Original Article

Application of the Grey System Theory in Vehicles Marketing

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Abstract

In this study, fuzzy sets, soft sets, and fuzzy soft sets are integrated with grey relational analysis to investigate decision-making under uncertainty. An algorithm is introduced, combining choice value and score value to improve evaluation accuracy and address limitations of traditional methods. The approach is applied to sustainable development goals, emphasizing electric vehicles as a solution to reduce carbon emissions and promote clean energy. The paper provides theoretical insights and practical case study.

Keywords: Riyadh Expo 2030; Fuzzy set; Soft set; Fuzzy soft set; Grey theory; Decision-making.

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1 INTRODUCTION

In our real and wide world clarity does not always come on a golden platter. Instead, there are innumerable issues that are shrouded in confusion and doubt. Zadeh[1] defined fuzzy sets as categories and the degree of each member within these categories as a first step in removing any doubt. Molodstove then introduced the concept of soft sets, which may be described as a new mathematical paradigm for dealing with uncertainty, and he successfully applied it in a number of domains [2] and [3]. After that, Maji et al. conducted a thorough theoretical analysis of soft sets [4] and demonstrated how to use them in decision-making problems [5]. One of the many academics who have lately examined the qualities and applications of soft sets is Xiao et al. [6], who specifically examined a synthetically evaluating approach for business competitive capability and who also recognized soft information based on the theory of soft sets. Soft sets are a class of particular information systems, according to scholars Pei and Miao [7]. One of the most significant aspects of this work was the presentation of data analysis approaches for soft sets with imperfect information by Zoe and Xiao [8]. Ali et al. [10] presented the examination of several operations on soft sets, while Majumdar and Samanta [9] investigated the similarity measure of soft sets. Maji et al. [11] introduced the notion of fuzzy soft sets, or *f*s-sets, by incorporating the concepts of fuzzy sets. In addition to several researchers who have sets, Roy and Maji [12] provided some applications of fs-sets. Zoe and Xiao [9] introduced the fuzzy soft set and soft set into the incomplete environment.

There are many different ways to study every aspect of a decision before making it, and in order to help us make the best choice, there are evaluation bases (value of expression when the variables are replaced by a given number), and the evaluation methods used to deal with that are completely different. In this study, we used two evaluation bases: score value (the quantity of parameters with a significantly higher membership value of an item) and choice value (for a single object, we compute the total of all membership levels). Both choice value and score value are based on a single judgment, are biased, and lack sufficient information. The grey relational analysis approach, a vital method in grey system theory, created by Ding Julong, will be applied in the algorithm of this paper to address a decision-making problem rooted in grey theory [13]. In this context, we combine the two evaluation methods to facilitate decision-making within a fuzzy soft set through grey relational analysis. Alongside employing the relational degree for each item, we also utilize the relational grade as the basis for evaluation, we also compute the correlational degree for each object. It is important to note that research on the grey hypothesis is still ongoing, albeit with various standards, models, and evaluations, as seen in [14][15].

In the context of worldwide innovations and sustainability projects, the Riyadh Expo 2030[16] is a significant venue for showcasing innovative ideas and global endeavors to accomplish sustainable development. One of its primary goals is to promote clean energy alternatives, which aligns with the seventh Sustainable Development Goal (SDG), which emphasizes the need for affordable, reliable, and sustainable energy sources. This emphasis on clean energy is crucial for addressing climate issues and reducing carbon emissions in industries like transportation, where electric vehicles (EVs) present a viable alternative to fossil fuel-dependent solutions.

In this paper, we connect the seventh Sustainable Development Goal—which is related to electric vehicles—to the goals of Expo Riyadh 2030. This is based on the notion that in order to reduce carbon emissions from the use of traditional, fossil fuel-powered cars and to slow down climate change, inexpensive, renewable energy sources are required.

The justification for supporting climate change programs worldwide is that the global unification of vehicle carbon emissions legislation could improve air quality in countries [17]. Compared to cars that run on gasoline or diesel, electric vehicles (EVs) are a more environmentally responsible choice since they emit fewer greenhouse gases that contribute to climate change and less damaging air pollution.

Most cars and other vehicles use a "internal combustion engine" (ICE), which burns fuels produced from oil. These fuels release various pollutants from the exhaust systems of the cars, including carbon dioxide (CO2), which is a contributing factor to climate change [18].

The structure of the paper is as follows. We went over some fundamental definitions of fuzzy sets, soft sets, and fuzzy soft sets in section 2. An algorithm employed in the gray theory system is demonstrated, defined, and presented in section 3. We talk about case studies in section 4. The conclusion of this paper is presented in section 5.

2 Materials and Methods

In this section, we examine definitions of fuzzy sets, soft sets and fuzzy soft sets. Let $\boldsymbol{U}$ represent an initial universe set and let $\boldsymbol{E}$ denote a set of parameters.

Definition 2.1 (See[19]) A pair (U,μ) is called a fuzzy set over U and $\mu: U \longrightarrow [0,1]$ is a membership function where for each element $x \in U$, the value $\mu(x)$ is called the grade of membership of x in (U,μ).

For a finite set $U = \{x_1, x_2, \dots, x_n\}$, the fuzzy set is often denoted by $\{\mu(x_1)/x_1, \mu(x_2)/x_2, \dots, \mu(x_n)/x_n\}$. The fuzzy set theory can be used in a wide range of domains in which information is incomplete or imprecise.

Example 2.1 Let $U = \{c_1, c_2, c_3, c_4, c_5\}$ be a set of chairs and let $\tilde{A}$ be the fuzzy set of "comfortable" chairs, where "comfortable" is fuzzy term.

$$\tilde{A} = \{(c_1, 0.6)(c_2, 0.4)(c_3, 0.9)(c_4, 1)(c_5, 0.2)\}.$$

Here $\tilde{A}$ indicates that of c_1 is 0.6 and so on.

Definition 2.2 (See[20]) A pair (F,E) is referred to as a soft set (over U) if and only if F is a maps of E into the collection of all subsets of the set U, i.e., $F: E \longrightarrow P(U)$ where $P(U)$ denotes as the power set of U, and E is the set of parameters.

The soft set is a parameterized family of subsets of the set U, Every set $F(\alpha)$, $\alpha \in E$, from this family may be considered as the set $\alpha -$ elements of the soft set (F,E) , or the set $\alpha -$ approximate elements of the soft set.

The primary distinction between classical mathematics and soft set theory is the introduction of approximate solutions in soft set, whereas classical mathematics lacks this feature and typically employs mathematical models that are overly complex for determining exact solutions

Example 2.2. Let $U = \{y_1, y_2, y_3, y_4\}$ be a set of yachts and $E = \{e_1, e_2, e_3, e_4\}$ be a set of status of yachts, which stand for parameters ''five passengers or more'', ''reasonable price'', ''have a bedroom'' and ''beautiful'' respectively. Consider the mapping F to be a function from E into the collection of all subsets of the set U. Now a soft set (F,E) is defined to describes the ''advantages of yachts for rent''.

Based on the gathered data, the soft set (F,E) is defined by

$\{F,E\} =$

$\{(e_1, \{y_1, y_4\}), (e_2, \{y_2, y_3, y_4\}), (e_3, \{y_2, y_3\}), (e_4, \{y_2, y_4\})\}$

where $F(e_1) = \{y_1, y_4\}, F(e_2) = \{y_2, y_3, y_4\}, F(e_3) = \{y_2, y_3\}$, $F(e_4) = \{y_2, y_4\}$. Assume that Mr.X is want to rent a yacht on the basis of his choice parameters ''five passengers or more'', ''have a bedroom''.etc. Refer to the choice value, Mr.X has the option to rent y_2 or he may opt to rent y_4.

To interduce the soft set (F,E) in computer for the last example we will use a table that have two-dimensional as in following

U	e_1	e_2	e_3	e_4	Choice value
y_1	1	0	0	0	1
y_2	0	1	1	1	3
y_3	0	1	1	0	2
y_4	1	1	0	1	3

Table 4: soft set table.

Table 1 is is the tabular representation of the soft set (F,E). If $y_i \in F(e_j)$, then $y_{ij} = 1$, otherwise $y_{ij} = 0$, where y_{ij} are the entries.

Definition 2.3 (See[12]) Let $\varsigma(U)$ represent the collection of all fuzzy sets of U. Let $A \subseteq E$ and (F,E) is a pair referred to as a fuzzy soft set (fs-set) defined over U where F is a mapping given by

$$F: A \longrightarrow \varsigma(U)$$

From this point onward, we will substitute the term 'fuzzy soft set' with 'fs-set'.

Definition 2.4 (See[11]) The union of a pair of fs-sets (F,N) and (S,R) in a soft class (U,E) it will be a fs-set (A,M) where $M = N \cup R$ and $\forall \varepsilon \in M$

$$A(\varepsilon) = \begin{cases} F(\varepsilon), & if\ \varepsilon \in N - R \\ S(\varepsilon), & if\ \varepsilon \in R - N \\ F(\varepsilon) \cup S(\varepsilon), & if\ \varepsilon \in N \cap R \end{cases}$$

And is written as $(F,N)\ \tilde{\cup}\ (S,R) = (A,M)$.

Definition 2.5 (See[11]) The intersection of two fs-sets (F,N) and (S,R) in a soft class (U,E) is a fs-set (A,M) where $M = N \cap R$ and $\forall \varepsilon \in M, A(\varepsilon) = F(\varepsilon)$ or $S(\varepsilon)$ (as both are same fuzzy set) and is written as $(F,N)\ \tilde{\cap}\ (S,R) = (A,M)$.

Definition 2.6 (See[12]) A fs-sets (F,N) and (S,R) across a shared universe U, (F,N) is a fuzzy soft subset of (S,R) if (i) $N \subset R$, and (ii) $\forall \varepsilon \in N, F(\varepsilon)$ is a fuzzy subset of $S(\varepsilon)$. We write $(F,N) \tilde{\subseteq} (S,R)$. (F,N) is said to be a fuzzy super set of (S,R), if (S,R) is a fuzzy soft subset of (F,N). We refer to it as $(F,N) \tilde{\supseteq} (S,R)$. The algorithm of fs-set in decision making problem is mentioned in [19].

Definition 2.7 (See[22]) The complement of fs-set (F,N) is denoted by $(F,N)^c$ and is defined by $(F,N)^c = (F^c, N)$ where $F^c: N \longrightarrow \tilde{P}$ is a mapping given by$|F^c(\alpha)| = |F(\alpha)|^c, \forall \alpha \in N$.

Grey systems theory, probability theory, fuzzy systems theory, and rough set theory are recognized as four scientific methodologies for managing uncertainty. In control theory[23], researchers commonly utilize colors to illustrate the level of certainty in information.

When a system's information is fully understood, it is classified as white. Conversely, if a system's information is entirely unknown, it is categorized as black. Therefore, systems that possess both known and unknown information are termed grey; similarly, phenomena that exhibit a mix of known and unknown information are described as having poor information.

Definition 2.8 (See[24]) The mathematical framework established around the foundation of grey hazy sets, grey operations, and covered operations; a collection of methods designed for managing information through grey incidence analysis, grey sequence generation, and the grey GM(1,1) model. This framework comprises techniques formulated for assessment, forecasting, decision-making, control, and optimization (the combination of these method and technique systems is referred to as the technology for processing grey information). Additionally, it includes a range of applications in grey systems engineering. etc.

Algorithm In this paragraph we show the steps of an algorithm that we will use at the case study of this paper.

Step 1.

Input specific evaluation criteria. For instance, we will utilize the choice value sequence c_i and the score value sequence s_i, which are linked to the object v_i.

Step 2.

Grey relational generating

$$c_i' = \frac{c_i - Min\{c_i, i = 1,2,\dots,n\}}{Max\{c_i, i = 1,2,\dots,n\} - Min\{c_i, i = 1,2,\dots,n\}}$$

$$s_i' = \frac{s_i - Min\{s_i, i = 1,2,\dots,n\}}{Max\{s_i, i = 1,2,\dots,n\} - Min\{s_i, i = 1,2,\dots,n\}}$$

Step 3.

Reorder sequence. $\{c_1', s_1'\}, \{c_2', s_2'\}, \dots,$ where $\{c_i', s_i'\}$ is associated with v_i.

Step 4.

Difference information.

$$c_{max} = Max\{c_i', i = 1,2,\dots,n\}, s_{max} = Max\{s_i', i = 1,2,\dots,n\},$$

$$\Delta c_i' = |c_{max} - c_i'|, \Delta s_i' = |s_{max} - s_i'|,$$

$$\Delta_{max} = Max\{\Delta c_i', \Delta s_i', i = 1,2,\dots,n\},$$

$$\Delta_{min} = Min\{\Delta c_i', \Delta s_i', i = 1,2,\dots,n\}.$$

Step 5.

Grey relative coefficient

$$\gamma(c, c_i) = \frac{\Delta_{min} + \xi * \Delta_{max}}{\Delta c_i' + \xi * \Delta_{max}},$$

$$\gamma(s, s_i) = \frac{\Delta_{min} + \xi * \Delta_{max}}{\Delta s_i' + \xi * \Delta_{max}}.$$

where ξ is a significant factor in Grey Relational Analysis (GRA) [16] is the distinguishing coefficient, which is utilized to broaden the scope of the grey relational coefficient. This coefficient is confined to a closed interval $\xi \in [0,1]$. We assume that $\xi = 0.85$ in this paper.

Step 6.

Grey relational grade:

The grey relational grade between two points is a measurement of their relationship in a certain data set. Where financial time series data are concerned,

$$\gamma(v_i) = \left(\omega_1 * \gamma(c, c_i) + \omega_2 * \gamma(s, s_i)\right),$$

Where $\omega_i, i = 1,2$ is the wight of evaluation factor, $\omega_1 + \omega_2 = 1$. In this paper $\omega_1 = 0.45$ and $\omega_2 = 0.55$.

Step 7.

Decision making. The decision is v_k if $v_k = \max \gamma(v_k)$. Beside the optimal choice code have more than one if there are more objects corresponding to the maximum.

3 Results

In this section, we aim to market in order to choose the best electric vehicle in terms of specifications to reduce the amount of carbon that causes climate problems. Since one of the most important goals of Riyadh Expo is to work on the climate so that the damage caused by carbon emissions from ordinary vehicles that rely on fossil fuels are reduced and replaced by electric vehicles that are less harm to the climate, much less carbonate and environmentally friendly. We evaluate various options and implement the grey analysis algorithm to address a decision-making issue using a fs-set.

The dataset we have considered for input variable from Electric Vehicle Database.

Let universe $U = \{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}\}$ be a set of electric vehicles display in Saudi Arabia, $E = \{e_1, e_2, e_3, e_4, e_5, e_6, e_7, e_8, e_9\}$ be a set of parameters of vehicles specifications which are "acceleration", "charge speed", "charge time", "efficiency", "number of cells", "price", "real range", "top speed" and "usable battery" respectively.

Next we will find all the tables that we need to applied algorithm on it.

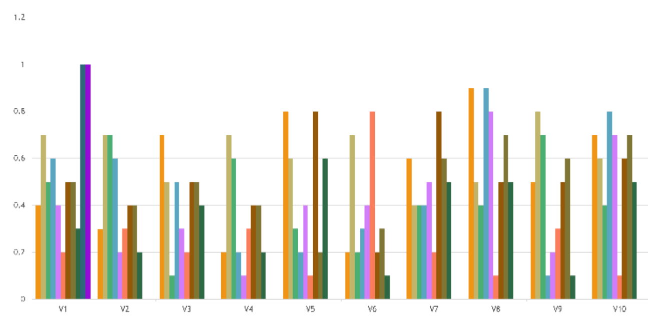

Figure 1:graphic design of selected parameters in each electric vehicle.

U	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	Choice value
v_1	0.4	0.7	0.5	0.6	0.4	0.2	0.5	0.5	0.3	$c_1 = 4.1$
v_2	0.3	0.7	0.7	0.6	0.2	0.3	0.4	0.4	0.2	$c_2 = 3.8$
v_3	0.7	0.5	0.1	0.5	0.3	0.2	0.5	0.5	0.4	$c_3 = 3.7$
v_4	0.2	0.7	0.6	0.2	0.1	0.3	0.4	0.4	0.2	$c_4 = 3.1$
v_5	0.8	0.6	0.3	0.2	0.4	0.1	0.8	0.2	0.6	$c_5 = 4.0$
v_6	0.2	0.7	0.2	0.3	0.4	0.8	0.2	0.3	0.1	$c_6 = 3.2$
v_7	0.6	0.4	0.4	0.4	0.5	0.2	0.8	0.6	0.5	$c_7 = 4.3$
v_8	0.9	0.5	0.4	0.9	0.8	0.1	0.5	0.7	0.5	$c_8 = 5.3$
v_9	0.5	0.8	0.7	0.1	0.2	0.3	0.5	0.6	0.1	$c_9 = 3.8$
v_{10}	0.7	0.6	0.4	0.8	0.7	0.1	0.6	0.7	0.5	$c_{10} = 5.1$

Table 2: fuzzy soft set table.

U	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}
v_1	9	7	7	7	6	8	4	3	4	3
v_2	4	9	4	9	5	7	4	3	5	3
v_3	5	5	9	6	3	5	4	1	5	2
v_4	3	5	3	9	5	6	3	3	3	3
v_5	4	4	6	5	9	5	4	4	5	5
v_6	3	3	4	5	5	9	2	2	4	2
v_7	6	5	6	6	5	7	9	5	7	4
v_8	6	6	8	6	6	7	7	9	6	7
v_9	6	7	5	7	4	6	4	3	9	3

v_{10}	6	6	8	6	6	7	7	8	6	9

Table 3:comparison table.

	Row sum	Column sum	Score value
v_1	58	64	-6
v_2	53	57	-4
v_3	45	60	-15
v_4	43	66	-23
v_5	51	54	-3
v_6	39	67	-28
v_7	60	48	12
v_8	68	41	27
v_9	54	54	0
v_{10}	69	41	28

Table 4: score table.

Step 1.
From table 2 the choice value sequence
$\{c_1, c_2, \dots, c_{10}\} = \{4.1, 3.8, 3.7, 3.1, 4.0, 3.2, 4.3, 5.3, 3.8, 5.1\}$
And from table 4 the score value sequence
$\{s_1, s_2, \dots, s_n\} = \{-6, -4, -15, -23, -3, -28, 12, 27, 0, 28\}$

Step 2.

$$Min\{c_i, i = 1,2, \dots, 10\} = 3.1\,,$$
$$Max\{c_i, i = 1,2, \dots, 10\} = 5.3\,,$$
$$Min\{s_i, i = 1,2 \dots, 10\} = -28\,,$$
$$Max\{s_i, i = 1,2, \dots, 10\} = 28\,.$$

$\{c'_1, c'_2, \dots, c'_{10}\}$
$= \{0.454, 0.318, 0.272, 0, 0.409, 0.045, 0.545, 1, 0.318, 0.909\}$,
$\{s'_1, s'_2, \dots, s'_{10}\}$
$= \{0.392, 0.428, 0.232, 0.089, 0.446, 0, 0.714, 0.982, 0.5, 1\}$.

Step 3.

$$\{c'_1, s'_2\} = \{0.454, 0.392\}, \{c'_2, s'_2\} = \{0.318, 0.428\},$$
$$\{c'_3, s'_3\} = \{0.272, 0.232\}, \{c'_4, s'_4\} = \{0, 0.089\},$$
$$\{c'_5, s'_5\} = \{0.045, 0.446\}, \{c'_6, s'_6\} = \{0.045, 0\},$$
$$\{c'_7, s'_7\} = \{0.545, 0.714\}, \{c'_8, s'_8\} = \{1, 0.982\},$$
$$\{c'_9, s'_9\} = \{0.318, 0.5\}, \{c'_{10}, s'_{10}\} = \{0.909, 1\}.$$

Step 4.

$$c_{max} = 1, s_{max} = 1,$$
$$\Delta c'_1 = 0.546,\ \Delta c'_2 = 0.682, \Delta c'_3 = 0.728,$$
$$\Delta c'_4 = 1, \Delta c'_5 = 0.591, \Delta c'_6 = 0.955,$$
$$\Delta c'_7 = 0.355, \Delta c'_8 = 0, \Delta c'_9 = 0.682, \Delta c'_{10} = 0.091,$$
$$\Delta s'_1 = 0.608, \Delta s'_2 = 0.572, \Delta s'_3 = 0.768,$$
$$\Delta s'_4 = 0.911, \Delta s'_5 = 0.554, \Delta s'_6 = 1,$$
$$\Delta s'_7 = 0.286, \Delta s'_8 = 0.019, \Delta s'_9 = 0.5, \Delta s'_{10} = 0,$$
$$\Delta_{max} = 1, \Delta_{min} = 0.$$

Step 5.

$$\gamma(c, c_1) = 0.608, \gamma(c, c_2) = 0.554, \gamma(c, c_3) = 0.538,$$
$$\gamma(c, c_4) = 0.459, \gamma(c, c_5) = 0.589, \gamma(c, c_6) = 0.470,$$
$$\gamma(c, c_7) = 0.651, \gamma(c, c_8) = 1, \gamma(c, c_9) = 0.554, \gamma(c, c_{10}) = 0.903.$$
$$\gamma(s, s_1) = 0.582, \gamma(s, s_2) = 0.597, \gamma(s, s_3) = 0.525,$$
$$\gamma(s, s_4) = 0.482, \gamma(s, s_5) = 0.605, \gamma(s, s_6) = 0.459,$$
$$\gamma(s, s_7) = 0.748, \gamma(s, s_8) = 0.978, \gamma(s, s_9) = 0.629, \gamma(s, s_{10}) = 1.$$

Step 6.

$$\gamma(v_1) = 0.593, \gamma(v_2) = 0.577, \gamma(v_3) = 0.530, \gamma(v_4) = 0.471,$$
$$\gamma(v_5) = 0.597, \gamma(v_6) = 0.463, \gamma(v_7) = 0.704, \gamma(v_8) = 0.987,$$
$$\gamma(v_9) = 0.595, \gamma(v_{10}) = 0.956.$$

Step 7.
After following the steps of the algorithm, it appears to us that the decision in this making decision problem is v_8.

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