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Wildcards – natural and artificial: the combination of a panel of experts and Fuzzy TOPSIS

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Abstract

Purpose – *The purpose of this paper is threefold: to classify wildcards into three particular types sharing similar characteristics; use the Fuzzy TOPSIS as a new method in foresight to turn qualitative ideas into quantitative ones; and apply a combination of Fuzzy TOPSIS and a panel of experts to prioritize weak signals.*

Design/methodology/approach – *In this paper, the authors classify wildcards into three particular types which share similar character: natural wildcards, artificial wildcards (Degree 1) and artificial wildcards (Degree 2). Wildcards point to unexpected and surprising events including important results that can form watershed in the development of a specific trend. In addition, the authors present a Fuzzy TOPSIS model which can be used in various cases to prioritize a number of weak signals and put them in order, so that the most important ones are likely to yield the wildcard in the future*

Findings – *The authors presented a classification of wildcards with the same characteristics being natural wildcards, artificial wildcards (Degree 1) and artificial wildcards (Degree 2). The authors also prioritized the weak signals to deal with the most important ones and take appropriate action in advance so as to minimize possible damages and maximize the benefits of potential wildcards in an uncertain environment.*

Originality/value – *In this paper, the authors report on the prioritizing of weak signals by applying Fuzzy TOPSIS and classify wildcards. This is significant because, by identifying the most important weak signals, appropriate actions can be taken in the future if necessary. The paper should be of interest to readers in the area of participatory foresight.*

Keywords *Fuzzy TOPSIS, Environmental scanning, Futurist, Panel of experts, Weak signals, Wildcards*

Paper type *Research paper*

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1. Introduction

As the correlation between different variables and their interaction is not considered, forecasting methods are no longer responsive to today's world questions in a turbulent and rapidly changing globe. In such circumstances, an unexpected event could destroy the value of forecast equations. Futurists should be like an eagle flying at high altitude that can observe all events. For instance, when a river suddenly overflows, the eagle spots the event and sees it as a potential danger to the nearby village. By identifying this potential wildcard, the village can be adjusted to the shock. As a result, the destructive effects of flood can be decreased. Futurists should be able to identify opportunities and threats of potential wildcards and make the best use of them by converting the threats into the opportunities, so that favorable impacts could be achieved. A "weak signal" is a decision-support "tool". It occurs as an ordinary-looking "data" item, albeit one whose interpretation could trigger a warning. Such a warning indicates that an event could occur that may have considerable consequences (in terms of opportunity or threat) (Lesca and Lesca, 2013).

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Wildcard study is generally one of the most stimulating subjects in foresight. Wildcards are earthquakes of the mental landscape. In addition, it undermines current trends, and consequently causes a sharp change in the slope of the trend and influences our way of thinking about the future and past. Hence, wildcards are of considerable help for pioneer foresight practitioners.

A wildcard is a depiction of an incident that is imagined to be improbable, but which would have enormous and instant consequences if it took place. There is little knowledge accessible to help a futurist make an informed decision about what wildcards are. In this regard, the description that might have the most eloquent definitions is "Low Probability, High Impact Events that happen quickly". Petersen's intelligible definition is "Big Surprises" (Petersen, 1999). The importance of wildcard study is understood when we discover how much loss would have been prevented if the eagle had considered weak signals to cope with. A weak signal is a piece of data that usually appears insignificant, or is swamped in a sea of raw data, which generated "noise". It is difficult to perceive, because it does not, a priori, impose itself; therefore, it is qualified as "weak". If it catches our attention, it then assumes the status of information (Lesca and Lesca, 2014). Ignoring the weak signals sometimes leads to a wildcard with numerous potential damages. Accordingly, it is important to take into account weak signals to deal with wildcards and reduce their destructive consequences by appropriate initial preventive actions. It should be emphasized that Petersen asks three significant questions in connection with these wildcards (Petersen, 1999):

Q1. Which are the most important wildcards for an organization?

Q2. Can we anticipate their arrival?

Q3. Is there anything we can do about them?

It is required to consider the specification of different categories of wildcards to answer these questions. Actually, futurists can provide solutions for Petersen's three questions when they are aware of the environmental changes in advance. Warning and weak signals, coming from the environmental scanning, may herald the advent of a wildcard. Generally, weak signals are considered as information on possible change of a system toward an obscure direction. The crisis management literature has repeatedly noted the fact that "long before its actual occurrence a crisis sends off a repeated and persistent trail of early warning signals" (Mitroff, 1988).

According to the aforementioned cases, the importance and necessity of weak signals are revealed. An appropriate environmental scanning is required to identify the weak signals of a particular case. Thus, we apply the combination of panel of experts and Fuzzy TOPSIS method to identify the most important weak signals. On the one hand, panel of experts consists of a group of influential specialists (between 12 to 20 people) who reflect on the future of specific issues in the determined time and offer advice; the selected experts have high formal status in a business community (e.g. CEOs) or in some scientific community (e.g. leading professors) in the fields of economic, social sciences, politic, technology and environment. This group is trying to understand the future and achieve the desired future by using the collective thinking. On the other hand, Fuzzy TOPSIS is a multi-criteria decision analysis method in which the linguistic variables are used to make the qualitative ideas of experts into the quantitative ones.

This paper intends to convert qualitative opinions of experts to the quantitative ones, so Fuzzy logic is used. To explain the meaning and policy implication, the following section and one case study, which has been carried out in a tobacco company, have been included in the introduction and body of the paper, respectively.

As a matter of fact, the applied method can be used when there is a series of high-potential waves (weak signals) in a high-uncertainty environment. Considering qualitative opinions of experts on a relevant subject, one can use the Fuzzy TOPSIS method to convert them into quantitative ones to prioritize weak signals.

Computing with words (CW), especially when data are vague, is a methodology in which words are used in place of numbers for computing and reasoning. The point of this note is that Fuzzy logic plays a pivotal role in CW and vice-versa. Thus, as an approximation, Fuzzy logic may be equated to CW. There are two major imperatives for computing with words. First, computing with words is a necessity when the available information is too imprecise to justify the use of numbers, and second, when there is a tolerance for imprecision which can be exploited to achieve tractability, robustness, low-cost solution and better rapport with reality. Exploitation of the tolerance for imprecision is an issue of central importance in CW. In CW, a word is viewed as a label of a granule; that is, a fuzzy set of points drawn together by similarity, with the fuzzy set playing the role of a fuzzy constraint on a variable. The premises are assumed to be expressed as propositions in a natural language. In coming years, computing with words is likely to evolve into a basic methodology in its own right with wide-ranging ramifications on both basic and applied levels.

The remainder of this research is organized as follows: In the beginning of this essay, introduction section, we discussed about the importance and necessity of the wildcard study. In Section 2, as the meaning of the concept, weak signal, differs from researcher to researcher, we refer to some definitions of weak signals and the overall philosophy and objectives of the environmental scanning methodology and its application in an environmental analysis process. Then, in Section 3, different classifications of wildcards are discussed, and also, we present our classification of wildcards with the same characteristics, natural wildcards, artificial wildcards (Degree 1) and artificial wildcards (Degree 2); afterward, in Section 4, we apply a combination of panel of experts and Fuzzy TOPSIS method to prioritize weak signals. Ultimately, in Section 5, we conclude and give a briefly explanation of what has been done in this paper.

2. Definition of weak signals and environmental scanning

Weak signals are defined as a significant indication of changes in the environment. In recent literature, there is a wide variety of the definitions of weak signals. The meaning of this concept differs from researcher to researcher, and therefore, the perception of weak signals and also applying them in an organization can be challenging. Note that another challenge to this issue is caused by concepts close to weak signals such as emerging issues, seeds of change, wildcards and early warning signals (Nikander, 2002; Molitor, 2003). Some authors referred to signals of wildcards as weak signals, early warnings or early indicators. It is vital to know that weak signals are not always the evidence of the true state of the emerging issue, which calls for trying to find out more about initial sources of information. It is noticeable to make an obvious distinction between the concept of "weak signal" and the concept of "wildcard". It should be noted that it is theoretically possible that weak signals are dispersed data that mention the appearance of possible wildcard incidents to the policymakers. Generally, there is a large quantity of weak signals in the environment before a wildcard event occurs. However, it is clear that a single weak signal cannot display the mysteries of the future. According to Coffman (1997a), the key factor in utilizing weak signals is to count on the power of a number of signals of emerging issues. If a number of weak signals mentions some development path in the future to us, the possible development can be taken more seriously than with one signal. Also, it is possible that a weak signal continues to be a weak signal and never becomes a vigorous signal or changes into a substantial wildcard. Nevertheless, weak signals are distinguished signs of changes in the natural world. Somehow, the conception of a wildcard is like a sense in which some things are factual shocks to some groups and some individuals. However, some people, who are aware of weak signals, do not get a shock when a wildcard occurs.

Sometimes, researchers consider weak signals as emerging issues or even first indications of change. Moijanen (2003) stated that the only characteristic of a weak signal which is commonly accepted among researchers is the first sign of a possible change in the future. Ansoff was the pioneer of weak signal analysis development and defined weak signals as external (e.g. quality of the work of suppliers is getting worse) or internal (e.g. increase or decrease of absence of the personnel) warnings that are too incomplete to allow a precise estimation of their impact, and/or to determine a complete reply (Ansoff, 1982). He suggested that every event goes through a sequence of levels of knowledge (from weak signal to strong signal). Usually, a sense of environmental turbulence is the earliest identification of the signal. According to Moijanen (2003), there is confusion about the following points and questions in the terms of weak signals: 1 – its relationship to the transition phenomenon, 2 – its duration, 3 – its objectivity versus subjectivity, 4 – different ways to interpret the same signal and strengthening of a weak signal, 5 – receivers/observers/analysts of the signal and 6 – who analyzes and draws the conclusions? These points and questions were discussed by Hiltunen (2008). According to Coffman's (1997a) definition, a weak signal is:

- an idea or a trend that will affect the business or the business environment;
- new and surprising from the signal receiver's vantage point;
- sometimes difficult to track down amid other noise and signals;
- a threat or opportunity to an organization;
- often scoffed at by people who "know";
- has substantial lag time before maturing and becoming mainstream; and
- represents a chance to learn, grow and evolve.

It is also known that an appropriate environmental scanning is required to identify the weak signals of a particular case. Therefore, the overall philosophy and objectives of the environmental scanning methodology and its application in an environmental analysis process are also discussed in this section. Actually, environmental scanning is the careful monitoring of an organization's internal and external environments for discovering early signals of opportunities and threats that may affect its current and future plans. It contains both looking at information (which is called viewing) and looking for information (which is called searching). It should be taken into consideration that surveillance is confined to a specific objective or a narrow sector. Due to the fact that the environmental scanning is a systematical process, the environment will be purposelessly scanned if there is no structured approach and particular purpose to scanning. Clearly, it means that something useful may only be found by luck, not because of an organized approach. However, it is essential to recognize more precisely the effects of correlation between driving forces which have strong impacts on shaping the future. Environmental scanning is known as one of the most basic methods in the futures studies literature, yet is considered the cornerstone of futures studies. A simple but effective definition of environmental scanning is considering it as the acquisition and use of information about events, trends and relationships in an organization's external environment to assist the management in planning the organization's future course of action (Choo and Auster, 1993).

Today's environment is characterized by two features of increasing complexity and rapid changes. Initially, we define the term "rapid changes" in such an environment. "Rapid changes" in various fields of science and technology actually means "rapid progress". Any small or big advances in the fields of science and technology are considered as "rapid change". Rapid changes in other areas such as politics, economy, security, military and industry refer to any kind of small or large evolutions in this context. A glance at what is going on around the world is sufficient to notice that this kind of change has accelerated. Let's not forget that many of the rapid developments in this field are rooted in the rapid advances in science and technology. By environmental scanning, early signs of change are discovered. Meaning of these words is to identify preemptive changes that will occur in the near future. These changes are discovered by the "weak signals of change". For instance, cloudy weather can be a sign of rain in the near future. Rainfall is a climate change that can be damaging in an area. If this change is detected early, local residents and particularly farmers can be prepared in advance to face and deal with it. The example of cloudy weather and rain forecast can imply that the ultimate goal of environmental scanning is to avoid being surprised against changes. Here, a futurist's responsibility is to do an adequate environmental scanning process and to cluster and sense how to identify the emerging futures through a systematically analyzing of patterns, trends, causes of change and stability and economic, technological, social, environmental and political drivers with the aim of making the threats into the opportunities and likely yielding the greatest benefits.

Environmental scanning can be separated into two approaches. On the one hand, the outside-in approach endeavors to scan the entire operational landscape to prevent blind spots. Nevertheless, this approach is easily hampered by the problem of information abundance. On the other hand, the second approach of environmental scanning is the inside-out approach, which restricts the number of fields of interest and the amount of information gathered, but carries the danger of enhancing blind spots by limiting the focus of the organization (Choo and Auster, 1993).

Environmental scanning makes a subjective evaluation of the worth of what is being discovered. Futurists who are doing the scanning process should not ignore what is happening around them and give all their attention to their private thoughts. They need to make sure that their minds do not stop when an inexperienced thing is not suitable for expected patterns. In fact, if futurists are not aware of their world view when scanning, evidence that just might be significant will be missed and, consequently, wrong assumptions will be made (Conway, 2010). This is about taking action beyond conventional and common sources, doing anything new or different rather than following ideas and methods that have existed for a long time and thinking in new ways about existing and potential issues and emerging technologies. It is about looking beyond current ways of working and thinking the unbelievable to find out what might be needed in the future. In brief, it is important to take into account the following points before scanning environment:

- Have an open mind about what might be significant, and deliberately do not make a decision or form a definite opinion about something.
- Continually test your assumptions about why you think something is valuable or not.
- Dismiss nothing until tested (particularly if you think it is rubbish).

As a precedent for classifying wildcards, a detailed definition of weak signals and environmental scanning is presented until this stage. So, the different kinds of wildcards are classified in the next section.

3. Classification of wildcards

On account of the dilemma of the duration of wildcards, Hiltunen (2006) divided wildcard events into irreversible and reversible changes. In this study, when the reversibility of a particular system is considered, the time variable will be the most important element. For some changes to take the same values as in the original state prior to the wildcard event, it might only take some months or years, and subsequently, these events are categorized as reversible changes. If, nevertheless, it takes more than tens of years to restore the original state of affairs or it does not occur at all, that event is labeled as irreversible. Examples of these categories are shown in Table I.

Table I Two types of wildcards

Type of the wildcard	*Example*
Irreversible	Shift of earth's axis
Reversible	Stock market crash

The second classification of wildcards is listed in Table II. In this Table, some examples of wildcards are categorized by reference to change. According to Elina Hiltunen's thesis, "weak signals in organizational futures learning", most of the incidents that authors have called wildcards are very similar to gradual type of change (Table II).

Now, we develop a new classification for wildcards and divide them into three categories: natural wildcards, artificial wildcards (Degree 1) and artificial wildcards (Degree 2). Then, the characteristics of each category are described in detail. As a new classification of wildcards, we refer to natural disasters as "natural wildcards", phenomena such as floods, earthquakes, active or dormant volcanoes, tornados, tsunamis and meteors, which happen quickly and cause a lot of disastrous damage. The probability of occurrence of natural wildcards is not only commensurate with the geographical positions but also can be predictable. As a result, their destructive consequences can be reduced by proper preventive actions.

Also, we mention man-made shocks and surprises, which are named "artificial wildcards". Artificial wildcards (Degree 1) can be anticipated by taking into account weak signals obtained from scanning the decision environment (Ansoff, 1982); these kinds of wildcards are imaginable and probable surprises, such as the 2008 economic crisis, revolutions, oil price shock, etc. In these kinds of wildcards, when identified weak signals get ignored, they might result in wildcards.

Artificial wildcards (Degree 2) are imaginable and improbable surprises with so intangible weak signals. However, they might be difficult to spot. Indeed, despite the wildcards Degree 1, weak signals cannot be detected by the environmental scanning in occurrence of the wildcards Degree 2. In this kind of wildcards, just a particular team is aware of its occurrence, such as a global nuclear war (potentially, possible to happen), the September 11 attacks (Hiltunen, 2013) and atomic bombing of Hiroshima and Nagasaki (realized) (Ansoff, 1982). The artificial wildcards (Degree 2) have positive impacts on organizing stakeholders to achieve their goals and meet their requirements and negative impacts on others who have been chosen to be faced. However, the

Table II Practical examples of wildcards and categorization of them to gradual changes and wildcards

Authors	*Wildcard listed by authors*	*Possible/History wildcard*	*Wildcard/Gradual change*
Rockfellow (1994)	Hong Kong rules china	P	GC
Rockfellow (1994)	Europe goes regional	P	GC
Rockfellow (1994)	Leap from horse to car	H	GC
Rockfellow (1994)	Leap from typewriter to computer	H	GC
Petersen (1999)	A hurricane devastating a town	P/H	WC
Petersen (1999)	Shift of earth's axis	P	WC/GC
Petersen (1999)	Asteroid or comet hits the earth	P	WC
Petersen (1999)	Gulf or jet stream shifts location permanently	P	WC/GC
Cornish (2003), Mendonça *et al.* (2004)	Crashes of WTC Tower, 9/11	H	WC
Mendonça *et al.* (2004)	The fall of Berlin Wall (the reunion of Germany)	H	WC/GC
Mendonça *et al.* (2004)	Major stock market financial crash	P/H	WC
Futurist.com	Thermal depolymerization (everything into oil)	P	GC
Futurist.com	Doubling the life span	P	GC
Mannermaa (1999)	The rights of robots	P	WC/GC
Mannermaa (1999)	A global multimedia monopoly	P	GC

natural wildcards have the same impacts, either positive or negative, on anything (or anyone). For clearing the difference between the wildcards 1 and the wildcards 2, some examples are depicted in Table III.

4. A combination of panel of experts and Fuzzy TOPSIS method

In this paper, the Fuzzy TOPSIS method is applied to prioritize weak signals. Also, there are some prioritization methods, among which Likert scale and Fuzzy analytic hierarchy process (AHP) are the most significant ones; these two methods are mentioned in the following text.

4.1 Likert scale

A psychometric response scale that is primarily used in questionnaires to obtain participants' preferences or degree of agreement with a statement or set of statements. Likert scales are a non-comparative scaling technique and are one-dimensional (only measure a single trait) in nature. Respondents are asked to indicate their level of agreement with a given statement by way of an ordinal scale.

Likert scale weaknesses are as follows:

- *Central tendency bias*: Participants may avoid extreme response categories.
- *Acquiescence bias*: Participants may agree with statements as presented to "please" the experimenter.
- *Social desirability bias*: Participants portray themselves in a more socially favorable light rather than being honest.
- *Lack of reproducibility*.
- *Validity may be difficult to demonstrate*: Are you measuring what you set out to measure?

4.2 Fuzzy analytic hierarchy process

Fuzzy AHP is another method and proves to be a very useful methodology for multiple-criteria decision-making in fuzzy environments, which has found substantial applications in recent years.

In comparison with Fuzzy AHP and Likert scale, Fuzzy TOPSIS performs better in regard to changes of alternatives and criteria, agility and number of criteria and alternatives.

Differences and similarities between Fuzzy AHP and Fuzzy TOPSIS methods are as follows:

- When these two methods are compared with respect to the amount of computations, Fuzzy AHP requires more complex computations than Fuzzy TOPSIS.

Table III Categorization of wildcards

Wildcards	
Examples of wildcards	Type of wildcard N: Natural AD1: Artificial degree 1 AD2: Artificial degree 2
Crashes of WTC Tower, 9/11	AD2
Japan's 2011 earthquake and tsunami	N
Major stock market financial crash	AD1
Atomic bombings of Hiroshima and Nagasaki	AD2
Shift of earth's axis	N
The fall of Berlin Wall (the reunion of Germany)	AD1

- Pair-wise comparisons for criteria, sub-criteria and alternatives are made in Fuzzy AHP, while there is no pair-wise comparison in Fuzzy TOPSIS and is based on their relative distances to positive ideal solution and negative ideal solutions.
- TOPSIS has been proved to be one of the best methods addressing rank reversal issue, that is the change in the ranking of the alternatives when a non-optimal alternative is introduced.
- In the extent analysis of Fuzzy AHP, the priority weights of the criterion or alternative can be equal to zero. In this situation, we do not take this criterion or alternative into consideration. This is one of the disadvantages of this method (Moayeri *et al.*, 2015).

Like other prioritization methods, in TOPSIS, we need a panel of experts to give their opinions and make decisions regarding the issue. In most cases, providing this panel of experts and gathering them around a table are difficult. In addition, weak signals are simply not detectable most of the time, especially in an uncertain environment. Furthermore, this method is sensitive to the combination of panel of experts, and as a result, the final conclusion of the mentioned method can be changed according to the panel of experts' opinions.

The combination of panel of experts and Fuzzy TOPSIS method is applied in this study to identify the most important weak signals. Therefore, the way in which we applied the panel of experts is initially explained, and then application of Fuzzy TOPSIS in this method is described.

In this study, after carrying out the environmental scanning process, it is supposed that five weak signals are identified. The goal is to apply a method in which a panel of 20 experts attends to prioritize the aforementioned weak signals. The selected experts have high formal status in a business community (e.g. CEOs) or in some scientific community (e.g. leading professors) in the fields of economic, social sciences, politic, technology and environment. These weak signals can become the strong signals which likely yield to the wildcards. So, it is a good idea to put them in order of importance to deal with the most important ones sooner. As a matter of fact, this method ranks the weak signals from the most important one to the least important one. The sequence of steps that must be performed in this method is:

1. Determine the decision-making committee and identify the evaluation criteria.
2. Select the appropriate linguistic variables for the weight of each criterion and for the weight of each alternative.
3. Determine the weight of each criterion and the weight of criteria for each alternative after integrating opinions.
4. Formation of the fuzzy normalized decision matrix.
5. Create the fuzzy weighted normalized decision matrix.
6. Determine the fuzzy negative and positive ideal solutions.
7. Calculate the distance of each alternative from the positive and negative ideal solution.
8. Calculate the closeness coefficient of each alternative.
9. Rank the alternatives according to closeness coefficient.

Before explaining these steps in detail, we define the developed TOPSIS method which is used in some of these steps. A brief description of the TOPSIS method is presented here and then it is extended for fuzzy data. Indeed, TOPSIS is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon (2012), with further developments by Yoon (1987) and Hwang *et al.* (1993).

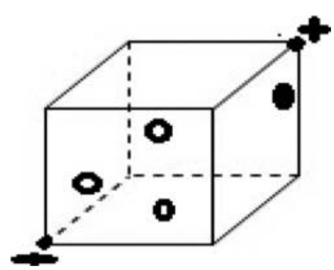
The underlying logic of TOPSIS is to define the ideal solution and negative ideal solution. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution is the solution that maximizes the cost criteria and minimizes the benefit criteria. In short, the ideal solution consists of all best values attainable of criteria, whereas the negative ideal solution is composed of all worst values attainable of criteria. The optimal alternative is the one which has the shortest distance from the ideal solution and the farthest distance from the negative ideal solution. Because of different comments of different experts for weighting the criteria, a fuzzy group weight is needed. In Fuzzy TOPSIS, in addition, the technique of positive and negative ideal solution is easily used to find the best alternative, considering that the chosen alternative should simultaneously have the shortest distance from the positive ideal point and the longest distance from the negative ideal point (Zadeh, 1975; Yeh *et al.*, 1999, 2000; Kuo *et al.*, 2007).The positive ideal solution is composed of all best criteria values attainable, and the negative ideal solution is composed of all worst criteria values attainable.

To make it easy to understand, we illustrate an example of using the TOPSIS method for identifying the most important weak signal among four weak signals. In Figure 1, the (+) sign and the (–) sign in cube vertexes show the positive ideal solution and the negative ideal solution, respectively. The four circles inside the cube are the weak signals, and the shaded circle is chosen as the most important weak signal.

Fuzzy TOPSIS is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. Notice that an important assumption of TOPSIS is that the criteria are monotonically increasing or decreasing. Normalization is usually required, as the parameters or criteria are often of incongruous dimensions in multi-criteria problems (Yoon and Hwang, 1995; Zavadskas *et al.*, 2006). Compensatory methods such as TOPSIS allow trade-offs between criteria where a poor result in one criterion can be negated by a good result in another criterion. This provides a more realistic form of modeling than non-compensatory methods, which include or exclude alternative solutions based on hard cut-offs (Huang *et al.*, 2011). Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values), Fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions. Now, we can explain all steps of the aforementioned method as below:

1. *Step 1*: Determine the decision-making committee and identify the evaluation criteria:
   - establish a committee including 20 experts; and

Figure 1 A schematic example for understanding the TOPSIS method; the shaded circle is chosen as the most important weak signal



- choose 5 criteria which could have a strong impact on weak signals (economical driver, societal driver, political driver, technological driver and environmental driver) (Figure 2).

2. *Step 2*: Select the appropriate linguistic variables for the weight of each criterion and for the weight of each alternative.

   In fuzzy set theory, conversion scales are applied to transform the linguistic terms into fuzzy numbers. In this paper, we will apply a scale of 0 to 1 for rating the criteria and 1 to 10 for rating the weak signals. The linguistic variables and fuzzy ratings for the criteria and the weak signals are presented in Tables IV and V.

3. *Step 3*: Determine the weight of each criterion and the weight of criteria for each alternative after integrating opinions (Tables VI-VIII).

   Let's say the panel of experts has K members. If the fuzzy rating and importance weight of the *K*th expert, about the *i*th weak signals on *jth* criterion, are:

   $\tilde{x}_{ij}^{k} = (a_{ij}^{k}, b_{ij}^{k}, c_{ij}^{k})$ and $\widetilde{w}_{j}^{k} = (w_{j1}^{k}, w_{j2}^{k}, w_{j3}^{k})$, respectively, where $i = 1, 2, \ldots, m$, and $j = 1, 2, \ldots, n$, then aggregated fuzzy ratings $\tilde{x}_{ij}$ of weak signals (i) with respect to each criterion (j) are given by $\tilde{x}_{ij} = (a_{ij}, \ b_{ij}, c_{ij})$ such that:

Figure 2 A hierarchy model for prioritizing the weak signals

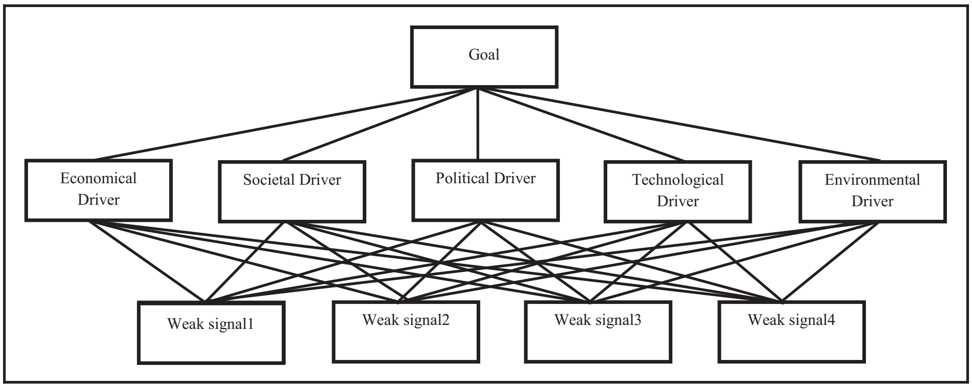


Table IV Linguistic variables for the importance weight of each criterion

Linguistic variables	
Very low (VL)	(0, 0, 0.1)
Low (L)	(0, 0.1, 0.3)
Medium low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium high (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)
Very high (VH)	(0.9, 1.0, 1.0)

Table V Linguistic variables for the ratings

Linguistic variables	
Very poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very good (VG)	(9, 10, 10)

Table VI The ratings of the four weak signals by experts under all criteria

Driver forces Criteria	*Weak signals*	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}	E_{16}	E_{17}	E_{18}	E_{19}	E_{20}
Economical driver	Weak signal$_1$	MG	G	G	MG	G	MG	G	VG	MG	MG	VG	VG	MG	G	MG	VG	VG	G	MG	MG
	Weak signal$_2$	F	MG	G	F	G	MG	MG	F	MG	F	MG	VG	MG	G	F	F	MG	G	MG	VG
	Weak signal$_3$	MP	P	F	F	MG	P	MP	F	G	MP	MG	P	G	P	P	MP	P	G	MG	MP
	Weak signal$_4$	MG	F	MG	VG	VG	G	MG	G	G	MG	G	MG	G	F	MP	VG	G	F	MP	MG
Societal driver	Weak signal$_1$	F	MP	G	F	G	MG	F	MG	F	MG	MP	MG	G	MP	F	MP	MG	P	G	MG
	Weak signal$_2$	VP	F	MP	P	MP	MG	VP	F	G	G	P	VP	F	MG	MP	P	G	F	MP	P
	Weak signal$_3$	VG	MP	MG	G	F	P	VG	G	MG	F	G	F	MG	MG	VG	G	MG	MP	VG	F
	Weak signal$_4$	MP	MG	P	G	P	F	MP	P	G	MP	G	MG	MG	VG	MP	MG	G	MP	F	MG
Political driver	Weak signal$_1$	VG	F	G	MG	MG	G	MG	F	G	F	MG	G	MP	MG	P	G	P	VG	F	MG
	Weak signal$_2$	MP	P	MG	VP	F	P	G	G	MP	F	G	MG	MP	MG	VG	G	MG	MP	P	MP
	Weak signal$_3$	VG	F	MG	VG	VG	G	MG	G	G	MG	G	VG	G	F	MP	VG	G	F	VG	G
	Wek signal$_4$	VP	MP	F	P	MG	MP	VP	P	MP	VP	P	VP	MP	F	P	G	MG	MP	VP	F
Technological driver	Weak signal$_1$	G	MG	MG	VG	G	F	VG	F	MG	MG	VG	G	G	MG	MG	VG	G	VG	F	MG
	Weak signal$_2$	p	F	MP	MG	G	F	MP	F	MG	MG	F	G	MP	MG	MG	F	G	p	F	MG
	Weak signal$_3$	VG	G	F	MP	VG	G	F	VG	G	VG	G	F	VG	G	MG	MG	G	MG	F	VG
	Weak signal$_4$	MP	P	MG	VP	F	P	F	G	MP	F	G	MG	MP	MG	VP	G	MG	MP	P	MP
Environmental driver	Weak signal$_1$	VG	G	MG	F	G	MG	MG	G	MG	F	VG	VG	G	MG	MG	F	G	MG	VG	G
	Weak signal$_2$	VP	P	MP	VP	P	VP	MP	MG	VP	G	MG	MP	P	MP	MP	MG	G	F	VP	MP
	Weak signal$_3$	F	MG	VG	VG	G	MG	MG	F	G	MG	MG	G	MG	F	VG	MG	VG	G	G	MG
	Weak signal$_4$	VG	F	F	G	MG	MG	G	MG	F	VG	VG	MG	F	MG	F	VG	VG	G	MG	MG

Table VII The importance of the criteria

Driver forces	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}	E_{16}	E_{17}	E_{18}	E_{19}	E_{20}
Economical driver	ML	VL	M	L	M	MH	L	ML	L	VL	VL	M	M	M	MH	L	VL	M	M	ML
Societal driver	H	VH	MH	H	M	MH	L	ML	H	VH	VL	ML	H	M	MH	H	VH	M	MH	VH
Political driver	VH	VH	M	MH	H	MH	H	VH	M	H	VH	M	H	VH	VH	VH	H	MH	H	VH
Technological driver	M	ML	H	M	VH	MH	VH	ML	H	H	MH	VH	M	M	VH	MH	VH	MH	M	H
Environmental driver	L	ML	H	M	M	MH	ML	ML	H	L	ML	MH	M	ML	MH	MH	ML	MH	M	ML

Table VIII The fuzzy decision matrix and fuzzy weights of four weak signals

Weak signals	*Economical driver*	*Societal driver*	*Political driver*	*Technological driver*	*Environmental driver*
Weak signal$_1$	(6.6, 8.4, 9.6)	(3.9, 5.8, 7.6)	(4.8, 6.6, 8.2)	(6.2, 8, 9.2)	(6.1, 7.9, 9.2)
Weak signal$_2$	(5.2, 7.1, 8.7)	(2.4, 3.9, 5.6)	(1.3, 2.3, 3.6)	(3.6, 5.5, 7.4)	(1.9, 3.3, 4.9)
Weak signal$_3$	(2.5, 4.2, 6)	(5.2, 7, 8.3)	(6.4, 8.1, 9.2)	(6.2, 7.9, 9)	(6, 7.8, 9.2)
Weak signal$_4$	(5.5, 7.4, 8.8)	(3.7, 5.5, 7.2)	(1.6, 2.9, 4.6)	(2.8, 4.4, 6.2)	(5.8, 7.6, 8.9)
Weight	(0.17, 0.3, 0.5)	(0.5, 0.68, 0.8)	(0.7, 0.85, 0.94)	(0.55, 0.73, 0.85)	(0.3, 0.48, 0.67)

$$\alpha_{ij} = \frac{1}{k}\sum_{k=1}^{k} \alpha_{ij}^{k},\quad b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ij}^{k},\; c_{ij} = \frac{1}{k}\sum_{k=1}^{k} c_{ij}^{k}$$

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \dots & \tilde{x}_{1n} \\ \vdots & \dots & \vdots \\ \tilde{x}_{m1} & \dots & \tilde{x}_{mn} \end{bmatrix} \qquad \tilde{W} = [\tilde{w}_{1,} \dots \tilde{w}_{k,} \dots \tilde{w}_{n}]$$

$$\tilde{x}_{ij} = \frac{1}{k}[\tilde{x}_{ij}^{1} + \tilde{x}_{ij}^{2} + \dots + \tilde{x}_{ij}^{k}] \qquad \tilde{w}_{j} = \frac{1}{k}[\tilde{w}_{j}^{1} + \tilde{w}_{j}^{2} + \dots + \tilde{w}_{j}^{k}]$$

Where $\tilde{x}_{ij}$, $\forall\, i, j$ and $\tilde{w}_j$, $i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$ are linguistic variables which can be described by triangular fuzzy numbers, $\tilde{x}_{ij} = (a_{ij},\ b_{ij},\ c_{ij})$ and $\tilde{w}_j = (w_{j1},\ w_{j2},\ w_{j3})$. To keep the normalization formula simple, the linear scale transformation is used to transform various criteria scales into a comparable scale. Thus, we have the normalized fuzzy decision matrix as follows:

4. *Step 4*: Formation of the fuzzy normalized decision matrix (Table IX):

Table IX The fuzzy normalized decision matrix

	Economical	*Societal*	*Political*	*Technological*	*Environmental*
Weak $signal_1$	(0.69, 0.88, 1)	(0.47, 0.7, 0.92)	(0.52, 0.72, 0.89)	(0.67, 0.87, 1)	(0.66, 0.86, 1)
Weak $signal_2$	(0.54, 0.74, 0.9)	(0.29, 0.47, 0.67)	(0.14, 0.25, 0.4)	(0.4, 0.6, 0.8)	(0.21, 0.36, 0.53)
Weak $signal_3$	(0.26, 0.44, 0.63)	(0.63, 0.84, 1)	(0.7, 0.88, 1)	(0.67, 0.86, 0.98)	(0.65, 0.85, 1)
Weak $signal_4$	(0.57, 0.77, 0.92)	(0.45, 0.66, 0.87)	(0.17, 0.32, 0.5)	(0.3, 0.48, 0.67)	(0.63, 0.83, 0.97)

$$\widetilde{R} = [\tilde{r}_{ij}]_{m\times n},\ \mathrm{i} = 1, 2, \ldots, \mathrm{m};\ \mathrm{j} = 1, 2, \ldots, \mathrm{n}$$

Where:

$$\tilde{r}_{ij} = \left(\frac{\alpha_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right),\ \mathrm{j} \in \mathrm{B};\ \text{for positive criteria}$$

$$\tilde{r}_{ij} = \left(\frac{\alpha_j^-}{c_{ij}}, \frac{\alpha_j^-}{c_{ij}}, \frac{\alpha_j^-}{c_{ij}}\right),\ \mathrm{j} \in \mathrm{C};\ \text{for negative criteria}$$

$$c_j^* = \max{}_i c_{ij}\ \text{if j} \in \mathrm{B};$$

$$\alpha_j^- = \min{}_i a_{ij}\ \text{if j} \in \mathrm{C};$$

The above normalization on method preserves the property that the ranges of normalized triangular fuzzy numbers belong to [0, 1].

5. *Step 5*: Create the fuzzy weighted normalized decision matrix.

   The weighted normalized fuzzy decision matrix $\tilde{\nu}$ is computed by multiplying the weights ($\widetilde{w_j}$) of evaluation criteria with the normalized fuzzy decision matrix $\tilde{r}_{ij}$ as (Table X):

$$\tilde{\nu} = [\tilde{\nu}_{ij}]_{m\times n}, i = 1, 2, \ldots, m, j = 1, 2, \ldots, n, \tilde{\nu}_{ij} = \tilde{r}_{ij}(.)\widetilde{w_j}$$

6. *Step 6*: Determine the fuzzy negative and positive ideal solution: FNIS, FPIS.

   The FNIS and FPIS of the alternatives are defined as follows:

$$A^* = (\tilde{\nu}_1^*, \tilde{\nu}_2^*, \ldots, \tilde{\nu}_n^*),$$

$$A^- = (\tilde{\nu}_1^-, \tilde{\nu}_2^-, \ldots, \tilde{\nu}_n^-),$$

$$A^* = [(1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1)]$$

$$A^- = [(0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0)]$$

7. *Step 7*: Calculate the distance of each alternative from the positive and negative ideal solution.

   The distance (d_i^* *and* d_i^-) of each weighted alternative i = 1, 2, ..., n from the FNIS and the FPIS is computed as follows:

$$d_i^* = \sum_{j=1}^{n} d(\tilde{\nu}_{ij}, \tilde{\nu}_j^*), \quad i = 1, 2, \ldots, m,$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{\nu}_{ij}, \tilde{\nu}_j^-), \quad i = 1, 2, \ldots, m,$$

   Where d($\widetilde{m}$, $\tilde{n}$) is the distance measurement between two fuzzy number $\widetilde{m}$ and $\tilde{n}$. The distance between two fuzzy numbers is calculated by the following formula:

Table X The fuzzy weighted normalized decision matrix

	Economical	*Societal*	*Political*	*Technological*	*Environmental*
Weak $signal_1$	(0.12, 0.26, 0.5)	(0.23, 0.48, 0.73)	(0.37, 0.61, 0.84)	(0.37, 0.63, 0.85)	(0.2, 0.41, 0.67)
Weak $signal_2$	(0.09, 0.22, 0.45)	(0.14, 0.32, 0.54)	(0.1, 0.21, 0.37)	(0.22, 0.44, 0.68)	(0.06, 0.17, 0.36)
Weak $signal_3$	(0.04, 0.13, 0.31)	(0.31, 0.57, 0.8)	(0.49, 0.75, 0.94)	(0.37, 0.63, 0.83)	(0.2, 0.41, 0.67)
Weak $signal_4$	(0.1, 0.23, 0.46)	(0.22, 0.45, 0.69)	(0.12, 0.27, 0.47)	(0.17, 0.35, 0.57)	(0.19, 0.4, 0.65)

$$\tilde{m} = (m_1, m_2, m_3), \tilde{n} = (n_1, n_2, n_3)$$

$$d(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$$

For instance, we calculate the distance of weak signal_1 from the positive ideal solution by the above-mentioned formula:

$$A^* = [(1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1)]$$

$$\tilde{m} = [(0.12,\ 0.26,\ 0.5), (0.23,\ 0.48,\ 0.73), (0.37,\ 0.61,\ 0.84), (0.37,\ 0.63,\ 0.85), (0.2,\ 0.41,\ 0.67)]$$

$$\boldsymbol{d}(\tilde{m}, A^*) = \sqrt{\begin{array}{l}\frac{1}{3}[(0.12 - 1)^2 + (0.26 - 1)^2 + (0.5 - 1)^2] + \quad \ldots \quad + \\ \frac{1}{3}[(0.2 - 1)^2 + (0.41 - 1)^2 + (0.67 - 1)^2]\end{array}} = 2.76$$

The distance measurement of each alternative from the positive and negative ideal solution is shown in Table XI:

8. *Step 8*: Calculate the closeness coefficient of each alternative.

   In this step, we want to prioritize alternatives and to put them in order so that the first alternative is the one which not only has the longest distance from the negative ideal solution but also has the lowest distance from the positive ideal solution.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-},\ i = 1, 2, ..., m,$$

$$CC_1 = \frac{2.61}{2.76 + 2.61} = 0.49, CC_2 = 0.33, CC_3 = 0.51, CC_4 = 0.36$$

- Weak signal_3
- Weak signal_1
- Weak signal_4
- Weak signal_2

The alternative with the highest coefficient represents the best alternative and is closest to the FPIS and farthest from the FNIS.

In this way, we were able to prioritize identified weak signals; it helps us take into account the most important of them and take necessary and appropriate actions to avoid their catastrophic consequences in the n future. To clarify the proposed method, a case study is carried out in a tobacco company:

Please note that the presented quantities in context of the article (Tables VI and VII) are based on this case study.

After environmental scanning, four relevant weak signals which could have threatened the company's market were identified; then, a panel of 20 experts from the sales and marketing, research and development, financial and strategic planning departments was asked to give their opinions about the importance of identified weak signals on the tobacco market taking into account five driver forces (economical, societal, political, technological and environmental). The procedure is elaborated in the following text.

Table XI The distance measurement

	A^+	A^-
Weak signal_1	2.76	2.61
Weak signal_2	2.81	1.4
Weak signal_3	2.09	2.18
Weak signal_4	2.72	1.52

The identified weak signals are:

1. Weak signal 1: Appointments based on favoritism not on meritocracy:
   - It is revealed that in the abovementioned company, appointments are not based on meritocracy, which will lead to loss of the market in the future.
2. Weak signal 2: Plain packaging:
   - In some countries, special laws have been enacted to minimize any attractiveness of tobacco products using plain packaging.
3. Weak signal 3: Increase in tax and toll:
   - According to the World Health Organization (WHO), there is a negative correlation between increasing taxes and reducing the consumption of cigarettes.
4. Weak signal 4: Electronic cigarettes:
   - This type of cigarettes does not cause many diseases, and it may be used as a surrogate of tobacco cigarettes.

Prioritizing the four weak signals using the Fuzzy TOPSIS method:

1. *Step 1:* A committee including 20 experts from the sales and marketing, research and development, financial and strategic planning departments was established.

   Five criteria, including economical driver, societal driver, political driver, technological driver and environmental driver, were chosen as important criteria.
2. *Step 2:* Appropriate linguistic variables for criteria (driver forces) and the weight of weak signals are shown with triangle fuzzy numbers in Tables IV and V, respectively.
3. *Step 3:* 20 experts, as mentioned before, were asked to rate the importance of weak signals using linguistic variables with regard to driver forces (Table VI); in addition, experts were asked to rate the importance of each driver force in comparison to the others using linguistic variables (Table VII). Using the equations described in Step 3, the fuzzy decision matrix and fuzzy weights of four weak signals were established (Table VIII).

   During the next steps, mathematical fuzzy formulas were applied on the fuzzy decision matrix (Table VIII) to put the weak signals in order. Finally, we were able to prioritize identified weak signals as follows:
   - *Weak signal 3*: Increase in tax and toll.
   - *Weak signal 1*: Appointments based on favoritism not on meritocracy.
   - *Weak signal 4*: Electronic cigarettes.
   - *Weak signal 2*: Plain packaging.

The proposed method has been applied in the tobacco Company to prioritize identified weak signals which could have strong impacts on the future of the company's market; as a result, increase in tax and toll was chosen as the most important weak signal. So that, if the company ignores this weak signal and does not take appropriate action, it will end up with market share loss and illicit tobacco products will be replaced by its products.

5. Conclusion

In this paper, first, we examined Hiltunen's categorizations of wildcards. Afterward, we presented our classification of wildcards with the same characteristics being natural wildcards, artificial wildcards (Degree 1) and artificial wildcards (Degree 2); according to all aforementioned explanations, it is notable that the most unimportant changes in turbulent environments may cause a substantial change; environmental scanning makes it easy to see and notice weak signals in advance. As the result, the environmental scanning should be required to collect information on the future emerging issues and weak signals. Following environmental scanning and identifying weak signals, the proposed method "combination of panel of experts and Fuzzy TOPSIS" can be applied to prioritize the weak signals to deal with the most important ones and take appropriate action in advance so as to minimize possible damages and maximize the benefits of potential wildcards in an uncertain environment. To clarify the proposed method, a case study is carried out in a tobacco company and the results of this case study have been shown in the paper.

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