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A Soft Interval Based Decision Making Method and Its Computer Application

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Abstract. In today's society, decision making is becoming more important and complicated with increasing and complex data. Decision making by using soft set theory, herein, we firstly report the comparison of soft intervals (SI) as the generalization of interval soft sets (ISS). The results showed that SIs are more effective and more general than the ISSs, for solving decision making problems due to allowing the ranking of parameters. Tabular form of SIs were used to construct a mathematical algorithm to make a decision for problems that involves uncertainties. Since these kinds of problems have huge data, constructing new and effective methods solving these problems and transforming them into the machine learning methods is very important. An important advance of our presented method is being a more general method than the Decision-Making methods based on special situations of soft set theory. The presented method in this study can be used for all of them, while the others can only work in special cases. The structures obtained from the results of soft intervals were subjected to test with examples. The designed algorithm was written in recently used functional programing language $C\#$ and applied to the problems that have been published in earlier studies. This is a pioneering study, where this type of mathematical algorithm was converted into a code and applied successfully.

Keywords: Soft Set Theory, Interval Soft Set, Soft Interval, Decision Making, Orderings on Soft Set, Algorithm

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1. Introduction

Scientific fields such as economics, engineering, environment, and social always need precise mathematical solutions. However, classical mathematical structures are insufficient to satisfy their needs regarding uncertainties or uncertainties caused by complicated problems. So cybernetics is a very essential research area to overcome these kinds of problem having huge and complicated data.

Molodtsov [10] defined the Soft Set Theory to overcome these kind of uncertainties, followed by Maji et al., who introduced many operators on soft sets [8]. In recent years, many researchers have been studying the properties and applications of soft set theory and fuzzy soft set theory [3], [7], [13]. Babitha and Sunil [1], [2] introduced the soft set relation and orderings on soft sets. However, definitions of preordered soft sets, infimum of soft sets and supremum of soft sets were discovered by Tanay and Yaylalı [14]. In a later study, Yang and Gu [15] improved the definitions of soft set relations. Furthermore, the equivalence soft set relation was studied by Park et al. [11].

Decision making (DM) has very important role for daily life problem because we make dozens of decisions during the day. So real world application of our method of making decisions in accordance with certain preference to priority ranking can be seen in the Example 5.1 and 5.2. Although there are many studies on decision-making, it has become essential to try to solve the decision making problems with a new theory, the soft set theory. Maji et al. [9] and Zhu et al. [23] have discovered certain soft sets-based methods of DM, that solves the complicated social life problems related to uncertainties. In a similar work, Yao found [16] interval set theory as another mathematical tool to deal with uncertainties, while Zhang introduced the interval soft set (ISS) and applied the theory of ISS to solve DM problems [21]. Additionally, the concept of the soft intervals (SI), whose special case is Zhang's ISS, was also defined by Yaylalı et al. [17]. More studies on decision making problems by using soft sets, fuzzy soft sets, and rough soft sets can be found in [4], [9], [16], [19], [20], [21], [22], [23], [24]. Moreover some researchers uses special soft sets for decision making such as M. Kirişçi [6], who is defined $\Omega-$ soft set and presented the decision making problem solution as an application of $\Omega-$ soft set and Khan et al. [5] introduced a method to solve decision making problems by fuzzy soft set. Qamar and Hassan [12] defined the Q-neutrosophic-set aggregation operator and use it to develop an algorithm for using a Q-neutrosophic soft set in decision-making issues.

Herein, we apply the notion of the SIs to construct a DM method. We established a tabular form of the SI for making the relevant calculations more clearly and assessed an interval choice value by using Zhang's study [21]. Then a generalization of the Zhang's algorithm [21], to make a decision was proposed in this study. This method which is based on SIs, becomes more effective because it is the generalization of ISS. In addition to these, we applied the designed DM method to the problems which were reported in the earlier DM methods based on the soft set theory and we obtained same results successfully.

In the International Congress on Fundamental and Applied Sciences, Skopje, Macedonia (ICFAS 2018) we introduced the computer application part of the designed DM method in our oral presentation whose abstract was published only in the Abstract Book of ICFAS 2018 [18]. In fact, the DM methods should be faster and they should be handle huge data easily. Thus to come through those problem and make the DM method more practical, the designed algorithm was coded in $C\#$ and applied to the examples (see Appendix 1).

2. Preliminaries

In this section, we review some basic definitions such as soft set, soft subset, cartesian product of two soft sets and soft set relation which will be used in this paper.

Definition 2.1 *[10] Let E be the set of parameters, U be an initial universe, $\mathcal{P}(U)$ be a set of all subsets of U and A be a subset of E. A pair (F, A) is called a soft set over U, where $F : A \longrightarrow \mathcal{P}(U)$ is a set-valued function.*
In other words, the soft set is a parametrized family of subsets of the set U. $F(e)$ may be considered as a e-approximate elements of the soft set (F, A), for every $e \in U$.

Definition 2.2 *[8] If for all $\epsilon \in A$, $F(\epsilon) = \emptyset$, then soft set (F, A) over U is said a Null soft set and it is denoted by Φ,*

Definition 2.3 *[8] Let (F, A) and (G, B) be soft sets over a common universe U. (F, A) is called a soft subset of (G, B) if*

i) $A \subseteq B$, and

ii) $\forall e \in A$, $F(e) \subseteq G(e)$.

We write $(F, A)\widetilde{\subseteq}(G, B)$.

Definition 2.4 *[1] Let (F, A) and (G, B) be two soft sets over a common universe U, then $(F, A) \times (G, B) = (H, A \times B)$ is the Cartesian product of (F, A) and (G, B), where $(a, b) \in A \times B$, $H : A \times B \rightarrow \mathcal{P}(U \times U)$ and $H(a, b) = F(a) \times G(b)$, i.e., $H(a, b) = \{(h_i, h_j)|h_i \in F(a), h_j \in G(b)\}$.*

Definition 2.5 *[1] Let (F, A) and (G, B) be two soft sets over a common universe U, then a soft set relation R from (F, A) to (G, B) is a soft subset of $(F, A) \times (G, B)$. In other words, a soft set relation R from (F, A) to (G, B) is of the form $R = (H_1, S)$, where for all $(a, b) \in S$, $S \subset A \times B$ and $H_1(a, b) = H(a, b)$, where $(H, A \times B) = (F, A) \times (G, B)$.*

Definition 2.6 *[1] Let R be a soft set relation on (F, A), then:*

1. *If $H_1(a, a) \in R$, $\forall a \in A$, then R is reflexive soft set relation.*
2. *If $H_1(a, b) \in R \Rightarrow H_1(b, a) \in R$, then R is symmetric soft set relation.*
3. *If $H_1(a, b) \in R$, $H_1(b, c) \in R \Rightarrow H_1(a, c) \in R$ for every $a, b, c \in A$, then R is transitive soft set relation.*

Definition 2.7 *[2] Let R be a binary soft set relation on (F, A). R is called antisymmetric if $F(a) \times F(b) \in R$ and $F(b) \times F(a) \in R$ for every $F(a), F(b) \in (F, A)$ imply $F(a) = F(b)$.*

Definition 2.8 *[2] A reflexive, antisymmetric and transitive binary soft set relation $\leq$ on (F, A) is called a partial ordering of (F, A) and the triple $(F, A, \leq)$ is called a partially ordered soft set.*

Definition 2.9 *[14] Let $\leq$ be a reflexive, transitive soft set relation on a soft set (F, A). Then this soft set relation is called a preorder and (F, A) is called a preordered soft set.*

Definition 2.10 *[2] Let $\leq$ be an ordering of (F, A) and let $F(a)$ and $F(b)$ be any two elements in (F, A). $F(a)$ and $F(b)$ are called comparable in the ordering $\leq$, if $F(a) \leq F(b)$ or $F(b) \leq F(a)$. If they are not comparable, then $F(a)$ and $F(b)$ are incomparable.*

3. Soft Intervals (SI) vs Interval Soft Sets (ISS)

In this section, we recall definitions of simple ordered soft set, soft intervals, interval set and interval soft sets also we make a comparison between soft intervals (SI) and interval soft sets (ISS). As a result of this comparison we will show that the soft intervals (SI) is the generalization of interval soft sets (ISS).

Definition 3.1 *[17] Let R be a soft set relation on a soft set (F, A). The soft set relation R is called nonreflexive, if for no $a \in A$ the soft set relation $F(a)RF(a)$ holds.*

Definition 3.2 *[17] If a soft set relation R is comparable, nonreflexive and transitive on a soft set (F, A), then it is called simple order soft set relation and (F, A, R) is called a simple ordered soft set.*

Definition 3.3 *[17] Let $\leq$ be a soft set relation on (F, A), then restriction of a soft set relation $\leq$ to a soft subset (G, B) is defined by:*

$$G(a) \leq_{(G,B)} G(b) :\Leftrightarrow F(a) \leq F(b) \text{ for all } a, b \in B.$$

Example 3.1 *[17] Let $U = \{c_1, c_2, c_3, c_4, c_5, c_6\}$ be a universe and $A = \{a_1, a_2, a_3\}$ be a parameter set. The soft set (F, A) and (G, B) are defined by:*
$F(a_1) = \{c_1, c_2\}$, $F(a_2) = \{c_3, c_4, c_5\}$, $F(a_3) = \{c_5\}$;
$B = \{a_1, a_2\}$, $G(a_1) = \{c_1\}$, $G(a_2) = \{c_3, c_5\}$. *Then* $(G, B)\widetilde{\subseteq}(F, A)$.

Consider the soft set relation on (F, A) is $\leq = \{F(a_1) \times F(a_2), F(a_2) \times F(a_3)\}$ $= \big\{\{(c_1, c_3), (c_1, c_4), (c_1, c_5), (c_2, c_3), (c_2, c_4), (c_2, c_5)\}, \{(c_3, c_5), (c_4, c_5), (c_5, c_5)\}\big\}$ *on* (F, A).

Then restriction of soft set relation $\leq$ to a soft subset (G, B) is $\leq_{(G,B)} = \{G(a_1) \times G(a_2)\} = \big\{\{(c_1, c_3), (c_1, c_5)\}\big\}$.

Definition 3.4 *[17] Let $(F, A, \prec)$ be a simple order soft set and let for $a, b \in A$, $F(a)$ and $F(b)$ be elements of (F, A) with $F(a) \prec F(b)$. Then four soft subsets of (F, A) given below are called soft intervals (SI) (respectively; soft open interval, soft half open intervals, soft closed interval) determined by $F(a)$ and $F(b)$ and they can be defined as follows:*

a ***Soft Open Interval:***

The soft open interval is a soft subset (G, B) of (F, A), where $B = \{x|\, F(a) \prec F(x) \prec F(b)\}$, $G = F|_B$ and denoted by

$\big(F(a), F(b)\big) = \{F(x)|\, F(a) \prec F(x) \prec F(b)\}.$

b ***Soft Right Half Open Interval:***

The soft right half open interval is a soft subset (G, B) of (F, A), where $B = \{x|\, F(a) \prec F(x) \prec F(b)\, or\, F(x) = F(b)\}$, $G = F|_B$ and denoted by

$\big(F(a), F(b)\big] = \{F(x)|\, F(a) \prec F(x) \prec F(b)\, or\, F(x) = F(b)\}.$

c ***Soft Left Half Open Interval:***

The soft left half open interval is a soft subset (G, B) of (F, A), where $B = \{x|\, F(a) \prec F(x) \prec F(b),\, or\, F(x) = F(a)\}$, $G = F|_B$ and denoted by

$\big[F(a), F(b)\big) = \{F(x)|\, F(a) \prec F(x) \prec F(b)\, or\, F(x) = F(a)\}.$

d ***Soft Closed Interval:***

The soft closed interval is a soft subset (G, B) of (F, A), where $B = \{x|\, F(a) \prec F(x) \prec F(b)\, or\, F(x) = F(a)\, or\, F(x) = F(b)\}$, $G = F|_B$ and denoted by

$\big[F(a), F(b)\big] = \{F(x)|\, F(a) \prec F(x) \prec F(b)\, or\, F(x) = F(a)\, or\, F(x) = F(b)\}.$

These are the SIs of an arbitrary simple ordered soft set (F, A).

Remark 1 *[17] If $(F, A, \leq)$ is a partially ordered soft set, instead of a simple ordered soft set with a soft set relation $\prec$, SIs can be written as below:*

a $\big(F(a), F(b)\big) = \{F(x)|\, F(a) \leq F(x) \leq F(b),\ \ F(x) \neq F(a)\, and\, F(x) \neq F(b)\};$

b $\big(F(a), F(b)\big] = \{F(x)|\, F(a) \leq F(x) \leq F(b)\, and\ F(x) \neq F(a)\};$

c $\big[F(a), F(b)\big) = \{F(x)|\, F(a) \leq F(x) \leq F(b)\, and\ F(x) \neq F(b)\};$

d $\big[F(a), F(b)\big] = \{F(x)|\, F(a) \leq F(x) \leq F(b)\}.$

Definition 3.5 *[16] Let U be a finite set, which is called the universe or the reference set, and 2^U be its power set. A subset of 2^U of the form*

$$\mathcal{A} = [A_l, A_u] = \{A \in 2^U | A_l \subseteq A \subseteq A_u\}$$

is called an interval set, where $A_l \subseteq A_u$. The set of all interval sets denoted by $I(2^U)$.

Definition 3.6 *[21] Let U be an initial universe, E be a set of parameters and $A \subseteq E$. If F is a mapping of A into the set of all interval sets over U, that is, $F : A \to I(2^U)$, then the pair (F, A) is called an interval soft set (ISS) over U.*

Example 3.2 *[21] Consider the universe $U = \{h_1, h_2, h_3, h_4, h_5, h_6\}$ and the parameter set $E = \{e_1, e_2, e_3, e_4, e_5\}$. If we define soft set as in below*
$F(e_1) = [\{h_2\}, \{h_2, h_4\}]$, $F(e_2) = [\{h_1\}, \{h_1, h_3\}]$,
$F(e_3) = [\{h_3, h_4\}, \{h_3, h_4\}]$, $F(e_4) = [\{h_5\}, \{h_1, h_3, h_5\}]$,
$F(e_5) = [\{h_4\}, \{h_1, h_4, h_6\}]$.

Then (F, E) is an ISS over U.

Note that, if the soft set relation is choosen as $F(e_i) \leq F(e_j) :\Leftrightarrow F(e_i) \subseteq F(e_j)$, then the Zhang's ISS [21] is a special case of the SI [17]. Hence, the soft closed intervals are ISSs [21]. If we choose different soft set relation, we will obtain different structures from the ISS, which shows that SIs are the general form of the ISS. So SIs may have more application area than ISSs.

Similarities between these structures are examined in the following example:

Example 3.3 *Let $U = \{h_1, h_2, h_3, h_4, h_5, h_6\}$ be the universe as in the Example 3.2 and $A = \{a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}, a_{12}, a_{13}\}$ be the parameter set. Define $G(a_1) = \{h_1\}$, $G(a_2) = \{h_2\}$, $G(a_3) = \{h_1, h_3\}$, $G(a_4) = \{h_2, h_4\}$, $G(a_5) = \{h_3, h_4\}$, $G(a_6) = \{h_4\}$, $G(a_7) = \{h_5\}$, $G(a_8) = \{h_1, h_3, h_5\}$, $G(a_9) = \{h_1, h_4, h_6\}$, $G(a_{10}) = \{h_1, h_5\}$, $G(a_{11}) = \{h_3, h_5\}$, $G(a_{12}) = \{h_1, h_4\}$, $G(a_{13}) = \{h_4, h_6\}$. Then (G, A) is a soft set over U.*
Now let us define a soft set relation $\leq$ such that $G(a_i) \leq G(a_j) \Leftrightarrow G(a_i) \subseteq G(a_j)$. Then the soft closed intervals
$[G(a_2), G(a_4)] = [\{h_2\}, \{h_2, h_4\}]$, $[G(a_1), G(a_3)] = [\{h_1\}, \{h_1, h_3\}]$,
$[G(a_5), G(a_5)] = [\{h_3, h_4\}, \{h_3, h_4\}]$, $[G(a_7), G(a_8)] = [\{h_5\}, \{h_1, h_3, h_5\}]$,
$[G(a_6), G(a_9)] = [\{h_4\}, \{h_1, h_4, h_6\}]$
are the ISSs as in Example 3.2.

According to this example we can say that ISSs can be obtained as soft closed intervals but the following example states that SIs are not ISSs in general.

Example 3.4 *Consider the soft set (G, A) which is defined in the Example 3.3 but consider a different soft set relation which is defined by $\leq = \{G(a_1) \times G(a_2), G(a_2) \times G(a_7), G(a_1) \times G(a_7)\}$. Then the soft closed intervals according to this soft set relations are*
$[G(a_1), G(a_2)] = [\{h_1\}, \{h_2\}]$ $[G(a_2), G(a_7)] = [\{h_2\}, \{h_5\}]$
$[G(a_1), G(a_7)] = [\{h_1\}, \{h_5\}]$
It can be seen that non of $G(a_1), G(a_2), G(a_7)$ are contained by each other. So it can be observed that these SIs are not ISSs.

4. Decision Making (DM) Algorithm By Using Soft Intervals (SIs)

Zhang [21] introduced interval choice value of the tabular representation of the interval soft sets (ISS) and used it to solve the DM problems. By using this idea, we can find the interval choice value of the tabular form of SI and as well as apply Zhang's algorithm to the SIs. So, in this section, we firstly give how to make the tabular representation of SI and then we give the DM algorithm.

Example 4.1 *A soft set (F, E) describes the attractiveness of the houses to be bought for Mr. X. Let $U = \{h_1, h_2, h_3, h_4, h_5, h_6\}$ be the set of houses under consideration and $E = \{e_1 = \text{expensive}, e_2 = \text{beautiful}, e_3 = \text{wooden}, e_4 = \text{cheap}, e_5 = \text{in green surroundings}\}$ be the parameter set. Let a soft set (F, E) be defined as $F(e_1) = \{h_2, h_3\}$, $F(e_2) = \{h_2, h_3, h_5\}$, $F(e_3) = \{h_1, h_4\}$, $F(e_4) = \{h_1\}$, $F(e_5) = \{h_1, h_2, h_6\}$. Let Mr. X has priority ranking when buying a house be beautiful, green surroundings, cheap, expensive, wooden houses. By considering this priority ranking, a soft set relation on (F, E) can be defined as follows:*

$$\begin{aligned} \prec = \ & \{F(e_1) \times F(e_1), F(e_2) \times F(e_2), F(e_3) \times F(e_3), F(e_4) \times F(e_4), F(e_5) \times F(e_5), \\ & F(e_3) \times F(e_1), F(e_3) \times F(e_4), F(e_3) \times F(e_5), F(e_3) \times F(e_2), F(e_1) \times F(e_4), \\ & F(e_1) \times F(e_5), F(e_1) \times F(e_2), F(e_4) \times F(e_5), F(e_4) \times F(e_2), F(e_5) \times F(e_2)\}. \end{aligned}$$

Then this soft set relation $\prec$ is comparable, transitive, reflexive and antisymmetric so it is partially ordered soft set relation.

$$\begin{array}{lllll} [F(e_1), F(e_1)], & [F(e_2), F(e_2)], & [F(e_3), F(e_3)], & [F(e_4), F(e_2)], & [F(e_3), F(e_5)], \\ [F(e_4), F(e_4)], & [F(e_5), F(e_5)], & [F(e_3), F(e_1)], & [F(e_1), F(e_4)], & [F(e_4), F(e_5)], \\ [F(e_1), F(e_5)], & [F(e_3), F(e_4)], & [F(e_1), F(e_2)], & [F(e_5), F(e_2)], & [F(e_3), F(e_2)]. \end{array}$$

Table representations provide convenience in making calculations. We can also tabulate all soft closed intervals, similar to the reported study [21], whose columns represent intervals while rows show elements of the universe.

To express the tabular form of all soft closed intervals, αs will be used for the soft closed intervals after arbitrary ordering on soft closed intervals and we will use an interval number $c_{ij} = [a_{ij}, b_{ij}]$, where c_{ij} are entries in the tabular representation. For a soft closed interval $\alpha_j = [F(a), F(b)]$,

$$\text{if } h_i \in F(a), \text{ then } a_{ij} = 1, \text{ otherwise } a_{ij} = 0;$$

$$\text{if } h_i \in F(b), \text{ then } b_{ij} = 1, \text{ otherwise } b_{ij} = 0;$$

where $1 \leq j \leq n$ and n is the number of all soft closed intervals.

Example 4.2 *Consider the Example 4.1. Let*

$$\begin{array}{lll} \alpha_1 = [F(e_3), F(e_1)], & \alpha_6 = [F(e_1), F(e_5)], & \alpha_{11} = [F(e_1), F(e_1)], \\ \alpha_2 = [F(e_3), F(e_4)], & \alpha_7 = [F(e_1), F(e_2)], & \alpha_{12} = [F(e_2), F(e_2)], \\ \alpha_3 = [F(e_3), F(e_5)], & \alpha_8 = [F(e_4), F(e_5)], & \alpha_{13} = [F(e_3), F(e_3)], \\ \alpha_4 = [F(e_3), F(e_2)], & \alpha_9 = [F(e_4), F(e_2)], & \alpha_{14} = [F(e_4), F(e_4)], \\ \alpha_5 = [F(e_1), F(e_4)], & \alpha_{10} = [F(e_5), F(e_2)], & \alpha_{15} = [F(e_5), F(e_5)]. \end{array}$$

Thus, according to the informations given above, the tabular representation of all soft closed intervals of the previous example is given below:

Table 1. Tabular representation of soft closed intervals of soft set (F, E)

	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}	α_{13}	α_{14}	α_{15}
h_1	[1,0]	[1,1]	[1,1]	[1,0]	[0,1]	[0,1]	[0,0]	[1,1]	[1,0]	[1,0]	[0,0]	[0,0]	[1,1]	[1,1]	[1,1]
h_2	[0,1]	[0,0]	[0,1]	[0,1]	[1,0]	[1,1]	[1,1]	[0,1]	[0,1]	[1,1]	[1,1]	[1,1]	[0,0]	[0,0]	[1,1]
h_3	[0,1]	[0,0]	[0,0]	[0,1]	[1,0]	[1,0]	[1,1]	[0,0]	[0,1]	[0,1]	[1,1]	[1,1]	[0,0]	[0,0]	[0,0]
h_4	[1,0]	[1,0]	[1,0]	[1,0]	[0,0]	[0,0]	[0,0]	[0,0]	[0,0]	[0,0]	[0,0]	[0,0]	[1,1]	[0,0]	[0,0]
h_5	[0,0]	[0,0]	[0,0]	[0,1]	[0,0]	[0,0]	[0,1]	[0,0]	[0,1]	[0,1]	[0,0]	[1,1]	[0,0]	[0,0]	[0,0]
h_6	[0,0]	[0,0]	[0,1]	[0,0]	[0,0]	[0,1]	[0,0]	[0,1]	[0,0]	[1,0]	[0,0]	[0,0]	[0,0]	[0,0]	[1,1]

Definition 4.1 *[21] For an object $h_i \in U$, interval choice value is an interval number v_i given by*

$$v_i = [v_i^{(1)}, v_i^{(2)}],\ v_i^{(1)} = \sum_j a_{ij},\ v_i^{(2)} = \sum_j b_{ij},$$

where a_{ij}, b_{ij} are defined in tabular representation.

Example 4.3 *Consider Example 4.1. The interval choice values are the followings:*
$v_1 = [10, 8]$, $v_2 = [7, 11]$, $v_3 = [5, 7]$, $v_4 = [5, 1]$, $v_5 = [1, 5]$, $v_6 = [2, 4]$.

The algorithm published earlier in [21], where interval choice value of ISS are used, is given in the following steps:

- input the object set U and the parameters set E (may be the subset of E),
- input the ISS (F, E),
- give the tabular representation of the ISS (F, E),
- compute the interval choice value v_i ,
- find k such that $v_k^{(1)} = \max v_i^{(1)}$ and $v_k^{(2)} = \max_{\{m \mid v_m^{(1)} = \max v_i^{(1)}\}} v_m^{(2)}$,

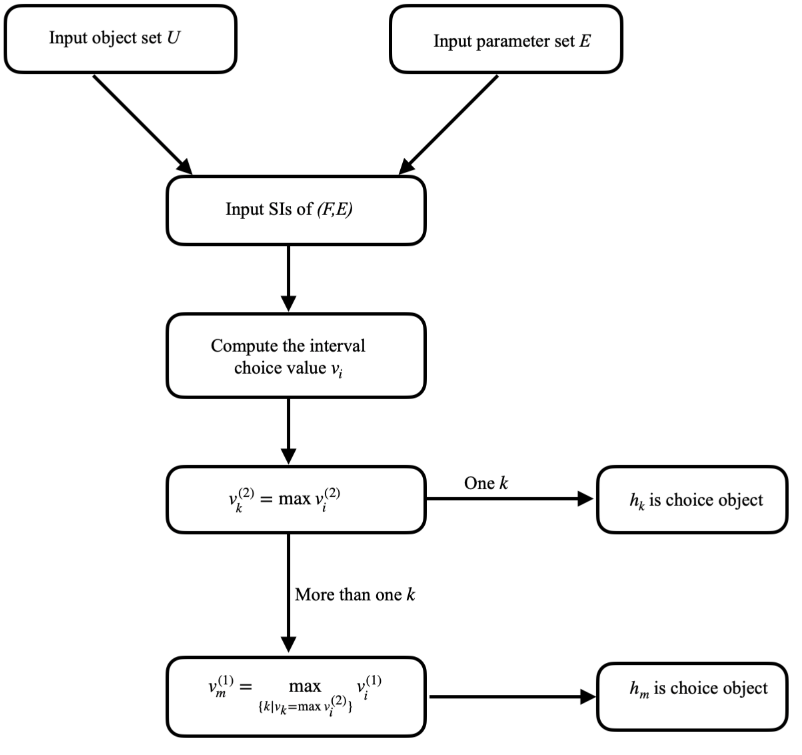
then h_k is the choice object.

The stated algorithm for the soft intervals can be improved according to the following steps:

- input the object set U and the parameters set E (may be the subset of E),
- input the SIs of (F, E),
- give the tabular representation of the SIs of (F, E),
- compute the interval choice value v_i,
- find k for $v_k^{(2)} = \max v_i^{(2)}$, then h_k is the choice object. If there are more than one ks, then find k for $v_m^{(1)} = \max_{\{k \mid v_k^{(2)} = \max v_i^{(2)}\}} v_k^{(1)}$, then h_m is the choice object. Still, if there are more than one m, then any one of them could be the choice object.

According to the previous steps of our algorithm, we can briefly describe the algorithm by the following diagram to clarify the proposed approach.

Diagram of the decision making algorithm:



Example 4.4 *According to the interval choice values, which are obtained in Example 4.3, the choice object is* h_2.

Example 4.5 *Consider the soft set and the SIs in the Example 3.3 and indicate these SIs by* α_i*'s as following*
$\alpha_1 = [G(a_2), G(a_4)]$, $\alpha_2 = [G(a_1), G(a_3)]$, $\alpha_3 = [G(a_5), G(a_5)]$, $\alpha_4 = [G(a_7), G(a_8)]$, $\alpha_5 = [G(a_6), G(a_9)]$.

Then the tabular representation of these SIs is given in Table 2.

Table 2. Tabular representation of soft closed intervals

	α_1	α_2	α_3	α_4	α_5
h_1	[0,0]	[1,1]	[0,0]	[0,1]	[0,1]
h_2	[1,1]	[0,0]	[0,0]	[0,0]	[0,0]
h_3	[0,0]	[0,1]	[1,1]	[0,1]	[0,0]
h_4	[0,1]	[0,0]	[1,1]	[0,0]	[1,1]
h_5	[0,0]	[0,0]	[0,0]	[1,1]	[0,0]
h_6	[0,0]	[0,0]	[0,0]	[0,0]	[0,1]

According to the tabular form of these SIs, the interval choice values are $v_1 = [1, 3]$, $v_2 = [1, 1]$, $v_3 = [1, 3]$, $v_4 = [2, 3]$, $v_5 = [1, 1]$ *and* $v_6 = [0, 1]$. *Following these interval choice values, the choice object is* h_4 *that is also in agreement with the reported results by Zhang [21].*

Example 4.6 *Consider the same soft set as in the previous example but with different order, as given in Example 3.4 and indicate these SIs by* α_i*'s as follows:*

$$\alpha_1 = [G(a_1), G(a_2)] = [\{h_1\}, \{h_2\}] \quad \alpha_2 = [G(a_2), G(a_7)] = [\{h_2\}, \{h_5\}]$$
$$\alpha_3 = [G(a_1), G(a_7)] = [\{h_1\}, \{h_5\}]$$

Then the tabular representation of these SIs is given in the following table.

Table 3. Tabular representation of soft closed intervals

	α_1	α_2	α_3
h_1	[1,0]	[0,0]	[1,0]
h_2	[0,1]	[1,0]	[0,0]
h_3	[0,0]	[0,0]	[0,0]
h_4	[0,0]	[0,0]	[0,0]
h_5	[0,0]	[0,1]	[0,1]
h_6	[0,0]	[0,0]	[0,0]

According to the tabular form of these SIs, the interval choice values are $v_1 = [2, 0]$, $v_2 = [1, 1]$, $v_3 = [0, 0]$, $v_4 = [0, 0]$, $v_5 = [0, 2]$ *and* $v_6 = [0, 0]$. *Following these interval choice values, the choice object is* h_5.

Recall that in this example SIs are not ISSs, so we can not able to use the Zhang's algorithm [21] here. This example shows that the method given in [21] is not enough for solving these kinds of DM problems.

There some other studies about DM problems by using soft sets. For instance, Zhu et al. [23] gave an application of a DM problem in the soft set theory. In the following, we take an example that is solved by Zhu et al. in [23] and apply our method successfully to this example.

Example 4.7 *Consider the soft set as given in the Table 4 which is from Zhu et al. [23].*

Table 4. Tabular Representation of Soft Set

U	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}
h_1	1	0	1	0	1	1	1	1	1	0
h_2	0	1	1	1	0	1	0	1	1	1
h_3	1	1	0	0	1	1	1	0	1	1
h_4	1	1	1	1	0	0	0	0	1	1
h_5	1	0	1	1	1	1	0	0	0,67	0
h_6	1	0	1	1	0	1	1	1	1	1
h_7	1	1	1	0	1	1	0	0	1	0
h_8	0,5	1	0	0	0	0	0	1	1	0
h_9	0	0	1	1	1	0	1	1	0	0
h_{10}	0	1	1	1	1	1	0	0	1	1
h_{11}	1	0	1	1	1	1	0	0	0,67	1
h_{12}	0	0	0	0	1	0	0	0	1	0

According to Zhu et al., suppose that a customer gives $e_1 \sim e_{10}$ *attribute weight as* $0.1, 0.1, 0.2, 0.1, 0.6,\ 0.1, 0.5, 0.2, 0.1, 0.1$. *Now let us apply our presented method to this problem. Firstly a soft set relation can be obtained as follows:*

$$
\begin{array}{lllll}
\leq= & \{F(e_{10})\times F(e_9), & F(e_9)\times F(e_{10}), & F(e_{10})\times F(e_6), & F(e_6)\times F(e_{10}), \\
& F(e_{10})\times F(e_4), & F(e_4)\times F(e_{10}), & F(e_{10})\times F(e_2), & F(e_2)\times F(e_{10}), \\
& F(e_{10})\times F(e_1), & F(e_1)\times F(e_{10}), & F(e_{10})\times F(e_8), & F(e_{10})\times F(e_3), \\
& F(e_{10})\times F(e_7), & F(e_{10})\times F(e_5), & F(e_9)\times F(e_6), & F(e_6)\times F(e_9), \\
& F(e_9)\times F(e_4), & F(e_4)\times F(e_9), & F(e_9)\times F(e_2), & F(e_2)\times F(e_9), \\
& F(e_9)\times F(e_1), & F(e_1)\times F(e_9), & F(e_9)\times F(e_8), & F(e_9)\times F(e_3), \\
& F(e_6)\times F(e_2), & F(e_2)\times F(e_6), & F(e_6)\times F(e_1), & F(e_1)\times F(e_6), \\
& F(e_6)\times F(e_8), & F(e_6)\times F(e_3), & F(e_6)\times F(e_7), & F(e_6)\times F(e_5), \\
& F(e_4)\times F(e_2), & F(e_2)\times F(e_4), & F(e_4)\times F(e_1), & F(e_1)\times F(e_4), \\
& F(e_4)\times F(e_8), & F(e_4)\times F(e_3), & F(e_4)\times F(e_7), & F(e_4)\times F(e_5), \\
& F(e_2)\times F(e_1), & F(e_1)\times F(e_2), & F(e_2)\times F(e_8), & F(e_2)\times F(e_3), \\
& F(e_2)\times F(e_7), & F(e_2)\times F(e_5), & F(e_1)\times F(e_8), & F(e_1)\times F(e_3), \\
& F(e_1)\times F(e_7), & F(e_1)\times F(e_5), & F(e_8)\times F(e_3), & F(e_3)\times F(e_8), \\
& F(e_8)\times F(e_7), & F(e_8)\times F(e_5), & F(e_3)\times F(e_7), & F(e_3)\times F(e_5), \\
& F(e_7)\times F(e_5), & F(e_1)\times F(e_1), & F(e_2)\times F(e_2), & F(e_3)\times F(e_3), \\
& F(e_4)\times F(e_4), & F(e_5)\times F(e_5), & F(e_6)\times F(e_6), & F(e_7)\times F(e_7), \\
& F(e_8)\times F(e_8), & F(e_9)\times F(e_9), & F(e_{10})\times F(e_{10}), & F(e_9)\times F(e_7), \\
& F(e_9)\times F(e_5)\} & & &
\end{array}
$$

By using this soft set relation we obtained SIs as follows:

$$\begin{array}{lll}
\alpha_1=[F(e_1),F(e_8)], & \alpha_{14}=[F(e_4),F(e_5)], & \alpha_{27}=[F(e_{10}),F(e_3)],\\
\alpha_2=[F(e_1),F(e_3)], & \alpha_{15}=[F(e_6),F(e_8)], & \alpha_{28}=[F(e_{10}),F(e_7)],\\
\alpha_3=[F(e_1),F(e_7)], & \alpha_{16}=[F(e_6),F(e_3)], & \alpha_{29}=[F(e_{10}),F(e_5)],\\
\alpha_4=[F(e_1),F(e_5)], & \alpha_{17}=[F(e_6),F(e_7)], & \alpha_{30}=[F(e_1),F(e_1)],\\
\alpha_5=[F(e_2),F(e_8)], & \alpha_{18}=[F(e_6),F(e_5)], & \alpha_{31}=[F(e_2),F(e_2)],\\
\alpha_6=[F(e_2),F(e_3)], & \alpha_{19}=[F(e_7),F(e_5)], & \alpha_{32}=[F(e_3),F(e_3)],\\
\alpha_7=[F(e_2),F(e_7)], & \alpha_{20}=[F(e_8),F(e_7)], & \alpha_{33}=[F(e_4),F(e_4)],\\
\alpha_8=[F(e_2),F(e_5)], & \alpha_{21}=[F(e_8),F(e_5)], & \alpha_{34}=[F(e_5),F(e_5)],\\
\alpha_9=[F(e_3),F(e_7)], & \alpha_{22}=[F(e_9),F(e_8)], & \alpha_{35}=[F(e_6),F(e_6)],\\
\alpha_{10}=[F(e_3),F(e_5)], & \alpha_{23}=[F(e_9),F(e_3)], & \alpha_{36}=[F(e_7),F(e_7)],\\
\alpha_{11}=[F(e_4),F(e_8)], & \alpha_{24}=[F(e_9),F(e_7)], & \alpha_{37}=[F(e_8),F(e_8)],\\
\alpha_{12}=[F(e_4),F(e_3)], & \alpha_{25}=[F(e_9),F(e_5)], & \alpha_{38}=[F(e_9),F(e_9)],\\
\alpha_{13}=[F(e_4),F(e_7)], & \alpha_{26}=[F(e_{10}),F(e_8)], & \alpha_{39}=[F(e_{10}),F(e_{10})].
\end{array}$$

Then the tabular representation of all soft closed intervals is as following:

Table 5. Tabular representation of soft closed intervals of the soft set (F, A) - Part 1

	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}	α_{13}	α_{14}	α_{15}	α_{16}	α_{17}	α_{18}	α_{19}	α_{20}
h_1	[1,1]	[1,1]	[1,1]	[1,1]	[0,1]	[0,1]	[0,1]	[0,1]	[1,1]	[1,1]	[0,1]	[0,1]	[0,1]	[0,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]
h_2	[0,1]	[0,1]	[0,0]	[0,0]	[1,1]	[1,1]	[1,0]	[1,0]	[1,0]	[1,0]	[1,1]	[1,1]	[1,0]	[1,0]	[1,1]	[1,1]	[1,0]	[1,0]	[0,0]	[1,0]
h_3	[1,0]	[1,0]	[1,1]	[1,1]	[1,0]	[1,0]	[1,1]	[1,1]	[0,1]	[0,1]	[0,0]	[0,0]	[0,1]	[0,1]	[1,0]	[1,0]	[1,1]	[1,1]	[1,1]	[0,1]
h_4	[1,0]	[1,1]	[1,0]	[1,0]	[1,0]	[1,1]	[1,0]	[1,0]	[1,0]	[1,0]	[1,0]	[1,1]	[1,0]	[1,0]	[0,0]	[0,1]	[0,0]	[0,0]	[0,0]	[0,0]
h_5	[1,0]	[1,1]	[1,0]	[1,1]	[0,0]	[0,1]	[0,0]	[0,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[0,1]	[0,0]
h_6	[1,1]	[1,1]	[1,1]	[1,0]	[0,1]	[0,1]	[0,1]	[0,0]	[1,1]	[1,0]	[1,1]	[1,1]	[1,1]	[1,0]	[1,1]	[1,1]	[1,1]	[1,0]	[1,0]	[1,1]
h_7	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[0,0]	[0,1]	[0,0]	[0,1]	[1,0]	[1,1]	[1,0]	[1,1]	[0,1]	[0,0]
h_8	[0.5,1]	[0.5,0]	[0.5,0]	[0.5,0]	[1,1]	[1,0]	[1,0]	[1,0]	[0,0]	[0,0]	[0,1]	[0,0]	[0,0]	[0,0]	[0,1]	[0,0]	[0,0]	[0,0]	[0,0]	[1,0]
h_9	[0,1]	[0,1]	[0,1]	[0,1]	[0,1]	[0,1]	[0,1]	[0,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[0,1]	[0,1]	[0,1]	[0,1]	[1,1]	[1,1]
h_{10}	[0,0]	[0,1]	[0,0]	[0,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[0,1]	[0,0]
h_{11}	[0,0]	[1,0]	[1,1]	[1,0]	[1,1]	[0,0]	[0,1]	[0,0]	[0,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[0,1]
h_{12}	[0,0]	[0,0]	[0,0]	[0,0]	[0,1]	[0,0]	[0,0]	[0,0]	[0,1]	[0,0]	[0,1]	[0,0]	[0,0]	[0,0]	[0,1]	[0,0]	[0,0]	[0,0]	[0,1]	[0,1]

Table 6. Tabular representation of soft closed intervals of the soft set (F, A) - Part 2

	α_{21}	α_{22}	α_{23}	α_{24}	α_{25}	α_{26}	α_{27}	α_{28}	α_{29}	α_{30}	α_{31}	α_{32}	α_{33}	α_{34}	α_{35}	α_{36}	α_{37}	α_{38}	α_{39}
h_1	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[0,1]	[0,1]	[0,1]	[0,1]	[1,1]	[0,0]	[1,1]	[0,0]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[0,0]
h_2	[1,0]	[1,1]	[1,1]	[1,0]	[1,0]	[1,1]	[1,1]	[1,0]	[1,0]	[0,0]	[1,1]	[1,1]	[1,1]	[0,0]	[1,1]	[0,0]	[1,1]	[1,1]	[1,1]
h_3	[0,1]	[1,0]	[1,0]	[1,1]	[1,1]	[1,0]	[1,0]	[1,1]	[1,1]	[1,1]	[1,1]	[0,0]	[0,0]	[1,1]	[1,1]	[1,1]	[0,0]	[1,1]	[1,1]
h_4	[0,0]	[1,0]	[1,1]	[1,0]	[1,0]	[1,0]	[1,1]	[1,0]	[1,0]	[1,1]	[1,1]	[1,1]	[1,1]	[0,0]	[0,0]	[0,0]	[0,0]	[1,1]	[1,1]
h_5	[0,1]	[0.67,0]	[0.67,1]	[0.67,0]	[0.67,1]	[0,0]	[0,1]	[0,0]	[0,1]	[1,1]	[0,0]	[1,1]	[1,1]	[1,1]	[1,1]	[0,0]	[0,0]	[0.67,0.67]	[0,0]
h_6	[1,0]	[1,1]	[1,1]	[1,1]	[1,0]	[1,1]	[1,1]	[1,1]	[1,0]	[1,1]	[0,0]	[1,1]	[1,1]	[0,0]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]
h_7	[0,1]	[1,0]	[1,1]	[1,0]	[1,1]	[0,0]	[0,1]	[0,0]	[0,1]	[1,1]	[1,1]	[1,1]	[0,0]	[1,1]	[1,1]	[0,0]	[0,0]	[1,1]	[0,0]
h_8	[1,0]	[1,1]	[1,0]	[1,0]	[1,0]	[0,1]	[0,0]	[0,0]	[0,0]	[0.5,0.5]	[1,1]	[0,0]	[0,0]	[0,0]	[0,0]	[0,0]	[1,1]	[1,1]	[0,0]
h_9	[1,1]	[0,1]	[0,1]	[0,1]	[0,1]	[0,1]	[0,1]	[0,1]	[0,1]	[0,0]	[0,0]	[1,1]	[1,1]	[1,1]	[0,0]	[1,1]	[1,1]	[0,0]	[0,0]
h_{10}	[0,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[0,0]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[0,0]	[0,0]	[1,1]	[1,1]
h_{11}	[0,1]	[0.67,0]	[0.67,1]	[0.67,0]	[0.67,0]	[1,0]	[1,1]	[1,0]	[1,1]	[1,1]	[0,0]	[1,1]	[1,1]	[1,1]	[1,1]	[0,0]	[0,0]	[0.67,0.67]	[1,1]
h_{12}	[0,1]	[1,0]	[1,0]	[1,0]	[1,1]	[0,0]	[0,0]	[0,0]	[0,1]	[0,0]	[0,0]	[1,1]	[0,0]	[1,1]	[0,0]	[0,0]	[0,0]	[1,1]	[0,0]

According to the tabular form of these SIs, the interval choice values are $v_1 = [24,36]$, $v_2 = [31,19]$, $v_3 = [28,24]$, $v_4 = [28,12]$, $v_5 = [22.25,20.67]$, $v_6 = [33,28]$, $v_7 = [24,21]$, $v_8 = [15.5,9.5]$, $v_9 = [14,34]$, $v_{10} = [29,22]$, $v_{11} = [33.35,27.67]$ and $v_{12} = [7,12]$. Following these interval choice values, the choice object is h_1. So customer should buy h_1. So we obtain same result as in Zhu et al. [23].

5. Computer Applications of Proposed Decision Making (DM) Method

We need to utilize computers for our DM method to shorten the evaluation time and to deal with huge data. The computer application of the proposed algorithm was written in $C\#$ (Microsoft Visual Studio Professional 2015 Trial version, programming language). Some parts of the code is given in Appendix 1 (Full code is provided at http://akademik.mu.edu.tr/gozdeyaylali/tr). We solved the following examples both by hand and computer. Both methods successfully ensured the same objects.

Example 5.1 *Let* $U = \{c_1, c_2, c_3, c_4, c_5, c_6, c_7\}$ *be a set of cars and* E *be the parameter set such that* $E = \{e_1 = \text{diesel}, e_2 = \text{gasoline}, e_3 = \text{light color}, e_4 = \text{dark color}, e_5 = \text{manuel}, e_6 = \text{expensive}, e_7 = \text{new}, e_8 = \text{second hand}\}$.

Let (F, A) *soft set as attractiveness of the cars that Mr. X is going to buy. Consider* $A = \{e_1 = \text{diesel}, e_2 = \text{gasoline}, e_3 = \text{light color}, e_4 = \text{dark color}, e_5 = \text{manuel}, e_7 = \text{new}, e_8 = \text{second hand}\}$ *and* $F(e_1) = \{c_1, c_3, c_5\}$, $F(e_2) = \{c_2, c_4, c_6, c_7\}$, $F(e_3) = \{c_2, c_3, c_4\}$, $F(e_4) = \{c_1, c_7\}$, $F(e_5) = \{c_5, c_6, c_7\}$, $F(e_7) = \{c_1, c_2, c_7\}$, $F(e_8) = \{c_3, c_4, c_5, c_6\}$. *Let the priority ranking of Mr. X is in order of manuel, diesel, new, second hand and light color cars. By considering the priority ranking, a soft set relation on* (F, E) *can be defined as follows:*

$$\begin{aligned}\prec = \ & \{F(e_1)\times F(e_5), F(e_7)\times F(e_5), F(e_8)\times F(e_5), F(e_3)\times F(e_5), F(e_5)\times F(e_5),\\ & F(e_1)\times F(e_1), F(e_7)\times F(e_1), F(e_8)\times F(e_1), F(e_3)\times F(e_1), F(e_3)\times F(e_3),\\ & F(e_7)\times F(e_7), F(e_8)\times F(e_7), F(e_3)\times F(e_7), F(e_8)\times F(e_8), F(e_3)\times F(e_8)\}.\end{aligned}$$

Soft set relation $\prec$ *is comparable, transitive, reflexive and antisymmetric, hereby it is a partially ordered soft set relation. Thus all soft closed intervals are given below:*

$$\begin{array}{lllll} [F(e_8), F(e_5)], & [F(e_3), F(e_8)], & [F(e_3), F(e_1)], & [F(e_3), F(e_7)], & [F(e_7), F(e_7)],\\ [F(e_3), F(e_5)], & [F(e_7), F(e_5)], & [F(e_8), F(e_7)], & [F(e_1), F(e_5)], & [F(e_8), F(e_8)],\\ [F(e_1), F(e_1)], & [F(e_7), F(e_1)], & [F(e_3), F(e_3)], & [F(e_8), F(e_1)], & [F(e_5), F(e_5)] \end{array}$$

and indicate them by α_i *'s as following*

$$\begin{array}{lll} \alpha_1 = [F(e_3), F(e_8)], & \alpha_2 = [F(e_3), F(e_7)], & \alpha_3 = [F(e_3), F(e_1)],\\ \alpha_4 = [F(e_3), F(e_5)] & \alpha_5 = [F(e_8), F(e_8)], & \alpha_6 = [F(e_8), F(e_7)],\\ \alpha_7 = [F(e_8), F(e_1)], & \alpha_8 = [F(e_8), F(e_5)], & \alpha_9 = [F(e_7), F(e_7)],\\ \alpha_{10} = [F(e_7), F(e_1)], & \alpha_{11} = [F(e_7), F(e_5)], & \alpha_{12} = [F(e_1), F(e_1)],\\ \alpha_{13} = [F(e_1), F(e_5)], & \alpha_{14} = [F(e_3), F(e_3)], & \alpha_{15} = [F(e_5), F(e_5)]. \end{array}$$

Hence the tabular representation of all soft closed intervals

Table 7. Tabular representation of soft closed intervals of the soft set (F, A)

	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}	α_{13}	α_{14}	α_{15}
c_1	[0,0]	[0,1]	[0,1]	[0,0]	[0,0]	[0,1]	[0,1]	[0,0]	[1,1]	[1,1]	[1,0]	[1,1]	[1,0]	[0,0]	[0,0]
c_2	[1,0]	[1,1]	[1,0]	[1,0]	[0,0]	[0,1]	[0,0]	[0,0]	[1,1]	[1,0]	[1,0]	[0,0]	[0,0]	[0,0]	[1,1]
c_3	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[1,1]	[1,0]	[0,0]	[0,1]	[0,0]	[1,1]	[1,0]	[0,0]	[1,1]
c_4	[1,1]	[1,0]	[1,0]	[1,0]	[1,1]	[1,0]	[1,0]	[1,0]	[0,0]	[0,0]	[0,0]	[0,0]	[0,0]	[0,0]	[1,1]
c_5	[0,1]	[0,0]	[0,1]	[0,1]	[1,1]	[1,0]	[1,1]	[1,1]	[0,0]	[0,1]	[0,1]	[1,1]	[1,1]	[1,1]	[0,0]
c_6	[0,1]	[0,0]	[0,0]	[0,1]	[1,1]	[1,0]	[1,0]	[1,1]	[0,0]	[0,0]	[0,1]	[0,0]	[0,1]	[1,1]	[0,0]
c_7	[0,0]	[0,1]	[0,0]	[0,1]	[0,0]	[0,1]	[0,0]	[0,1]	[1,1]	[1,0]	[1,1]	[0,0]	[0,1]	[1,1]	[0,0]

According to the tabular form of these SIs, the interval choice values are $v_1 = [5,7]$, $v_2 = [8,4]$, $v_3 = [11,7]$, $v_4 = [9,3]$, $v_5 = [7,11]$, $v_6 = [5,7]$ *and* $v_7 = [4,8]$. *Following these interval choice values, the choice object is* c_5. *So Mr. X should buy the car* c_5.

Now we will implement the computer application to the previous example. It is seen that the result object "car5" is obtained faster with the help of computer program. Screenshots of some evaluation steps are demonstrated as below:

The main page of the computer application of Example 5.1 is in the following figure.

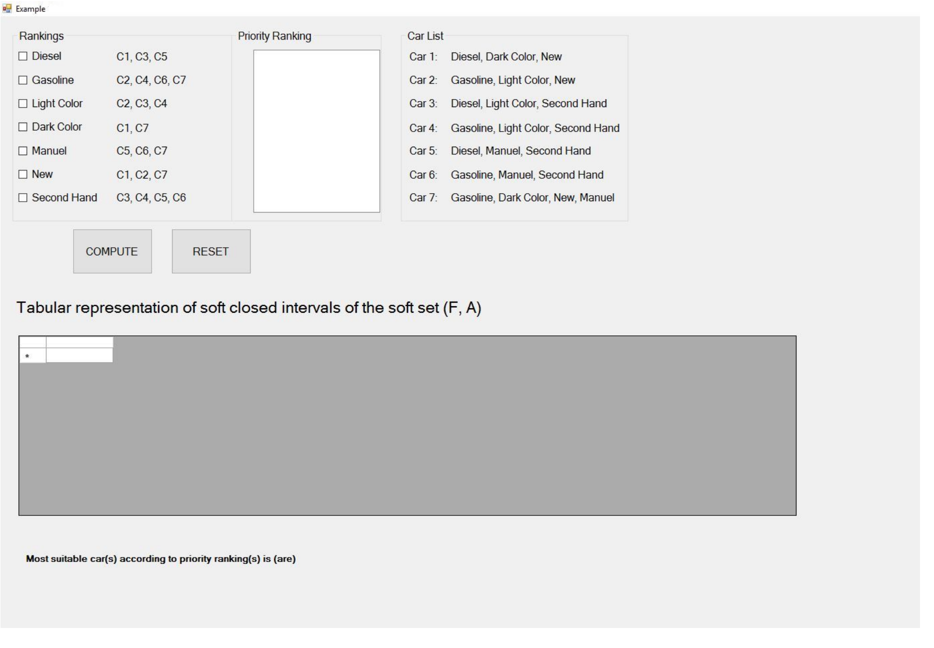


Figure 1. Screenshot of the beginning page of computer application for Example 5.1

"Rankings" part is the soft set of Example 5.1 in the Figure 1. "Priority Ranking" part is the order of the given soft set, which depends on the user's priority.

Now let us apply priority rankings of Mr. X to the computer application as follows:
Step 1: Choose first ranking according to Mr. X's priority

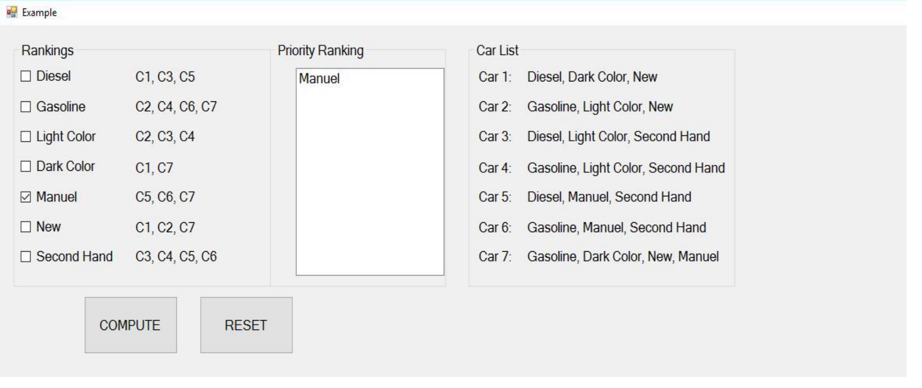


Figure 2. Screenshot of computer application for Example 5.1 step 1

Step 2: Choose the rest of rankings according to Mr. X's priority

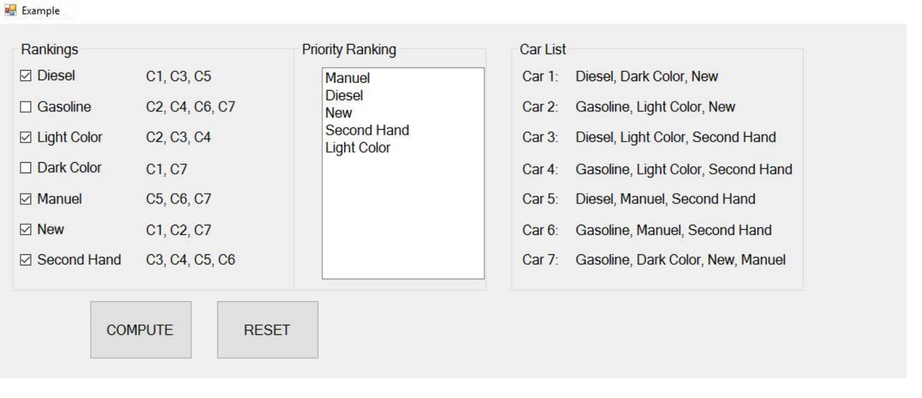


Figure 3. Screenshot of computer application for Example 5.1 step 2

Step 3: Press the COMPUTE button and find the result object.

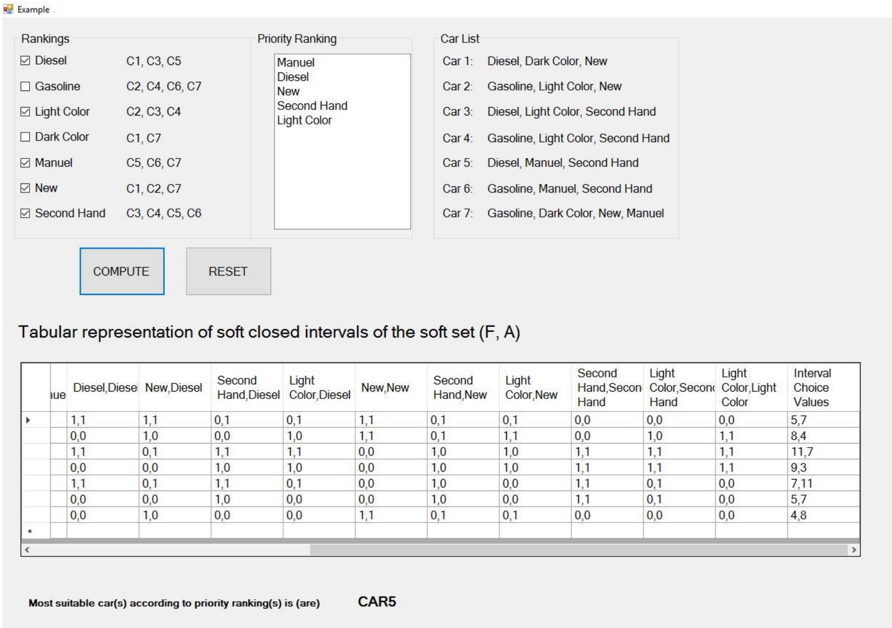


Figure 4. The final screenshot of computer application for Example 5.1

Note that, in the Figure 5, the first row of the tabular representation of the closed intervals of the soft set (F, A) corresponds to the SIs of the soft set (F, A).

According to this DM method, priority of the ranking is very important. In the Example 5.1, if Mr. X chooses same rankings with different order (light color - second hand - diesel - manuel - new), most suitable car for Mr. X will change. Our designed computer program can easily sense this situation and provide these correct results as shown in the following steps whose screenshots of computer application are given in Appendix 2:

Step 1: Choose first ranking according to Mr. X's priority.

Step 2: Choose the rest of rankings according to Mr. X's priority.

Step 3: Press the COMPUTE button.

According to this priority ranking, the most suitable result object for Mr. X is car3 instead of car5.

Maji and Roy [9] gave an application of the soft set theory in a DM problem by using an example. In the following example, we compare our method with their method on the same soft set.

Example 5.2 *Let us consider the soft set, which was used by Maji and Roy in [9]. Let* $U = \{h_1, h_2, h_3, h_4, h_5, h_6\}$ *be a set of six houses,* $E = \{e_1 =$ expensive; $e_2 =$ beautiful; $e_3 =$ wooden; $e_4 =$ cheap ; $e_5 =$ in the green surroundings; $e_6 =$ modern; $e_7 =$ in good repair; $e_8 =$ in bad repair$\}$ *be a set of parameters. Consider the soft set* (F, E) *that describes the attractiveness of the houses, given by* $(F, E) = \{$expensive $= \emptyset$, beautiful houses $= \{h_1, h_2, h_3, h_4, h_5, h_6\}$, wooden houses $=$

$\{h_1, h_2, h_6\}$, modern houses $= \{h_1, h_2, h_6\}$, in bad repair houses $= \{h_2, h_4, h_5\}$, cheap houses $= \{h_1, h_2, h_3, h_4, h_5, h_6\}$, in good repair houses $= \{h_1, h_3, h_6\}$, in the green surroundings houses $= \{h_1, h_2, h_3, h_4, h_6\}\}$.

According to Maji and Roy [9], Mr. X is interested to buy a house on the basis of his choice parameters 'beautiful', 'wooden', 'cheap', 'in the green surroundings', 'in good repair', which constitute the subset $P = \{$beautiful, wooden, cheap, in the green surroundings, in good repair $\}$ of the set E. That means, out of available houses in U, he is select that house which qualifies with all (or with maximum number of) parameters of P. The problem is to select the house which is most suitable with the choice parameters of Mr. X.

Maji and Roy [9] gave the following algorithm for the selection of the house that Mr. X wishes to buy
1, input the soft set (F, E),
2. input the set P of choice parameters of Mr. X which is a subset of E,
3. find all reduct-soft-sets of (F, P),
4. choose one reduct-soft-set, say (F, Q) of (F, P),
5. find k, for which $c_k = \max c_i$.
Then h_k is the optimal choice object. If k has more than one value, then any one of them could be chosen by Mr. X by using his option.
For this example, $\{e_1, e_2, e_4, e_5\}$ and $\{e_2, e_3, e_4, e_5\}$ are the two reducts of $P = \{e_1, e_2, e_3, e_4, e_5\}$. We can choose any one. Let us choose $Q = \{e_1, e_2, e_4, e_5\}$.
Incorporating the choice values, the reduct-soft-set can be represented in the following table.

Table 8. Tabular representation of the reduct soft set

U	e_1	e_2	e_4	e_5	choice value
h_1	1	1	1	1	$c_1 = 4$
h_2	1	1	1	0	$c_2 = 3$
h_3	1	0	1	1	$c_3 = 3$
h_4	1	0	1	0	$c_4 = 2$
h_5	1	0	0	0	$c_5 = 1$
h_6	1	1	1	1	$c_6 = 4$

Here $\max c_i = c_1$ or c_6. Therefore, Mr. X should buy either the house h_1 or the house h_6.
This algorithm is developed without bothering personal preference. The only important thing in this method is what parameters are provided. Since there is no personal ranking in this example, to applied our own method to this example we need to create a partial order on the soft set in the order in which the parameters were written. Now our decision making algorithm can apply to this example and we got the same result with Maji and Roy [9] as follows:
Suppose Mr. X is interested to buy a house on the basis of his choice parameters beautiful, wooden, cheap, in the green surroundings, in good repair. We can obtain an order relation

$$\begin{aligned}\leq = \quad & \{F(e_2) \times F(e_2), F(e_3) \times F(e_3), F(e_4) \times F(e_4), F(e_5) \times F(e_5), F(e_7) \times F(e_7), \\ & F(e_3) \times F(e_2), F(e_4) \times F(e_2), F(e_5) \times F(e_2), F(e_7) \times F(e_2), F(e_4) \times F(e_3), \\ & F(e_5) \times F(e_3), F(e_7) \times F(e_3), F(e_5) \times F(e_4), F(e_7) \times F(e_4), F(e_7) \times F(e_5)\}\end{aligned}$$

by using Mr. X's priorities. All soft closed intervals are as follows:

$$\begin{array}{lllll} [F(e_2), F(e_2)], & [F(e_3), F(e_3)], & [F(e_4), F(e_4)], & [F(e_5), F(e_5)], & [F(e_7), F(e_7)], \\ [F(e_3), F(e_2)], & [F(e_4), F(e_2)], & [F(e_5), F(e_2)], & [F(e_7), F(e_2)], & [F(e_4), F(e_3)], \\ [F(e_5), F(e_3)], & [F(e_7), F(e_3)], & [F(e_5), F(e_4)], & [F(e_7), F(e_4)], & [F(e_7), F(e_5)] \end{array}$$

and indicate them by α_i's as following

$$\begin{array}{lll} \alpha_1 = [F(e_2), F(e_2)], & \alpha_2 = [F(e_3), F(e_3)], & \alpha_3 = [F(e_4), F(e_4)], \\ \alpha_4 = [F(e_5), F(e_5)], & \alpha_5 = [F(e_7), F(e_7)], & \alpha_6 = [F(e_3), F(e_2)], \\ \alpha_7 = [F(e_4), F(e_2)], & \alpha_8 = [F(e_5), F(e_2)], & \alpha_9 = [F(e_7), F(e_2)], \\ \alpha_{10} = [F(e_4), F(e_3)], & \alpha_{11} = [F(e_5), F(e_3)], & \alpha_{12} = [F(e_7), F(e_3)], \\ \alpha_{13} = [F(e_5), F(e_4)], & \alpha_{14} = [F(e_7), F(e_4)], & \alpha_{15} = [F(e_7), F(e_5)]. \end{array}$$

Thus the tabular representation of all soft closed intervals is given in Table 9.

Table 9. Tabular representation of soft closed intervals of the soft set (F, A)

	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9	α_{10}	α_{11}	α_{12}	α_{13}	α_{14}	α_{15}
h_1	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]
h_2	[1,1]	[1,1]	[1,1]	[1,1]	[0,0]	[1,1]	[1,1]	[1,1]	[0,1]	[1,1]	[1,1]	[0,1]	[1,1]	[0,1]	[0,1]
h_3	[1,1]	[0,0]	[1,1]	[1,1]	[1,1]	[0,1]	[1,1]	[1,1]	[1,1]	[1,0]	[1,0]	[1,0]	[1,1]	[1,1]	[1,1]
h_4	[1,1]	[0,0]	[1,1]	[1,1]	[0,0]	[0,1]	[1,1]	[1,1]	[0,1]	[1,0]	[1,0]	[0,0]	[1,1]	[0,1]	[0,1]
h_5	[1,1]	[0,0]	[1,1]	[0,0]	[0,0]	[0,1]	[1,1]	[0,1]	[0,1]	[1,0]	[0,0]	[0,0]	[0,1]	[0,1]	[0,0]
h_6	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]	[1,1]

According to the tabular form of these SIs, the interval choice values are $v_1 = [15, 15]$, $v_2 = [10, 14]$, $v_3 = [13, 11]$, $v_4 = [8, 10]$, $v_5 = [4, 8]$ *and* $v_6 = [15, 15]$. *Following these interval choice values, the choice objects are* h_1 (house1), h_6 (house6) *which are the same results with Maji and Roy's results [9].*

Beside the stated points in earlier paragraphs, when computer application was applied to the Example 5.2, the result objects house1 and house6 were obtained faster. The final evaluation screenshot of the computer application is given as follows:

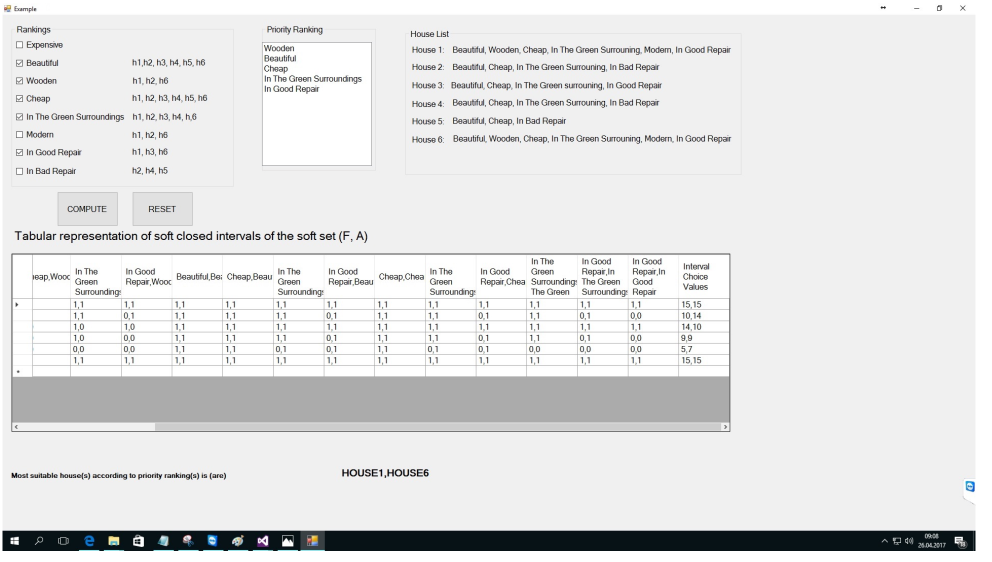


Figure 5. The final screenshot of the final page of computer application for Example 5.2

Example 5.3 *Consider the Example 4.6, which we have solved with our own method and obtained the object h_5 as a choice object. Let us solve this example with Maji and Roy's method [9] to compare with our method on the same soft set.*

Table 10. Tabular representation of the soft set

	a_1	a_2	a_7	choice value
h_1	1	0	0	$c_1 = 1$
h_2	0	1	0	$c_2 = 1$
h_3	0	0	0	$c_3 = 0$
h_4	0	0	0	$c_4 = 0$
h_5	0	0	1	$c_5 = 1$
h_6	0	0	0	$c_6 = 0$

According to the table, we have three choice object, that obtained by using Maji and Roy's method [9]; h_1, h_2 and h_5. Since we have only three possible houses to choose, Maji and Roy's method [9] does not offer a functional decision in this example actually, while our method offers a unique house h_5.

Example 5.4 *Consider Example 5.1. Let us apply Maji and Roy [9] method to this example to obtain a decision.*

Table 11. Tabular representation of the soft set

	e_1	e_3	e_5	e_7	e_8	choice value
c_1	1	0	0	1	0	$c_1 = 2$
c_2	0	1	0	1	0	$c_2 = 2$
c_3	1	1	0	0	1	$c_3 = 3$
c_4	0	1	0	0	1	$c_4 = 2$
c_5	1	0	1	0	1	$c_5 = 3$
c_6	0	0	1	0	1	$c_6 = 2$
c_7	0	0	1	1	0	$c_7 = 2$

In the both parts of the Example 5.1 if we use the method of Maji and Roy [9], we would obtain c_3, c_5 as a solution, because order is not taken into account in this method. But by using our presented method we obtain c_5 in the first part and c_3 in the second part according to the priority rankings as seen in the Example 5.1.

As can be seen from the examples given above, various types of problems including uncertainties can be modeled in daily life by changing the parameters and objects. Our presented method can be applied to them, no matter how many parameter or objects there are. This is one of the effective sides of our present method. Also, our method is a general method in making decisions by using soft sets and it can find the most accurate solution for such problems by considering the importance order of individual preferences.

6. Conclusions

In this study, we compared soft intervals (SI) with interval soft sets (ISS) and we explained the difference between the soft interval and the interval soft set. This comparison showed us that the SI is the generalization of ISS. At the same time, to solve real life problems, we introduced a Decision Making algorithm which is based on the soft intervals. Also tabular form of soft intervals was used to apply this algorithm. We applied the presented method to the examples which were from studies about decision making methods by using soft sets of Zhang [21], Zhu et al. [23] and Maji and Roy [9]. Then we obtained the same results with them in Example 4.7 and Example 5.2. As can be seen from these examples, presented method is a general method than the Decision-Making methods based on special situations of soft set theory. Since DM methods should be faster and they should be handle huge data easily, the computer application of our algorithm is written in C# and applied to the examples.

One can improve this algorithm and its computer application to other Decision Making Methods. Our designed computer program can be used in the machine learning algorithms as well as in the software development that can be used by the various types of property dealers.

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Appendix 1

Reader can find full codes of the computer application at
http://akademik.mu.edu.tr/gozdeyaylali/tr.

```
...
{
public Form1() {
InitializeComponent();
}
public string[] Diesel = { "c1", "c3", "c5" };
public string[] Gasoline = { "c2", "c4", "c6", "c7" };
public string[] LightColor = { "c2", "c3", "c4" };
public string[] DarkColor = { "c1", "c7" };
public string[] Manuel = { "c5", "c6", "c7" };
public string[] New = { "c1", "c2", "c7" };
public string[] SecondHand = { "c3", "c4", "c5", "c6" };
...
{
if (checkBox1.Checked == true)
{
int sonuc;
sonuc = listBox1.FindString(checkBox1.Text);
if (sonuc != -1)
{
...
{
for (int i = 1; i <8; i++)
...
}
```

Appendix 2

Screenshots of the Example 5.1 with different priority rankings.

Figure 6. Screenshot of computer application for Example 5.1 with different priority rankings step 1

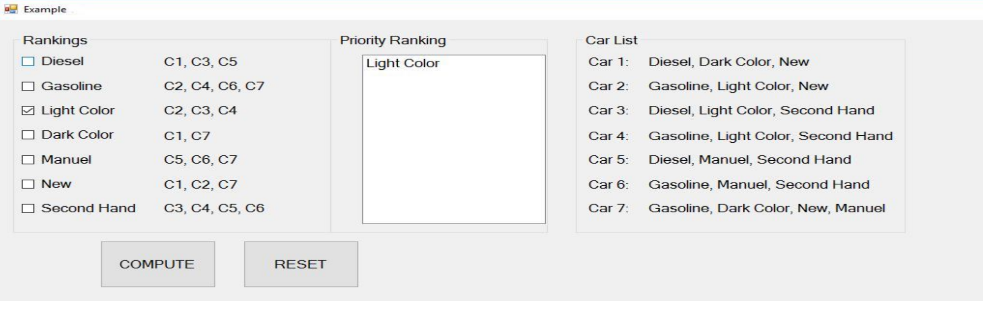


Figure 7. Screenshot of computer application for Example 5.1 with different priority rankings step 2

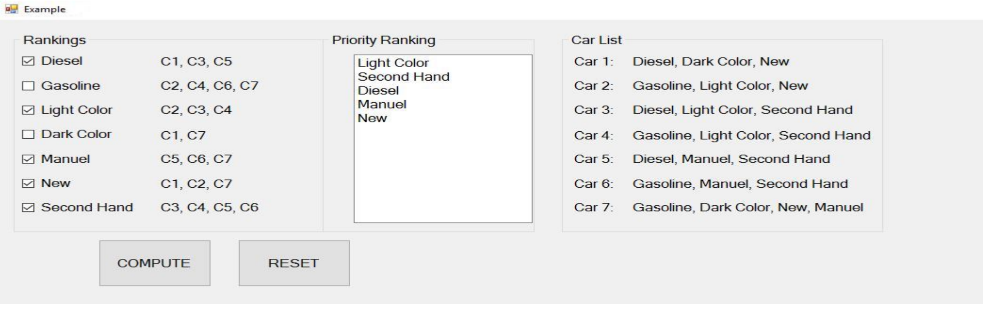
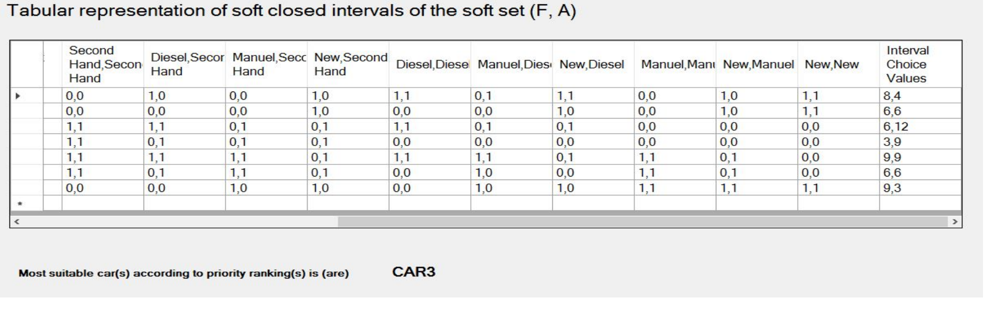


Figure 8. The final screenshot of computer application for Example 5.1 with different priority rankings



Tabular representation of soft closed intervals of the soft set (F, A)

Second Hand,Secon Hand	Diesel,Secor Hand	Manuel,Secc Hand	New,Second Hand	Diesel,Diese	Manuel,Dies	New,Diesel	Manuel,Manı	New,Manuel	New,New	Interval Choice Values
0,0	1,0	0,0	1,0	1,1	0,1	1,1	0,0	1,0	1,1	8,4
0,0	0,0	0,0	1,0	0,0	0,0	1,0	0,0	1,0	1,1	6,6
1,1	1,1	0,1	0,1	1,1	0,1	0,1	0,0	0,0	0,0	6,12
1,1	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	3,9
1,1	1,1	1,1	0,1	1,1	1,1	0,1	1,1	0,1	0,0	9,9
1,1	0,1	1,1	0,1	0,0	1,0	0,0	1,1	0,1	0,0	6,6
0,0	0,0	1,0	1,0	0,0	1,0	1,0	1,1	1,1	1,1	9,3

Most suitable car(s) according to priority ranking(s) is (are) CAR3

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