} - x_j^b)^2}$$

$$d_i^w = \sqrt{\sum_{j=1}^{N}(x_{ij} - x_j^w)^2}$$

54	S.No.	Name	Vaccination	Symptoms	Comorbidities	d_i^b	d_i^w
55							
56	1	Diksha Bhardwaj	0.0625	0.13538259	0	0.109424	0.135383
57	2	Ritka Goel	0.0625	0.027076518	0	0.188239	0.027077
58	3	Rakesh Kumar	0.03125	0.162459108	0.044901326	0.052433	0.171422
59	4	Rahul	0.0625	0.027076518	0	0.188239	0.027077
60	5	Naresh Kumar	0.0625	0.081229554	0.044901326	0.121338	0.092814
61	6	Jayesh Mehta	0.0625	0.13538259	0	0.109424	0.135383
62	7	Vibha agrawal	0.0625	0.081229554	0	0.144122	0.08123
63	8	Vipul Shah	0.0625	0.13538259	0.089802651	0.062523	0.162459
64	9	Jeeya Gupta	0.0625	0.189535626	0.089802651	0.03125	0.209734
65	10	Anil	0.0625	0.027076518	0.044901326	0.171422	0.052433
66	11	Ramsharan Yadav	0.0625	0.189535626	0.044901326	0.054705	0.194782
67	12	Anjali Sharma	0.03125	0.081229554	0.089802651	0.108306	0.125057
68	13	Sagar sharma	0.0625	0	0	0.212049	0
69	14	Preeti Gupta	0.03125	0.108306072	0.089802651	0.08123	0.144122
70	15	Manav Jain	0.0625	0.162459108	0.089802651	0.041349	0.185627
71	16	Bhavesh Kaushik	0.0625	0.081229554	0.044901326	0.121338	0.092814
72	17	Arjun Sharma	0.0625	0.108306072	0	0.125057	0.108306
73	18	Seeya Bhardwaj	0.03125	0.108306072	0.089802651	0.08123	0.144122
74	19	Mansi Singh	0.0625	0.13538259	0.044901326	0.076976	0.142634
75	20	Harsh Adhyaru	0.0625	0.081229554	0.044901326	0.121338	0.092814

Step6 For each alternative calculated the similarity to the worst alternative. The results are our TOPSIS scores.

$$P_i = \frac{d_i^w}{d_i^w + d_i^b}$$

	S.No.	Name	Vaccination	Symptoms	Comorbidities	d_i^b	d_i^w	Pi
54								
55								
56	1	Diksha Bhardwaj	0.0625	0.13538259	0	0.109424	0.135383	0.553018382
57	2	Ritka Goel	0.0625	0.027076518	0	0.188239	0.027077	0.125752563
58	3	Rakesh Kumar	0.03125	0.162459108	0.044901326	0.052433	0.171422	0.765771403
59	4	Rahul	0.0625	0.027076518	0	0.188239	0.027077	0.125752563
60	5	Naresh Kumar	0.0625	0.081229554	0.044901326	0.121338	0.092814	0.43340157
61	6	Jayesh Mehta	0.0625	0.13538259	0	0.109424	0.135383	0.553018382
62	7	Vibha agrawal	0.0625	0.081229554	0	0.144122	0.08123	0.360456302
63	8	Vipul Shah	0.0625	0.13538259	0.089802651	0.062523	0.162459	0.722098202
64	9	Jeeya Gupta	0.0625	0.189535626	0.089802651	0.03125	0.209734	0.870323237
65	10	Anil	0.0625	0.027076518	0.044901326	0.171422	0.052433	0.234228597
66	11	Ramsharan Yadav	0.0625	0.189535626	0.044901326	0.054705	0.194782	0.780728172
67	12	Anjali Sharma	0.03125	0.081229554	0.089802651	0.108306	0.125057	0.535890795
68	13	Sagar sharma	0.0625	0	0	0.212049	0	0
69	14	Preeti Gupta	0.03125	0.108306072	0.089802651	0.08123	0.144122	0.639543698
70	15	Manav Jain	0.0625	0.162459108	0.089802651	0.041349	0.185627	0.817828479
71	16	Bhavesh Kaushik	0.0625	0.081229554	0.044901326	0.121338	0.092814	0.43340157
72	17	Arjun Sharma	0.0625	0.108306072	0	0.125057	0.108306	0.464109205
73	18	Seeya Bhardwaj	0.03125	0.108306072	0.089802651	0.08123	0.144122	0.639543698
74	19	Mansi Singh	0.0625	0.13538259	0.044901326	0.076976	0.142634	0.649489568
75	20	Harsh Adhyaru	0.0625	0.081229554	0.044901326	0.121338	0.092814	0.43340157

Step7 Ranked alternatives according to the TOPSIS score by descending order.

	S.No.	Name	Vaccination	Symptoms	Comorbidities	d_i^b	d_i^w	Pi	Rank
54									
55									
56	1	Diksha Bhardwaj	0.0625	0.13538259	0	0.109424	0.135383	0.553018382	9
57	2	Ritka Goel	0.0625	0.027076518	0	0.188239	0.027077	0.125752563	18
58	3	Rakesh Kumar	0.03125	0.162459108	0.044901326	0.052433	0.171422	0.765771403	4
59	4	Rahul	0.0625	0.027076518	0	0.188239	0.027077	0.125752563	18
60	5	Naresh Kumar	0.0625	0.081229554	0.044901326	0.121338	0.092814	0.43340157	13
61	6	Jayesh Mehta	0.0625	0.13538259	0	0.109424	0.135383	0.553018382	9
62	7	Vibha agrawal	0.0625	0.081229554	0	0.144122	0.08123	0.360456302	16
63	8	Vipul Shah	0.0625	0.13538259	0.089802651	0.062523	0.162459	0.722098202	5
64	9	Jeeya Gupta	0.0625	0.189535626	0.089802651	0.03125	0.209734	0.870323237	1
65	10	Anil	0.0625	0.027076518	0.044901326	0.171422	0.052433	0.234228597	17
66	11	Ramsharan Yadav	0.0625	0.189535626	0.044901326	0.054705	0.194782	0.780728172	3
67	12	Anjali Sharma	0.03125	0.081229554	0.089802651	0.108306	0.125057	0.535890795	11
68	13	Sagar sharma	0.0625	0	0	0.212049	0	0	20
69	14	Preeti Gupta	0.03125	0.108306072	0.089802651	0.08123	0.144122	0.639543698	7
70	15	Manav Jain	0.0625	0.162459108	0.089802651	0.041349	0.185627	0.817828479	2
71	16	Bhavesh Kaushik	0.0625	0.081229554	0.044901326	0.121338	0.092814	0.43340157	13
72	17	Arjun Sharma	0.0625	0.108306072	0	0.125057	0.108306	0.464109205	12
73	18	Seeya Bhardwaj	0.03125	0.108306072	0.089802651	0.08123	0.144122	0.639543698	7
74	19	Mansi Singh	0.0625	0.13538259	0.044901326	0.076976	0.142634	0.649489568	6
75	20	Harsh Adhyaru	0.0625	0.081229554	0.044901326	0.121338	0.092814	0.43340157	13

Findings of the study

So according to the ranking we can see that *Jeeya Gupta* is **most** likely to have Covid19 Positive and *Sagar Sharma* is **least** likely to have Covid19 Positive.

Conclusion

There are a variety of decision-making methods to help you choose in case of multiple conditioning problems. One of them is the TOPSIS method, where the level of alternatives is based on similarities related to the appropriate solution, which avoids the tendency to have the same indicator of similarity in both positive and negative solutions. The TOPSIS method is an effective and useful method of measuring and selecting alternatives. In this paper we focus mainly on the concept of TOPSIS algorithm for fast and temporary data. The extension of the TOPSIS approach to the group decision area was also investigated. The high flexibility of the TOPSIS concept is able to carry additional extensions to make the best choice in a variety of situations. In fact, TOPSIS and its transformation are used to solve many theoretical and real-world problems. Additionally, preferences for more than one decision maker can be combined with the TOPSIS process. The classic TOPSIS has been expanded to meet the needs of different real-world decision-making problems that provide support for intermediate or ambiguous conditions, intermediate or ambiguous weights for model accuracy, uncertainty, lack of information or ambiguity, such as TOPSIS with intermittent data, Fuzzy TOPS -Fuzzy AHP with TOPSIS and TOPSIS team. In the TOPSIS model based on the concept of incomprehensible sets the scale of each method is expressed by vague triangular or trapezoidal numbers, the weight of each condition is represented by dim or clear values, and different variables (e.g., Euclidean, lines or others) are used *. Common unambiguous numbers can be calculated using the concept α-cuts [Jahanshaholoo, Lofti, Izadikhah, 2006b].

The TOPSIS model based on the intangible set of intuitionistic (IFS) also allows to measure the level of satisfaction and the level of dissatisfaction, respectively, in some variables analyzed throughout the set of conditions [Hung, Chen, 2009; Saghafian, Hejazi, 2005]. The TOPSIS hierarchical approach is being developed to benefit both the height of the AHP structure and the ease of use of the TOPSIS method [Kahraman, Buyukozkan, Ates 2007; Chiang, Cheng, 2009]. In the Polish literature, among many applications, the TOPSIS method (measuring items) and the sequence analysis method (weight measure) were used to assess the economic development of the rural Wielkopolska recognized as a regional group [Łuczak, Wysocki, 2006], the TOPSIS method indistinguishable α level sets were used to assess the quality of life of the people in selected districts of Wielkopolska Province [Łuczak, Wysocki, 2008], TOPSIS methods of quick data and breaks were used for the order offered to the merchant transaction [Roszkowska 2009].

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