Soft Computing Inspired by Prospect Theory: the TODIM method

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Some fundamental concepts:

- Soft computing is also known as computational intelligence. It makes use of inexact solutions to computationally hard tasks, by exploiting imprecision, uncertainty and incompleteness in order to reach robust, tractable and low cost solutions to ill-structured problems. The role model for soft computing is indeed the human mind. The field of Soft Computing encompasses areas such as Fuzzy and Rough Logics, Neural Networks, Evolutionary Algorithms and Genetic Programming, Machine Learning, Sentiment Analysis and Probabilistic Reasoning.
- Prospect Theory is a behavioral economic theory that attempts to describe how people select between probabilistic alternatives that involve risk, where the probabilities of outcomes are unknown. The theory states that people make decisions based on their expectation of losses and gains rather than the final outcome. Prospect Theory explains the heuristics that people follow in order to evaluate these losses and gains. The theory was first published in 1979 by Daniel Kahneman and Amos Tversky and further developed in 1992 by and Tversky and Kahneman as a psychologically more accurate description of decision making, as compared against the normative perspective of expected utility theory. The paper “Prospect Theory: An Analysis of Decision under Risk” (1979) is considered a landmark in Behavioral Economics.

MCDM/MCDA as part of Soft Computing:

Multi-Criteria Decision Analysis (MCDA) - or Multiple Criteria Decision Making (MCDM), which is practically the same – also relies on how the way human mind functions when trying to solve the following categories of multiple criteria problems: Selection, Ranking, Classification/Sorting and Description

Considering that large and heterogeneous data bases, imprecision, incompleteness of information, group behaviour as well as other complications are oftenly present when trying to solve the above problems, it is fair to say MCDA/MCDM tools fit well into to the realm of Soft Computing

Now speaking about the TODIM method:

- Today (October, 2018) a number of papers and a couple of book chapters making use of TODIM, its extensions, or combinations with other MCDA/MCDM methods have been published in international journals
- The TODIM method of MCDA/MCDM, like most O.R. methods, is founded on previous work done by some very important forefront researchers – those people were Herbert Simon (1916-2001), Thomas Saaty (1926-2017), Ward Edwards (1927-2005), Bernard Roy (1934-2017), Daniel Kahneman (1934-), Amos Tversky (1937-1996) and Ralph Keeney (1944-)

Behavioral and Multi-Criteria Decision Aiding:

- Decision aiders can do a much better job if their models are based on a solid behavioral foundation
- Behavioral decision theory is considered to have formally begun with Ward Edwards through his 1954 Psychological Bulletin article
- Behavioral decision theory has been established as "The approach of reflecting on axiomatic frameworks in the domain of descriptive theories (…) geared towards our goal of decision support" (Eisenführ, Weber, and Langer , 2010 or EWL)
- Cumulative Prospect Theory by Tversky and Kahneman is "currently the most prominent descriptive decision theory under uncertainty" (EWL)
- Again, according to EWL, "the original Prospect Theory (OPT) from 1979 is only of historical importance today. However, to prevent possible misunderstandings, the cumulative version of Prospect Theory is commonly referred to as CPT"
- OPT was developed by Daniel Kahneman and Amos Tversky and first published in 1979. The term prospect referred to a lottery in the original formulation of that theory. A prospect $(x_1, p_1; \ldots; x_n, p_n)$ is a contract that yields outcome x_i with probability p_i, where $p_1 + \ldots + p_n = 1$.

Two seminal articles:

ECONOMETRICA

VOLUME 47 MARCH, 1979 NUMBER 2

PROSPECT THEORY: AN ANALYSIS OF DECISION UNDER RISK

BY DANIEL KAHNEMAN AND AMOS TVERSKY[1]

This paper presents a critique of expected utility theory as a descriptive model of decision making under risk, and develops an alternative model, called prospect theory. Choices among risky prospects exhibit several pervasive effects that are inconsistent with the basic tenets of utility theory. In particular, people underweight outcomes that are merely probable in comparison with outcomes that are obtained with certainty. This tendency, called the certainty effect, contributes to risk aversion in choices involving sure gains and to risk seeking in choices involving sure losses. In addition, people generally discard components that are shared by all prospects under consideration. This tendency, called the isolation effect, leads to inconsistent preferences when the same choice is presented in different forms. An alternative theory of choice is developed, in which value is assigned to gains and losses rather than to final assets and in which probabilities are replaced by decision weights. The value function is normally concave for gains, commonly convex for losses, and is generally steeper for losses than for gains. Decision weights are generally lower than the corresponding probabilities, except in the range of low probabilities. Overweighting of low probabilities may contribute to the attractiveness of both insurance and gambling.

1. INTRODUCTION

EXPECTED UTILITY THEORY has dominated the analysis of decision making under risk. It has been generally accepted as a normative model of rational choice [**24**], and widely applied as a descriptive model of economic behavior, e.g. [**15, 4**]. Thus, it is assumed that all reasonable people would wish to obey the axioms of the theory [**47, 36**], and that most people actually do, most of the time.

The present paper describes several classes of choice problems in which preferences systematically violate the axioms of expected utility theory. In the light of these observations we argue that utility theory, as it is commonly interpreted and applied, is not an adequate descriptive model and we propose an alternative account of choice under risk.

2. CRITIQUE

Decision making under risk can be viewed as a choice between prospects or gambles. A prospect $(x_1, p_1; \ldots; x_n, p_n)$ is a contract that yields outcome x_i with probability p_i, where $p_1+p_2+\ldots+p_n=1$. To simplify notation, we omit null outcomes and use (x, p) to denote the prospect $(x, p; 0, 1-p)$ that yields x with probability p and 0 with probability $1-p$. The (riskless) prospect that yields x with certainty is denoted by (x). The present discussion is restricted to prospects with so-called objective or standard probabilities.

The application of expected utility theory to choices between prospects is based on the following three tenets.

(i) Expectation: $U(x_1, p_1; \ldots; x_n, p_n) = p_1u(x_1)+\ldots+p_nu(x_n)$.

[1] This work was supported in part by grants from the Harry F. Guggenheim Foundation and from the Advanced Research Projects Agency of the Department of Defense and was monitored by Office of Naval Research under Contract N00014-78-C-0100 (ARPA Order No. 3469) under Subcontract 78-072-0722 from Decisions and Designs, Inc. to Perceptronics, Inc. We also thank the Center for Advanced Study in the Behavioral Sciences at Stanford for its support.

Journal of Risk and Uncertainty, 5:297–323 (1992)

Advances in Prospect Theory: Cumulative Representation of Uncertainty

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Key words: cumulative prospect theory

Abstract

We develop a new version of prospect theory that employs cumulative rather than separable decision weights and extends the theory in several respects. This version, called cumulative prospect theory, applies to uncertain as well as to risky prospects with any number of outcomes, and it allows different weighting functions for gains and for losses. Two principles, diminishing sensitivity and loss aversion, are invoked to explain the characteristic curvature of the value function and the weighting functions. A review of the experimental evidence and the results of a new experiment confirm a distinctive fourfold pattern of risk attitudes: risk aversion for gains and risk seeking for losses of high probability; risk seeking for gains and risk aversion for losses of low probability.

Expected utility theory reigned for several decades as the dominant normative and descriptive model of decision making under uncertainty, but it has come under serious question in recent years. There is now general agreement that the theory does not provide an adequate description of individual choice: a substantial body of evidence shows that decision makers systematically violate its basic tenets. Many alternative models have been proposed in response to this empirical challenge (for reviews, see Camerer, 1989; Fishburn, 1988; Machina, 1987). Some time ago we presented a model of choice, called prospect theory, which explained the major violations of expected utility theory in choices between risky prospects with a small number of outcomes (Kahneman and Tversky, 1979; Tversky and Kahneman, 1986). The key elements of this theory are 1) a value function that is concave for gains, convex for losses, and steeper for losses than for gains,

*An earlier version of this article was entitled "Cumulative Prospect Theory: An Analysis of Decision under Uncertainty."

This article has benefited from discussions with Colin Camerer, Chew Soo-Hong, David Freedman, and David H. Krantz. We are especially grateful to Peter P. Wakker for his invaluable input and contribution to the axiomatic analysis. We are indebted to Richard Gonzalez and Amy Hayes for running the experiment and analyzing the data. This work was supported by Grants 89-0064 and 88-0206 from the Air Force Office of Scientific Research, by Grant SES-9109535 from the National Science Foundation, and by the Sloan Foundation.

OPT and CPT:

With Prospect Theory Kahneman and Tversky aimed to describe how people choose between probabilistic alternatives and evaluate potential losses and gains defined with respect to a reference point or *status quo*. Consequently two domains are identified, the domains of gains and the domain of losses. A number of experiments have allowed researchers to conclude that humans tend to show risk-averse behavior in the domain of gains and a risk-seeking behavior in the domain of losses.

The difference between CPT and OPT is that weighting is applied to the cumulative probability distribution function, as in rank-dependent Expected Utility Theory, instead of being applied to the probabilities of individual outcomes. CPT is therefore a further development of prospect theory. CPT overcomes some clear limitations that OPT had and, due to its success as a descriptive theory of how people decide when facing risk, it is considered as having more accuracy than Expected Utility Theory as a psychological theory of preferences under risk.

The role of Prospect Theory in decision aiding:

The decision aider aim's is prescriptive – to help determine what a decision maker could do under a given scenario

However, in order to be effective, the aider needs a comprehensive, descriptive understanding of the decision maker mental processes and capabilities

This leads us to understanding the difference between the two key decision paradigms: *Expected Utility Theory* (von Neumann & Morgenstern, 40's) and *Prospect Theory* (Kahneman & Tversky, 70's)

While the Expected Utility Theory paradigm is a normative view of decision making, the Prospect Theory paradigm allows describing how people make decisions under risk

On Risk:

The simplest notion of risk is that of a relationship between the chance of occurrence of an undesirable event and the seriousness of the consequences from such an event, it it really occurs

- In fields such as Accounting, Business Management, Engineering, Finance, International Politics and Policy-Making risk has a considerable importance and it has been studied in the domains of Risk Management (Finance) and Risk Analysis (Operations Management), just to name a few
- The history of risk is highly intermixed with the history of Probability Theory

Human decisions are always made under some risk level (i.e., nobody has a crystal ball and one may always run into the possibility of being far from satisfying a given objective)

When one is trying to help people that are to make complex decisions, their risk behaviour cannot be ignored

As human decisions always occur under some uncertainty, it is only natural that decision aiding explicitly takes risk into account

What is the first thing that comes to our mind when we talk about risk?

Classical (von Neumann) Utility Function

Expected Utility and Prospect Theory:

The Expected Utility Hypothesis (or Expected Utility Theory) is a paradigm represented by the curve on the previous slide - the von Neumann-Morgenstern theorem (1944) provides its modern mathematical foundation

However, when people make decisions under risk, they show a pattern of preferences that many times is not described by the Expected Utility Hypothesis

Prospect Theory may provide a broader, descriptive model for understanding how humans make decisions under risk

In essence, normally people tend to be risk-averse in the domain of gains and risk-prone in the domain of losses

Through many examples, it is not difficult to see that when problems are framed in terms of gains people react differently from when they are framed in terms of losses

An example – A city in the hinterland of South America is preparing to fight a rare and highly lethal virus (Problem 1)

- 600,000 fatal cases are expected
- Program A $\Rightarrow$ 200,000 people are saved
- Program B $\Rightarrow$ there is chance of 1 to 3 of saving 600,000 people and a chance of 2 to 3 that nobody will be saved
- Which Program would you implement, A or B?

Typical answers that we get from respondents:

- 72 % prefer Program A
- 28 % prefer Program B
- Conclusion: The majority choice (72 %) shows an aversion to risk

Another formulation of the same example (Problem 2)

- Program C $\Rightarrow$ 400,000 people die
- Program D $\Rightarrow$ there is a chance of 1 to 3 that noboby will die and a chance of 2 to 3 that 600,000 people will die
- Which Program would you implement, C or D?

Again, typical answers that we get from respondents:

- 22 % prefer Program C
- 78 % prefer Program D
- Conclusion: The majority choice (78 %) shows a risk proneness

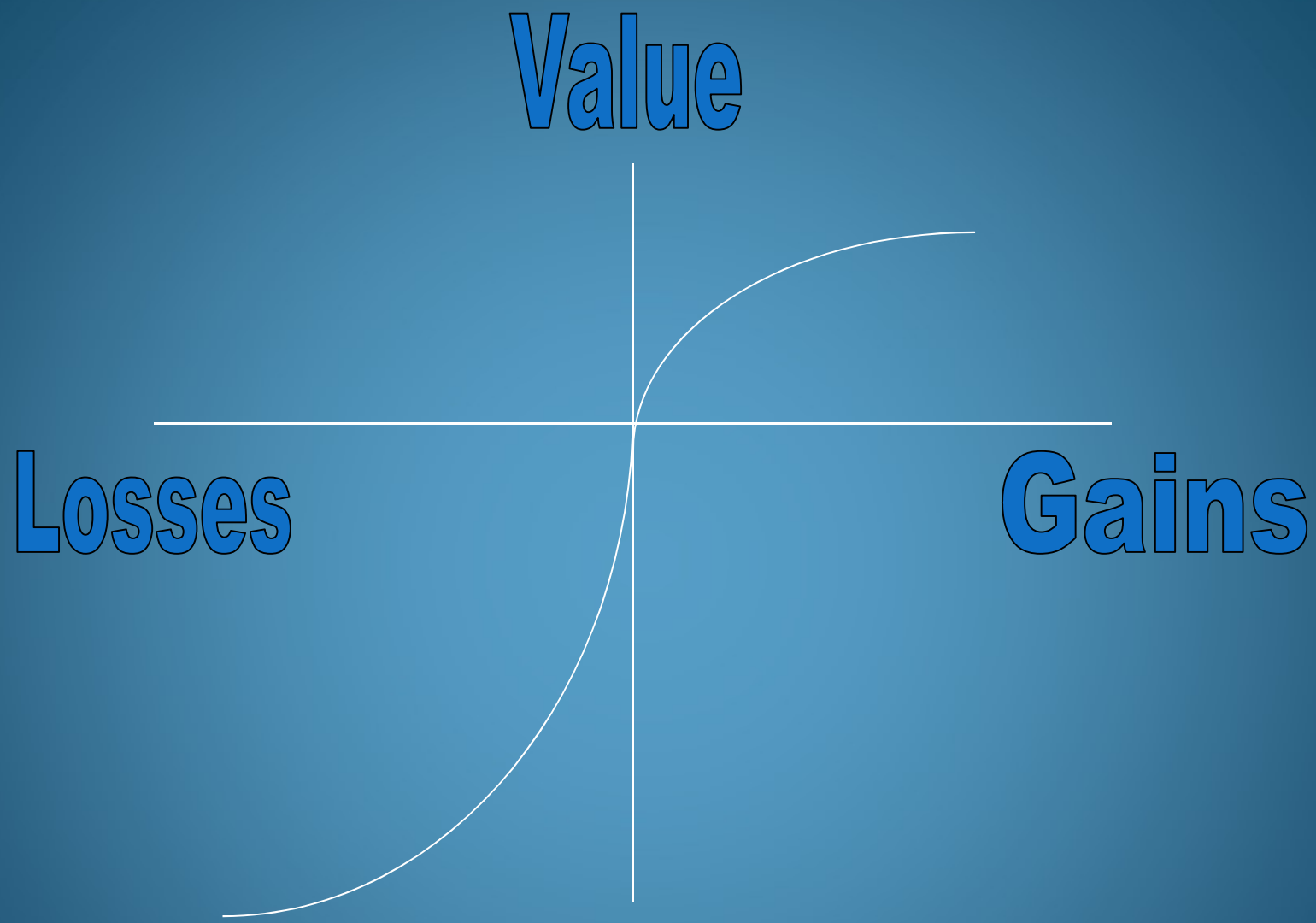
Overall conclusions:

When decision problems are formulated in terms of gains, choices are usually risk-averse. When problems are framed in terms of losses, choices tend to be risk-prone. Neverthless, Problems 1 e 2 are mathematically the same

This suggests that when people have to make decisions under risk, they show a pattern of preferences that may not be explained by Expected Utility Theory

Prospect Theory tends to provide a broader, descriptive model for understanding how humans make decisions under risk

In essence, people tend to be risk-averse in the domain of gains and risk-prone in the domain of losses



A Prospect Theoretical Value Function

Consequences to MCDM/MCDA:

How can we make use of the Prospect Theory paradigm for improving decision aiding?

Models of decision aiding that are based on the Prospect Theory paradigm would tend to have a better prospective capability – this is the case of the TODIM method (1991) and other posterior work

I.e., Prospect Theory-based, MCDA/MCDM models (e.g., TODIM and its extensions as well as some posterior work, e.g. Lerche, 2016) are in principle preferable over other types of decision aiding models. Why is that so? Simply because one cannot ignore risk behaviour when making complex decisions

Previous attempts to use Prospect Theory in MCDM/MCDA:

- Korhonen, Moskowitz and Wallenius (1990) investigated choice behavior in interactive multi-criteria decision making. The validation of Prospect Theory made by Korhonen, Moskowitz and Wallenius used a linear approximation to prospect theory. Korhonen, Moskowitz and Wallenius have shown that Tversky's additive difference model can indeed be regarded as a generalization of prospect theory to the multi-criteria context.
- Salminen and Wallenius (1993) tested linear prospect theory in a deterministic multi-criteria decision-making environment. These two authors then concluded that Prospect Theory was a reasonable model of choice for many individuals within the framework of their research.
- Salminen (1991, 1992, 1994) proposed an interactive method for solving discrete deterministic multi-criteria decision problems and assumed linear prospect theoretical value functions for the decision makers. He approximated the S-shaped value functions of prospect theory by piecewise linear marginal value functions. Salminen's proposed procedure was therefore valid only for convex preferences. This author pointed out that the major problem in putting OPT in practice was how to find an individual reference alternative. He then proposed as alternative possibilities the current option, the use of aspiration levels and the ideal point, but concluded that there was no unique solution to that problem.

The original Prospect Theory-based TODIM method:

- The TODIM (an acronym in Portuguese for *Interactive and Multicriteria Decision Making*) method is a discrete multicriteria method inspired by Prospect Theory
- The multiattribute value function of TODIM is built in parts, with their mathematical descriptions reproducing the gain/loss function of Prospect Theory. The global multiattribute value function of TODIM aggregates all measures of gains and losses over all criteria; that function is based on Tversky's idea of an additive difference function
- Being inspired by Prospect Theory , in principle TODIM can either use a *status quo*, a reference alternative or the concept of a floating reference alternative
- Getting the weights of criteria (Swing Weighting, AHP, Ratings, etc.)
- Valuation of the alternatives with respect to each criterion, with normalization by dividing each weight by largest weight for each criterion
- Computing a matrix of relative dominance
- Calculation of the measurements of the overall desirability of each alternative
- Sensitivity analysis
- An Excel®-based spreadsheet (or MATLAB®, for example) for calculations and eventually for producing graphs

MCDM/MCDA characteristics of the original TODIM method:

- It is a noncompensatory method (i.e., advantages of one attribute/criterion cannot be traded off against disadvantages of another; each attribute/criterion must stand on its own)
- Noncomparability between attributes/criteria is not generally allowed
- The aggregation procedure consists of using a multidimensional value (measured by relative dominance) function
- Alternatives are compared in pairs, transitivity is preserved
- Rank reversal is minimized due to the normalization procedure embedded in the method
- Weights of attributes/criteria are produced from usual weight elicitation techniques (e.g., point allocation, direct rating, SMART, Swing Weighting, AHP, etc)
- An early comment on TODIM: *An original method based on the French and the North-American schools. It combines aspects from Multiattribute Utility Theory, the AHP and ELECTRE methods*. (In the original: *Utilisation d'une méthode originale à cheval sur l'école française et américaine. Elle combine des aspects provenant de la théorie de l'utilité multiattribut, de la méthode AHP et des méthodes ELECTRE* (Roy and Bouyssou, *Aide Multicritère à la Décision: Methods et Cas.* Paris: Economica, 1993, p. 638)

Formulas of TODIM:

Measure of relative dominance of each alternative i over another alternative j:

$$\delta(A_i, A_j) = \sum_{c=1}^{m} \Phi_c(A_i, A_j), \qquad \forall (A_i, A_j)$$

Variables and parameters of TODIM:

$\delta(A_i,A_j)$ – dominance measurement of an alternative A_i in relation to another alternative A_j

$\Phi_c(A_i,A_j)$ – measure of value of alternative A_i as compared against alternative A_j according to criterion c

a_{rc} – substitution rate for criterion c as compared against criterion r

w_{ic} and w_{jc} – valuations of alternatives A_i and A_j according to criterion c

θ – attenuation factor, applicable to the segment of the value function in the negative quadrant

ξ_i – overall desirability of each i-th alternative

Gain, no gain & no loss, and loss parts of the value function:

$$\Phi_c(A_i, A_j) = \begin{cases} \sqrt{\dfrac{a_{rc}(w_{ic} - w_{jc})}{\sum_c a_{rc}}} & \text{if} \quad w_{ic} - w_{jc} > 0 \\ 0 & \text{if} \quad w_{ic} - w_{jc} = 0 \\ -\dfrac{1}{\theta}\sqrt{\dfrac{(\sum_c a_{rc})(w_{jc} - w_{ic})}{a_{rc}}} & \text{if} \quad w_{ic} - w_{jc} < 0 \end{cases}$$

The expressions above can be simplified

Desirability of each alternative:

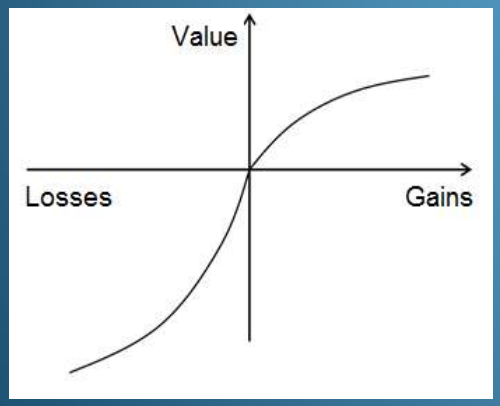
$$\xi_i = \frac{\sum_{j=1}^{n} \delta(A_i, A_j) - \min \sum_{j=1}^{n} \delta(A_i, A_j).}{\max \sum_{j=1}^{n} \delta(A_i, A_j) - \min \sum_{j=1}^{n} \delta(A_i, A_j)}$$

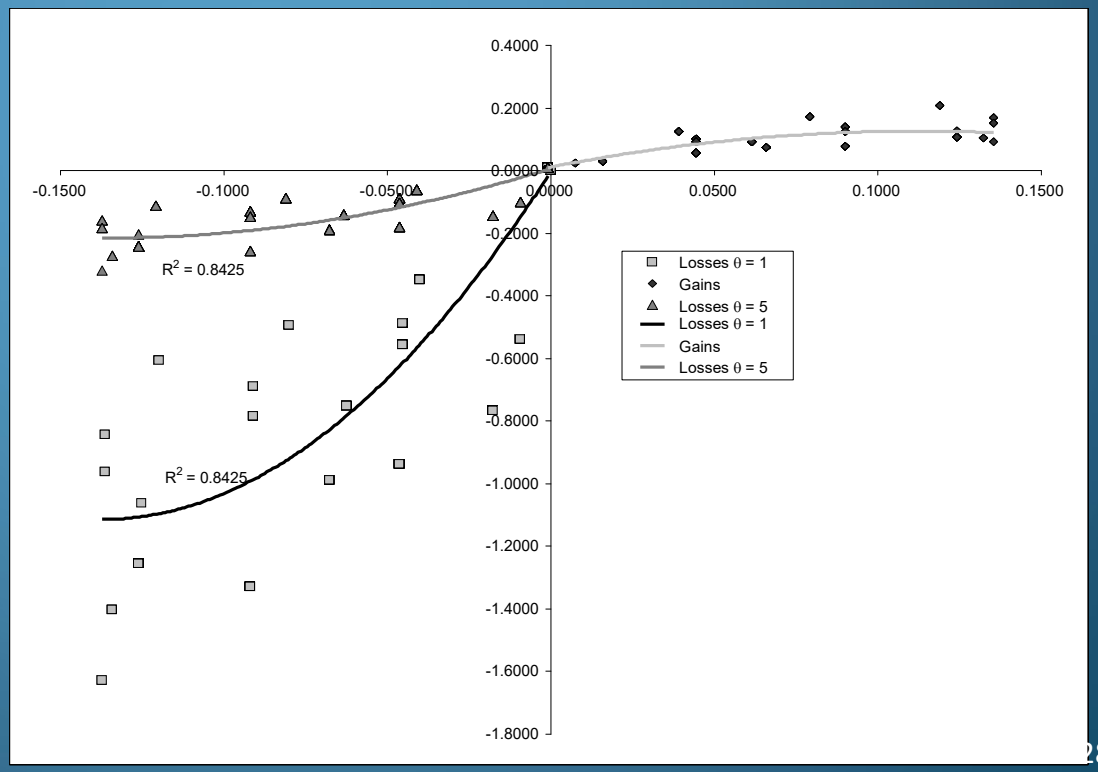
The function Φ_c reproduces the value function of OPT and replicates the most relevant shape characteristics. That function fulfills the concavity for positive outcomes (convexity for negative outcomes) and it enlarges the perception of negative values for losses than positive values for gains, both value functions are steeper for negative outcomes than for positive ones.

Each shape characteristic of the value function models psychological processes: the concavity for gains describes a risk aversion attitude, the convexity describes a risk seeking attitude; the assumption that losses carry more weight than gains is represented by a steeper negative function side.

Computations of the original TODIM method in algorithmic form:

- Step 1: From the evaluation matrix of size *m* (attributes/criteria) *versus n* (alternatives) and criteria weights, compute values of $\Phi_c(A_i, A_j)$ by using the appropriate equation and making θ vary in [1,10]
- Step 2: Compute values of $\delta(A_i, A_j)$
- Step 3: Compute values of ξ_i : those values lead to the ranking of alternatives





An early application of TODIM to health care:

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Statistics in Medicine

Research Article

Multi-criteria decision making – an approach to setting priorities in health care

Flávio Fonseca Nobre, Lilian Terezinha Ferreira Trotta, Luiz Flávio Autran Monteiro Gomes

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| https://doi.org/10.1002/(SICI)1097-0258(19991215)18:23<3345::AID-SIM321>3.0.CO;2-7 | Cited by: 24

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Abstract

The objective of this paper is to present a multi-criteria decision making (MCDM) approach to support public health decision making that takes into consideration the fuzziness of the decision goals and the behavioural aspect of the decision maker. The approach is used to analyse the process of health technology procurement in a University Hospital in Rio de Janeiro, Brazil. The method, known as TODIM, relies on evaluating alternatives with a set of decision criteria assessed using an ordinal scale. Fuzziness in generating criteria scores and weights or conflicts caused by dealing with different viewpoints of a group of decision makers (DMs) are solved using fuzzy set aggregation rules. The results suggested that MCDM models, incorporating fuzzy set approaches, should form a set of tools for public health decision making analysis, particularly when there are polarized opinions and conflicting objectives from the DM group.

An article published 8 years after the first two papers introducing TODIM and that has been cited by many other authors:

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Available online at www.sciencedirect.com

ScienceDirect

European Journal of Operational Research 193 (2009) 204–211

EUROPEAN JOURNAL OF OPERATIONAL RESEARCH

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Decision Support

An application of the TODIM method to the multicriteria rental evaluation of residential properties

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Abstract

This article presents an evaluation study of residential properties carried out together with real estate agents in the city of Volta Redonda, Brazil. The study aimed to define a reference value for the rents of these properties using the TODIM method of Multicriteria Decision Aiding. By applying this method to the ordering of properties with different characteristics, a ranking of all the properties was obtained and, as a result of this, diverse ranges of rental values for the properties under analysis. The study was complemented by an analysis of the sensitivity of the numerical results obtained.

Keywords: Multiple criteria analysis; Real estate market; Prospect theory

An extension towards Cumulative Prospect Theory:

Behavioral multi-criteria decision analysis: further elaborations on the todim method

Luiz Flavio Autran Monteiro Gomes[1] and Xavier Ignacio González[2]

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Vol. 37 (2012) No. 1

DOI: 10.2478/v10209-011-0001-1

BEHAVIORAL MULTI-CRITERIA DECISION ANALYSIS: FURTHER ELABORATIONS ON THE TODIM METHOD

Luiz Flavio AUTRAN MONTEIRO GOMES*
Xavier Ignacio GONZÁLEZ**

Abstract. This short communication reviews the role of the TODIM method within behavioral decision theory and presents its genesis. Two important aspects of the method such as generalizing that method towards cumulative prospect theory and the choice of a reference point are further clarified.

Keywords. Cumulative prospect theory, decisions under risk, multi-attribute decision making.

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Page

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A different model if we use CPT instead of OPT:

When introducing the CPT in 1992,Tversky & Kahneman define the subjective value ν of an outcome x, as a two-part power function of the form:

$$v = \begin{cases} x^{\alpha} & if \quad x \geq 0 \\ (-\lambda)(-x)^{\beta} & if \quad x < 0 \end{cases}$$

α quantifies the curvature of the subjective value function for gains, β does for losses, and the parameter λ quantifies the loss aversion. For α, β < 1, the value function exhibits risk aversion over gains and risk seeking over losses. Furthermore, if λ, the loss-aversion coefficient, is greater than one, individuals are more sensitive to losses than gains.

The original formulation of TODIM's value function is indeed a particular case of the more general Tversky and Kahneman's CPT where α=0.5 and λ=1/ θ:

$$v = \begin{cases} x^{\alpha} & if \quad x \geq 0 \\ (-\lambda)(-x)^{\beta} & if \quad x < 0 \end{cases}$$

A more general parametric form of the function Φ_c follows:

$$\Phi_c(A_i, A_j) = \begin{cases} \left(\dfrac{a_{rc}(w_{ic} - w_{jc})}{\sum_{c=1}^{m} a_{rc}} \right)^{\alpha} & if\ (w_{ic} - w_{jc}) > 0 \\ 0 & if\ (w_{ic} - w_{jc}) = 0 \\ (-\lambda)\left(\dfrac{(\sum_{c=1}^{m} a_{rc})(w_{jc} - w_{ic})}{a_{rc}} \right)^{\alpha} & if\ (w_{ic} - w_{jc}) < 0 \end{cases}$$

Additional thoughts:

Different kinds of decision makers can be understood in terms of their risk and loss attitude. Although the TODIM method does not deal with risk directly, the way the decision maker evaluates the outcomes of any decision can be expressed by their risk attitude: for instance, a cautious decision maker will undervalue a superior result more than a braver one. Apart from parameter θ, the attenuation factor of the losses, function Φ_c does not offer other parameters to delineate the behavior of diverse decision makers, therefore a generic formulation is proposed.

It can be shown that the ratio $a_{rc}/(\sum a_{rc})$ can be interpreted as a probability. This allows us to make full use of CPT, including its decision weights. We can therefore say that the formulation of TODIM in terms of CPT is indeed a formulation in terms of the concept of capacity. Here a capacity is a non-additive set function that generalizes the standard notion of probability. Capacities are also known under the name of fuzzy measures.

Examples of more recent work on the method and extensions follow

A SMAA formulation of the TODIM method:

Computers & Industrial Engineering 114 (2017) 130–141

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Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

The SMAA-TODIM approach: Modeling of preferences and a robustness analysis framework

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ARTICLE INFO

Keywords:
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TODIM
Stochastic multiobjective acceptability analysis (SMAA)
Robustness analysis

ABSTRACT

TODIM (an acronym in Portuguese of interactive and multicriteria decision making), which is founded on nonlinear cumulative prospect theory, has attracted increasing attention from the academic world since 1991. Up to now, a variety of TODIM multicriteria decision models have been developed and applied for solving decision making problems in a wide range of industries. In this study, we point out a limitation of TODIM, which is shared by all the TODIM-based models. Three types of inputs inherent in TODIM, i.e., criteria measurements, criteria weights and the attenuation factor of the losses, are usually uncertain. Moreover, these uncertainties may exist in TODIM at the same time, which has not been well investigated in the literature. To address this limitation, we apply stochastic multiobjective acceptability analysis (SMAA) to TODIM and therefore put forward the SMAA-TODIM method, to explore simultaneously the uncertainties inherent in the inputs of TODIM. In addition, a SMAA-TODIM-based robustness analysis framework for TODIM models is presented, based on which, the decision analyst can measure how robust a decision result is. Finally, applications of the robustness analysis framework for TODIM models are demonstrated by two examples.

Generalizing the TODIM method:

European Journal of Operational Research
Volume 269, Issue 3, 16 September 2018, Pages 1041-1049

Decision Support

An analysis of the generalized TODIM method

Bonifacio Llamazares

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Highlights

- A simplified version of the TODIM method is proposed.
- Two paradoxes of the TODIM method concerning the weights of the model are shown.
- A generalized TODIM method that avoids the previous paradoxes is introduced.
- SAW and, under certain hypotheses, PROMETHEE II are specific cases of this new method.

Abstract

The TODIM (an acronym in Portuguese for Interactive and Multicriteria Decision Making) method is a multicriteria procedure that is receiving increasing attention from the scientific community over the last few years. In this paper, we introduce a simplified version of this procedure, which allows us to easily show that this method is vulnerable to two paradoxes affecting the weights of the model. In order to overcome these inconsistencies, we propose a generalization of the TODIM method and establish conditions under which the previous paradoxes can be avoided. Moreover, we also show that the simple additive weighting (SAW) method and, under certain hypotheses, the PROMETHEE II method can be obtained as specific cases of the generalized TODIM method.

A classificatory version of TODIM:

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Computers & Operations Research

Volume 42, February 2014, Pages 40-48

Using the TODIM-FSE method as a decision-making support methodology for oil spill response

Aderson Campos Passos [a], Marcello Goulart Teixeira [b], Katia Cristina Garcia [c], Anelise Menezes Cardoso [c], Luiz Flavio Autran Monteiro Gomes [d]

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Abstract

This paper introduces a multi-criteria method for solving classification problems, called TODIM-FSE. This name was chosen because its structure merges characteristics from two different methods: TODIM and FSE. In order to demonstrate TODIM-FSE, a model was constructed aimed at helping potential users to decide upon suitable contingency plans for oil spill situations. The model is envisaged as embedded within SISNOLEO (a Portuguese acronym for An Information System for Oil Spill Planning) which is subsequently described in the article. The fundamentals of this method, several key references and a case study are also provided.

Previous article in issue

Next article in issue

Keywords

Multiple criteria analysis; TODIM-FSE; Oil spill response; SISNOLEO; Environmental damage

TODIM-FSE: a Multicriteria Classification and Sorting Method based on Prospect Theory

- There are relatively very few MCDA methods for solving classification and sorting problems
- TODIM-FSE is a multicriteria classification and sorting method that relies on the paradigm of Kahneman and Tversky (1979, 1992) known as Prospect Theory
- The concept of *contribution* presented in TODIM-FSE is a novel concept that enables the classification and sorting procedure
- TODIM-FSE is a multicriteria classification and sorting method that combines features of the TODIM method with the Fuzzy Synthetic Evaluation (FSE) approach [some early authors: LU, LO & HU (1999); CHANG, CHEN & NING (2001); ONKAL-ENGIN & DEMIR (2004); SADIQ, HUSAIN, VEITCH & BOSE (2004); KUO & CHEN (2006)]
- The method is applicable through a 7 step procedure and the last of those seps provides for a validation of the method's output

Procedure for applying TODIM-FSE

- **Step 1** – Identifying decision agents/makers and decision analyst(s)
- **Step 2** – Analyzing and structuring the decision (classification/sorting) problem
- **Step 3** – Identifying the attributes/criteria
- **Step 4 – Defining categories (i.e., classes) and contribution functions**
- **Step 5** – Eliciting the weights of attributes/criteria
- **Step 6 – Assigning each alternative to one of the proposed categories**
- **Step 7 – Validating the assignment carried out in Step 6 (i.e., Validation Analysis)**

Defining categories and contribution functions (Step 4)

- Here, the first concern is to define the number of categories
- Next, for every attribute/criterion it is necessary to define the *contribuition* that each of the criteria provides to assign one alternative to a certain category
- If the criterion is *qualitative* these contribuitions will be presented in a table, with values between 0 and 1
- If the criterion is *quantitative* these contribuitions will be presented similarly to fuzzy sets, with values also between 0 and 1

Table of contributions (for qualitative attributes/criteria)

The table below shows the values of contribution for the criteria *quality of deliverable* (for example) in a model of self evaluation of the quality of services provided to the customers

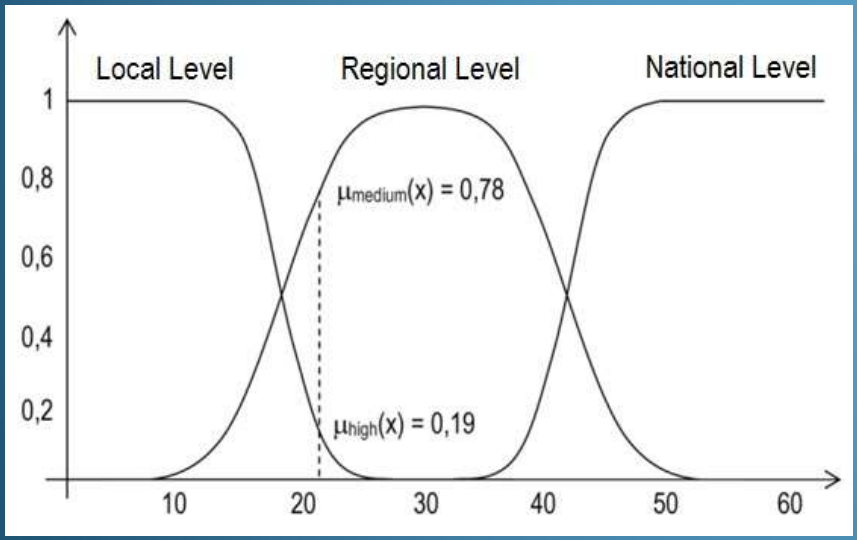
Evaluation Scale	Excellent	Very Good	Good	Bad
Very much Above Expectations	1	0.8	0.5	0
Above Expectations	0.8	1	0.8	0.2
Within Expectations	0.5	0.8	1	0.4
Below Expectations	0	0.2	0.4	1

Generalizing: Contribuitions table for qualitative attribute/criterion i

	Categories				
Evaluation	**Cat $_1$**	**Cat $_2$**	**...**	**Cat $_{k-1}$**	**Cat $_k$**
γ_1	μ_{11}	μ_{12}	...	μ_{1k-1}	μ_{1k}
γ_2	μ_{21}	μ_{22}	...	μ_{2k-1}	μ_{2k}
...	...	...	...	...	...
γ_m	μ_{m1}	μ_{m2}	...	μ_{mk-1}	μ_{mk}

Contribution Functions (for quantitative criteria)

In the example problem below, there are 3 classes of accidents in a case study of oil spill: (1) Local Level, (2) Regional Level, (3) National Level. Several criteria were taken into account for this evaluation



For the criteria *type of oil in terms of its persistence* the following contribution functions were defined, by using the opinions from experts

After analyzing the last figure a vector of contributions is created, with a value of contribuition associated to each category.

$[\mu_{LL}(x) = 0.19 \quad \mu_{RL}(x) = 0.78 \quad \mu_{NL}(x) = 0]$

Those figures mean that the oil that holds 21º API (American Petroleum Institute) contributes with the values of 0.19 to classify the accident in the lower category; 0.78 to classify the accident in the intermediate category; and 0 to classify the accident in the higher category

Generalizing: Table of attributes/criteria grouped contributions

	Categories				
Criterion	**Cat $_1$**	**Cat $_2$**	**...**	**Cat $_{k-1}$**	**Cat $_k$**
crit$_1$	μ_{11}	μ_{12}	...	μ_{1k-1}	μ_{1k}
crit$_2$	μ_{21}	μ_{22}	...	μ_{2k-1}	μ_{2k}
...	...	...	...	...	...
crit$_n$	μ_{n1}	μ_{n2}	...	μ_{nk-1}	μ_{nk}

Classification of each alternative (Step 6)

- The classification will be obtained by using a natural extension of the TODIM formulas by ranking the values of contributions of each criteria
- The problem in this step can be analyzed by showing which category has the greatest overall score when considering all attributes/criteria and their weights

Table of aggregated criteria contribuitions

Criteria	Categories					
	Cat_1	Cat_2	…	Cat_i	…	Cat_k
C_1	μ_{11}	μ_{12}	…	μ_{1i}	…	μ_{1k}
C_2	μ_{21}	μ_{22}	…	μ_{2i}	…	μ_{2k}
…	…	…	…	…	…	…
C_j	μ_{j1}	μ_{j2}	…	μ_{ji}	…	μ_{jk}
…	…	…	…	…	…	…
C_n	μ_{n1}	μ_{n2}	…	μ_{ni}	…	μ_{nk}

Values of contributions obtained in **Step 4**, for each criterion

Within the columns of this table we have the contributions associated to each criterion

Classification of each alternative (Step 6)

Classifying equations

$$\Phi_c(cat_i, cat_j) = \begin{cases} \sqrt{\dfrac{w_{rc}(\mu_{ic} - \mu_{jc})}{\sum_{c=1}^{n} w_{rc}}}, & \mu_{ic} - \mu_{jc} > 0 \\ 0, & \mu_{ic} - \mu_{jc} = 0 \\ -\dfrac{1}{\theta}\sqrt{\dfrac{(\sum_{c=1}^{n} w_{rc})(\mu_{jc} - \mu_{ic})}{w_{rc}}}, & \mu_{ic} - \mu_{jc} < 0 \end{cases}$$

$$\delta(cat_i, cat_j) = \sum_{c=1}^{n} \Phi_c\,(cat_i, cat_j) \qquad \forall(i, j)$$

$$\xi_i = \frac{\sum_{j=1}^{k} \delta(cat_i, cat_j) - min \sum_{j=1}^{k} \delta(cat_i, cat_j)}{max \sum_{j=1}^{k} \delta(cat_i, cat_j) - min \sum_{j=1}^{k} \delta(cat_i, cat_j)}$$

Validation analysis (Step 7)

- Here, the objective is to fine tune the model created in order to improve its effectiveness in supporting decision making (i.e., multicriteria classification/sorting)
- The weights of attributes/criteria and contribution values can be changed in this step
- In order to test the quality of the classification that was produced it is important to use some alternatives previously classified as benchmarks

TODIM with criteria interactions:

Annals of Operations Research
December 2013, Volume 211, Issue 1, pp 531–548 | Cite as

Behavioral multi-criteria decision analysis: the TODIM method with criteria interactions

Authors Authors and affiliations

Luiz Flavio Autran Monteiro Gomes, Maria Augusta Soares Machado, Luis Alberto Duncan Rangel

Article
First Online: 21 March 2013

Abstract

In this paper a multi-criteria decision aiding model is developed through the use of the Choquet integral. The proposed model is an extension of the TODIM method, which is based on nonlinear Cumulative Prospect Theory. The paper starts by reviewing the first steps of behavioral decision theory. A presentation of the TODIM method follows. The basic concepts of the Choquet integral as related to multi-criteria decision aiding are reviewed. It is also shown how the measures of dominance of the TODIM method can be rewritten through the application of the Choquet integral. From the ordering of decision criteria the fuzzy measures of criteria interactions are computed, which leads to the ranking of alternatives. A case study on the forecasting of property values for rent in a Brazilian city illustrates the proposed model. Results obtained from the use of the Choquet integral are then compared against a previously made usage of the TODIM method. It is concluded that significant advantages exist derived from the use of the Choquet integral. The paper closes with recommendations for future research.

Keywords

TODIM method Multicriteria decision aid Decision analysis

Note: Xavier Ignacio González was the third author of this article

First publication on TODIM with interval data:

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A Method for Interval Multiple Attribute Decision Making with Loss Aversion

5 Author(s) Fa-dong Chen ; Xiao Zhang ; Feng Kang ; Zhi-ping Fan ; Xi Chen View All Authors

Abstract

Document Sections

Authors

Figures

Abstract:
This paper proposes a method for solving interval multiple attribute decision-making problems with loss aversion. In this method, the behavioral and cognitive factors of decision makers in reality are considered. Firstly, each alternative is chosen as the reference point of another alternative in the process of pair comparisons, and the gains or losses of consequence for each alternative with respect to each attribute relative to the reference point are calculated according to prospect theory. Then, based on loss aversion, the dominance measurement of one alternative over another alternative and the global measurement of each alternative can be calculated by TODIM method, and the ranking result of the alternatives is obtained on the basis of the global measurement of each alternative. Finally, a numerical example is used to illustrate the feasibility and validity of the proposed method.

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TODIM with fuzzy input data:

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Combining prospect theory and fuzzy numbers to multi-criteria decision making

Renato A. Krohling [a], Talles T.M. de Souza [b]

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https://doi.org/10.1016/j.eswa.2012.04.006

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Abstract

Many multi-criteria decision making (MCDM) methods have been proposed to handle uncertain decision making problems. Most of them are based on fuzzy numbers and they are not able to cope with risk in decision making. In recent years, some MCDM methods based on prospect theory to handle risk MCDM problems have been developed. In this paper, we propose a hybrid approach combining prospect theory and fuzzy numbers to handle risk and uncertainty in MCDM problems. So, it is possible to tackle more challenging MCDM problems. A case study involving oil spill in the sea illustrates the application of the novel method.

Highlights

► Many problems in decision making are affected by risk and uncertainty. ► A novel method based on prospect theory and fuzzy numbers has been proposed to solve this kind of problem. ► Promising results show the feasibility of the approach.

The combined use of interval data and fuzzy information:

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Knowledge-Based Systems xxx (2012) xxx–xxx

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journal homepage: www.elsevier.com/locate/knosys

Multicriteria analysis of green supply chain management using interval-valued fuzzy TODIM

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ABSTRACT

This study aims to develop a mechanism to assist managers in green supplier evaluation and selection decisions under uncertainty. The process of evaluating suppliers' greenness is complex, as the attributes for environmental compliance tend to be vague and conflicting. This study proposes addressing the uncertainties in evaluation using a hybrid approach, specifically, a combination of fuzzy set theory and a discrete multi-criteria method based on prospect theory in uncertainty (known as TODIM in Portuguese). The advantages of the proposed hybrid approach were demonstrated using a case example. The results indicated that the fuzzy TODIM approach can easily and effectively accommodate criteria with gains and loss functions, hence, assisting managers to improve their firms' environmental performance and reducing overall green supply chain management uncertainty.

1. Introduction

In recent years, the European Union (EU) has established various environmental policies, including the RoHS (Restricted Use of Hazardous Substances in Electrical and Electronic Equipment) and the WEEE (Waste Electronics and Electrical Equipment) directives [21,18]. Thus, environmental management has evolved to include boundary-spanning activities in the upstream and the downstream supply chains. Srivastava [22] defined green supply chain management (GSCM) as a combination of environmental and supply chain management activities, including product design, material selection, manufacturing processes, final product delivery and end-of-life product management. With GSCM, firms select from a wide variety of suppliers and leverage resources throughout the firm to eliminate the environmental impacts of supply chain activities [27,31].

Firms typically expect their suppliers to surpass environmental compliance and to develop efficient and green product designs. In addition, suppliers are expected to assess the life cycle of a product. However, the qualitative criteria are littered with subjective perceptions because the GSCM evaluation criteria tend to be subjective, qualitative, or described with linguistic information. Thus, it is extremely difficult for the decision-makers to express their preferences using exact numerical values [25,30,34]. Nevertheless, a firm's suppliers must satisfy green criteria under the constraint of subjective human preferences (uncertainty), but this phenomenon has not been thoroughly examined in the current literature. GSCM has become an important source of competitive advantage and is expected to remain an important component of business strategy in the future. How can managers decide to select and justify suppliers under vague and subjective criteria that are subject to uncertainty?

Current studies offer several evaluation approaches for supplier selection based on GSCM criteria. Most of the studies assess GSCM based on its alignment with the identified firm's objectives and fulfillment of a set of assessment criteria. In general, the evaluation of the criteria is highly subjective and unstructured, as it relies significantly on managers' experience, knowledge, and intuition. However, managers cannot consider all relevant criteria due to bounded rationality and a limited capacity for information processing [6,27]. Hence, the evaluation approach often ineffectively implemented because management does not effectively use its knowledge of and experience with previously supplier selection as an input to the prioritization of GSCM. Due to the impact of this lack of application management is not confident that supplier selection is being studied and applied to a set of criteria to maximize firms' green supply chain benefits. How could management apply its knowledge of previously (successful and unsuccessful) supplier selections to support future decision making (i.e., to improve decision quality)?

The objectives of this study are to create a mechanism that could assist managers in analyzing and selecting green suppliers in GSCM. The proposed mechanism will allow a manager to make

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A neutrosophic group decision-making approach:

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Hybrid single-valued neutrosophic MCGDM with QFD for market segment evaluation and selection

Article type: Research Article

Authors: Tian, Zhang-Peng | Wang, Jian-Qiang* | Zhang, Hong-Yu

Affiliations: School of Business, Central South University, Changsha, PR China

Correspondence: [*] Corresponding author. Jian-Qiang Wang, School of Business, Central South University, Changsha 410083, PR China. E-mail: jqwang@csu.edu.cn.

Abstract: Market segment evaluation and selection (MSE/MSS) become one of the most essential elements in marketing practices of enterprises, since they assist enterprises in developing homogeneous market segments. In this paper, a hybrid single-valued neutrosophic multi-criteria group decision-making (MCGDM) approach with quality function deployment (QFD) is used to support the MSE/MSS process. Firstly, single-valued neutrosophic numbers are used to represent the decision-makers' qualitative assessments. Secondly, an extended QFD is used to translate the customer requirements (CRs) into relevant design requirements (DRs), and a single-valued neutrosophic DEMATEL (DEcision-MAking Trial and Evaluation Laboratory) is used to determine the importance weights of CRs and DRs. Thirdly, a single-valued neutrosophic TODIM (An acronym in Portuguese of interactive and multi-criteria decision-making) is employed to rank all the alternatives. Subsequently, a case study of MSE/MSS of a smart bike-sharing company is presented. Finally, some valuable managerial suggestions are provided through the results of sensitivity analysis and comparative analysis.

Keywords: Multi-criteria decision-making, single-valued neutrosophic set, quality function deployment, DEMATEL, TODIM

DOI: 10.3233/JIFS-171055

Journal: Journal of Intelligent & Fuzzy Systems, vol. 34, no. 1, pp. 177-187, 2018

Published: 12 January 2018

Neutrosophic models try to capture uncertainty, vagueness, incompleteness, inconsistency, redundancy and contradiction in data

With intuitionistic fuzzy information:

ELSEVIER

Knowledge-Based Systems

Volume 53, November 2013, Pages 142-146

Short Communication

IF-TODIM: An intuitionistic fuzzy TODIM to multi-criteria decision making

Renato A. Krohling [a], André G.C. Pacheco [b], André L.T. Siviero [b]

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Abstract

The recently developed fuzzy TODIM (an acronym in Portuguese for iterative multi-criteria decision making) method using fuzzy numbers has been applied to uncertain MCDM problems with promising results. In this paper, a more general approach to the fuzzy TODIM, which takes into account the membership and the non-membership of the fuzzy information is considered. So, the fuzzy TODIM method has been extended to handle intuitionistic fuzzy information. This way, it is possible to tackle more challenging MCDM problems. Two case studies are used to illustrate and show the suitability of the developed method.

Intuitionistic fuzzy models take into account the membership degree, the non-membership degree and hesitancy degrees of decision makers

With intuitionist-fuzzy, sentiment-based inputs:

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HOME / BROWSE JOURNALS & BOOKS / KYBERNETES / EARLYCITE / RANKING PRODUCTS WITH IF-BASED SENTIMENT WORD FRAMEWORK AND TODIM METHOD

Ranking products with IF-based sentiment word framework and TODIM method

Author(s): Chong Wu , (School of Management, Harbin Institute of Technology, Harbin, China) Show all authors

Abstract:

Purpose

The purpose of this paper is to rank products by combining sentiment analysis (SA) and multiple attribute decision-making (MADM).

Design/methodology/approach

This research constructs intuitionistic fuzzy (IF)-based sentiment word framework and corresponding computation rules, which aim to calculate the sentiment score of each sentiment phase. Based on intuitionistic fuzzy weighted averaging operator, the authors aggregate the overall performance of each feature for different products. Then, the MADM method can be used, TODIM (an acronym in Portuguese of interactive and multi-criteria decision making) in this paper, to rank product through online reviews.

Keywords: Sentiment analysis, Intuitionistic fuzzy set, Multiple attribute decision-making, Product ranking, Sentiment word framework

Type: Research Paper

Publisher: Emerald Publishing Limited

Citation: Chong Wu, Dong Zhang, (2018) "Ranking products with IF-based sentiment word framework and TODIM method", Kybernetes, https://doi.org/10.1108/K-01-2018-0029

Sentiment analysis is contextual mining that tries to identify and elicit subjective information in source material

An application to robot selection:

Entropy **2018**, *20*(5), 349; https://doi.org/10.3390/e20050349 Open Access Article

Robot Evaluation and Selection with Entropy-Based Combination Weighting and Cloud TODIM Approach

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(This article belongs to the Section Information Theory)

Full-Text | PDF [1078 KB, uploaded 9 May 2018] | Figures

Abstract

Nowadays robots have been commonly adopted in various manufacturing industries to improve product quality and productivity. The selection of the best robot to suit a specific production setting is a difficult decision making task for manufacturers because of the increase in complexity and number of robot systems. In this paper, we explore two key issues of robot evaluation and selection: the representation of decision makers' diversified assessments and the determination of the ranking of available robots. Specifically, a decision support model which utilizes cloud model and TODIM (an acronym in Portuguese of interactive and multiple criteria decision making) method is developed for the purpose of handling robot selection problems with hesitant linguistic information. Besides, we use an entropy-based combination weighting technique to estimate the weights of evaluation criteria. Finally, we illustrate the proposed cloud TODIM approach with a robot selection example for an automobile manufacturer, and further validate its effectiveness and benefits via a comparative analysis. The results show that the proposed robot selection model has some unique advantages, which is more realistic and flexible for robot selection under a complex and uncertain environment. View Full-Text

Keywords: robot selection; cloud model; TODIM method; combination weight; entropy method

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Regional differences of Chinese environmental protection institutional system's operation — An empirical analysis based on hybrid todim method

3 Author(s) Wenping Wang ; Dang Luo ; Wenxin Mao View All Authors

17 Full Text Views

Abstract
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Abstract:
Since Chinese reform and opening up, the total economy has kept a rapid development trend, which also makes Chinese environmental pollution problems become increasingly serious. In recent years, Chinese government has introduced a large number of environmental protection policies to alleviate the contradiction between economic development and environmental pollution. However, the economic level, resource endowment and government system of China vary from one region to another, which leads to the result that the implementation of environmental protection policies is not satisfactory. In order to achieve economic sustainable development better, each region of China needs to be tailored to develop respective environmental protection institution according to its own regional characteristics. Therefore, it is necessary to analyze and evaluate the operational effect of Chinese existing regional environmental protection institution and put forward the corresponding improvement measures. In order to evaluate the operational effect of Chinese environmental protection institution system (EPIS), the following works have been carried out: Firstly, the constitution and operational mechanism of EPIS are analyzed. The Chinese EPIS consists of the environmental laws and regulations subsystem, the environmental protection administrative institution subsystem, the environmental economic policy subsystem and the public participation institution subsystem, and the four subsystems are interdependent and interact with each other. Then, the comprehensive evaluation index system of EPIS is constructed with systemic completeness, systemic execution, ecological environment and economic development as the four criteria layers. There are total 15 indexes under four criteria layers. At last, the evaluation of the regional EPIS based on the hybrid extended TODIM (an acronym in Portuguese of interactive and multi criteria decision making) method is proposed with considering the hybrid evaluation information including real numbers and grey numbers. In addition, the novel ranking method and orthocenter distance of grey number based on whitening weight function are proposed to established
(View more)

Published in: 2017 International Conference on Grey Systems and Intelligent Services (GSIS)

Date of Conference: 8-11 Aug. 2017 **DOI:** 10.1109/GSIS.2017.8077661

With linguistic hesitant fuzzy information:

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Articles

Multi-criteria decision-making approaches based on distance measures for linguistic hesitant fuzzy sets

Huan Zhou, Jian-qiang Wang & Hong-yu Zhang

Pages 661-675 | Received 04 Mar 2015, Accepted 26 Apr 2016, Published online: 05 Jan 2018

Download citation https://doi.org/10.1080/01605682.2017.1400780

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Abstract

Linguistic hesitant fuzzy sets (LHFSs), which can be used to both represent decision-makers' qualitative preferences and reflect their hesitancy and inconsistency, have attracted much attention due to their flexibility and efficiency. In this paper, some distance-based approaches for resolving multi-criteria decision-making (MCDM) problems with linguistic hesitant fuzzy information are introduced. To begin, a new order relationship between LHFSs, based on the defined LHFSs, is presented. Then, distance measures for LHFSs are proposed, which include the generalised, Hamming, and Euclidean distance measures. Additionally, some approaches for handling MCDM problems with linguistic hesitant fuzzy information are proposed, which are based on the TOPSIS, VIKOR, and TODIM methods, as well as the proposed distance measures. Finally, an illustrative example is provided to show the feasibility and usability of the methods, which are then compared with the existing method.

Keywords: Multi-criteria decision-making, linguistic hesitant fuzzy sets, distance measures, TOPSIS, VIKOR, TODIM

Hesitant fuzzy models allow for considering the attitudes of many decision makers towards one decision

More on hesitant fuzzy information inputs:

International Journal of Computational Intelligence Systems, Vol. 8, No. 4 (2015) 701-712

A Hesitant Fuzzy Linguistic TODIM Method Based on a Score Function

Cuiping Wei [1,2] *, Zhiliang Ren [2], Rosa M. Rodríguez [3]

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Abstract

Hesitant fuzzy linguistic term sets (HFLTSs) are very useful for dealing with the situations in which the decision makers hesitate among several linguistic terms to assess an alternative. Some multi-criteria decision-making (MCDM) methods have been developed to deal with HFLTSs. These methods are derived under the assumption that the decision maker is completely rational and do not consider the decision maker's psychological behavior. But some studies about behavioral experiments have shown that the decision maker is bounded rational in decision processes and the behavior of the decision maker plays an important role in decision analysis. In this paper, we extend the classical TODIM (an acronym in Portuguese of interactive and multi-criteria decision-making) method to solve MCDM problems dealing with HFLTSs and considering the decision maker's psychological behavior. A novel score function to compare HFLTSs more effectively is defined. This function is also used in the proposed TODIM method. Finally, a decision-making problem that concerns the evaluation and ranking of several telecommunications service providers is used to illustrate the validity and applicability of the proposed method.

Keywords: Multi-criteria decision-making; Hesitant fuzzy linguistic term set; TODIM method; Distance measure; Score function; Comparison operator

1. Introduction

In multi-criteria decision-making (MCDM) problems, many criteria are of qualitative nature, so it is more suitable to evaluate them by using linguistic information [39]. For example, when we evaluate the "comfort" or "design" of a car, linguistic terms such as, "excellent", "good", "poor" etc. are preferred. Fuzzy linguistic approach [39] has obtained successful results dealing with linguistic information in decision making [18,23,27,38]. Many linguistic models have been presented to extend and improve the fuzzy linguistic approach in information modeling and computing processes [5,11,35]. These linguistic models use

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Group decision making with intuitionistic fuzzy information:

Hindawi Publishing Corporation
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Volume 2015, Article ID 672140, 9 pages
http://dx.doi.org/10.1155/2015/672140

Research Article

An Extended TODIM Method for Group Decision Making with the Interval Intuitionistic Fuzzy Sets

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Academic Editor: Elena Benvenuti

For a multiple-attribute group decision-making problem with interval intuitionistic fuzzy sets, a method based on extended TODIM is proposed. First, the concepts of interval intuitionistic fuzzy set and its algorithms are defined, and then the entropy method to determine the weights is put forward. Then, based on the Hamming distance and the Euclidean distance of the interval intuitionistic fuzzy set, both of which have been defined, function mapping is given for the attribute. Finally, to solve multiple-attribute group decision-making problems using interval intuitionistic fuzzy sets, a method based on extended TODIM is put forward, and a case that deals with the site selection of airport terminals is given to prove the method.

1. Introduction

Zadeh [1] put forward the concept of fuzzy sets in 1965; shortly afterward, the theory of fuzzy sets gradually developed. In 1986, Atanassov [2] proposed the theory of intuitionistic fuzzy set (IFS). However, the common fuzzy set can be seen as the special form of IFS. In real life, an accurate definition for the specific membership and the specific nonmembership degree of IFS is relatively difficult [3]. In 1989, Atanassov and Gargov [4] extended the IFS into the interval intuitionistic fuzzy set (IIFS). In the following years, the properties of the IIFSs were further expanded, the changes mainly included related algorithms, the correlation and decomposition theorem, topological properties, correlation coefficient, and the relationship between other fuzzy sets [5–9]. Xu [10] also put forward several kinds of weighted averaging operators for the IIFSs in 2007. Also, there are some applications and extensions for these operators [11–13].

Multiple-attribute decision making (MADM) belongs to multicriteria decision making (MCDM), which has characteristics of discrete types and limited alternatives. The process of decision making is to gather the opinions of all the decision makers for several alternatives. MADM means that there is not only one attribute, and how to integrate the attributes of various alternatives is very important. Therefore, many researchers have devoted themselves to the study of MADM, and rich achievements have been obtained. Specific methods have been used to solve the problems of multiple-attribute decision making, such as the method of choice [14, 15], the ordering method of compromise [16], the method of grey correlation analysis [17, 18], and the TOPSIS method [19, 20]. There are also many other methods [21–25], and multiple-attribute group decision making has a wide array of theory and practice basis [26, 27].

Park et al. [28] pointed out that problems in which the attribute weights were unknown and interval intuitionistic fuzzy decision was being applied were difficult. At present, general methods used to solve the problem of multiple-attribute decision making with IFS are based on the determination attribute weights [29, 30]. In the recent years, under the condition in which attribute weights are determined, studies have made great progress solving the problem of multiattribute group decision making using interval number information. For example, Bryson and Mobolurin [31] proposed a method of linear programming which was based on the deviation degree. Xu [32] presented the method of relative membership degree. Su et al. [33] put forward an extended VIKOR method for dynamic multiattribute decision making using interval numbers. And Wang et al. did some research that included the condition of uncertainty [34, 35].

A hybrid approach - 2-dimension uncertain linguistic variables, a cloud model and an extended TODIM:

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Renewable energy project performance evaluation using a hybrid multi-criteria decision-making approach: case study in Fujian, China

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Highlight

1. 2DULVs are adopted by DMs to evaluate the overall performance of alternatives
2. A novel conversion model is proposed to transform the 2DULVs into integrated clouds
3. A extended TODIM approach is used to evaluate and rank REPs
4. A case study in Fujian is given to state the applicability of the proposed approach

Abstract

The evaluation of the best renewable energy project (REP) among many alternatives is a complicated multi-criteria decision-making (MCDM) problem, which usually involves several criteria in economy, technicality, environment and society. To solve this problem, a hybrid approach mixing 2-dimension uncertain linguistic variables (2DULVs), a cloud model and an extended TODIM (an acronym in Portuguese of interactive and multicriteria decision making) together to evaluate REPs efficiently is proposed. Firstly, because of the extra reliability assessment, the 2DULVs are adopted by decision-makers (DMs) to evaluate the performance of alternatives. Secondly, given that the cloud model could vividly depict the fuzziness and randomness, a novel conversion model is proposed to transform the 2DULVs into integrated clouds. Thirdly, the extended TODIM approach is used to evaluate and rank REPs considering DMs' psychological behaviors. Following this, the Fujian case study has been provided to demonstrate to verify the feasibility of the hybrid approach. The results show that the most important criterion is the emission reduction of the greenhouse gases (GHG), and the wind power project is selected as the best alternative, but the later sensitivity analysis shows that the optimal alternative is sensitive to the attenuation factor of losses. Finally, a comparative analysis is conducted to demonstrate the correctness and superiority of the proposed approach. The originality of this work is the first time to put forward the model of transforming 2DULVS into integrated cloud.

Keywords

renewable energy project; performance evaluation; 2-dimension uncertain linguistic variables; cloud model; extended TODIM

Thank you very much! I trust future generations will make much better decisions than ours with the help of evolving tools of Soft Computing – the TODIM method and extensions are just a very tiny part of this much broader and captivating field of research