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An Application of Soft Set and Fuzzy Soft Set Theories to Stock Management

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Abstract: We give a new application of both notions of a soft set and of a fuzzy soft set to the effective management of stock-out situation. We construct a model to track the remaining raw materials in stock at the end of the first week (or first month) by using soft sets theory. Then we introduce an algorithm for factors influencing stock management using the notion of a fuzzy soft set. If we use these soft set and fuzzy soft set models at the same time, we can more accurately track the stock-out situations of raw materials.

Esnek Küme ve Bulanık Esnek Küme Teorisinin Stok Yönetimine Bir Uygulaması

Anahtar Kelimeler
Esnek küme,
Bulanık esnek küme,
Stok yönetimi,
Stok durumu

Özet: Bu çalışmada stok durumlarının etkili bir şekilde yönetimi probleminin çözümünde, esnek ve bulanık esnek kümelerin kullanılmasına ilişkin bir uygulama verilmiştir. İlk hafta (veya ilk ay) sonunda, esnek küme teorisinin kullanılması ile stokta bulunan hammaddelerin takibi için bir model oluşturulmuştur. Daha sonra bulanık esnek küme kavramı kullanılarak stok yönetimini etkileyen faktörler için bir algoritma verilmiştir. Bu esnek küme ve bulanık esnek küme modelleri aynı anda kullanılarak hammaddelerin stok durumlarının daha doğru takip edilebilmesi sağlanmıştır.

1. Introduction and Background

Recently, soft set theory was introduced as a generalization of mathematical tools by Molodtsov [10] as follows:

Definition 1.1. [10] Let X be a universal set, $P(X)$ be the power set of X and E be the set of all parameters. A soft set (F,E) on X is defined by

$$(F,E) = \{(e,F(e)) : e \in E,\, F(e) \in P(X)\},$$

where $F : E \to P(X)$.

We give the following example of a soft set.

Example 1.2. Let us consider the universal set X and the parameter set E as follows:

$$X = \{m_1,m_2,m_3,m_4,m_5\}$$

and

$$E = \{e_1,e_2,e_3,e_4,e_5,e_6\},$$

where m_i $(i \in \{1,2,3,4,5\})$ and e_j $(j \in \{1,2,3,4,5,6\})$ are given in the following table.

Raw Materials	Parameters
$m_1 = wood$	$e_1 = water$
$m_2 = fabric$	$e_2 = temperature$
$m_3 = screw$	$e_3 = moisture$
$m_4 = leather$	$e_4 = light$
$m_5 = rope$	$e_5 = hygiene$
	$e_6 = time$

.

The soft set (F,E) describes the raw materials affected by parameters. Let the function $F : E \to P(X)$ be defined as

$$\begin{aligned} F(e_1) &= X, \\ F(e_2) &= \{m_2,m_4\}, \\ F(e_3) &= \{m_1,m_3\}, \\ F(e_4) &= \{m_2,m_4\}, \\ F(e_5) &= \{m_1,m_2,m_4\}, \\ F(e_6) &= \emptyset. \end{aligned}$$

Then a soft set (F,E) can be written as follows:

$$(F,E) = \left\{ \begin{array}{c} (e_1,X),(e_2,\{m_2,m_4\}),(e_3,\{m_1,m_3\}), \\ (e_4,\{m_2,m_4\}),(e_5,\{m_1,m_2,m_4\}),(e_6,\emptyset) \end{array} \right\}.$$

Definition 1.3. [9] A soft set (F,E) on X is called a null soft set if $F(e) = \emptyset$ for all $e \in E$ and it is denoted by $\widetilde{\emptyset}$.

Example 1.4. Let us consider the universal set X and the parameter set E given in Example 1.2. If the soft set (F,E) is defined as

$$(F,E) = \{(e_1,\emptyset),(e_2,\emptyset),(e_3,\emptyset),(e_4,\emptyset),(e_5,\emptyset),(e_6,\emptyset)\},$$

then (F,E) is a null soft set on X.

Definition 1.5. [9] A soft set (F,E) on X is called an absolute soft set if $F(e) = X$ for all $e \in E$ and it is denoted by $\widetilde{X}$.

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Example 1.6. Let us consider the universal set X and the parameter set E given in Example 1.2. If the soft set (F,E) is defined as

$$(F,E)=\{(e_1,X),(e_2,X),(e_3,X),(e_4,X),(e_5,X),(e_6,X)\},$$

then (F,E) is an absolute soft set on X.

The notion of a fuzzy soft set was defined by Maji et al. [8]. Now we recall the following definitions.

Definition 1.7. [8] Let X be a universal set, $F(X)$ be the set of all fuzzy subsets of X and E be the set of all parameters. Then a pair (F,E) is called a fuzzy soft set on X, where $F:E\to F(X)$.

Example 1.8. Let us consider the universal set X and the parameter set E given in Example 1.2. If the soft set (F,E) is defined as

$$(F,E)=\left\{\begin{array}{c}\left(e_1,\left\{\frac{m_1}{0.8},\frac{m_2}{0.5},\frac{m_3}{0.8},\frac{m_4}{0.6},\frac{m_5}{0.1}\right\}\right),\left(e_2,\left\{\frac{m_2}{0.6},\frac{m_4}{0.7}\right\}\right),\\ \left(e_3,\left\{\frac{m_1}{0.3},\frac{m_3}{0.4}\right\}\right),\left(e_4,\left\{\frac{m_2}{0.2},\frac{m_4}{0.9}\right\}\right),\\ \left(e_5,\left\{\frac{m_1}{0.3},\frac{m_2}{0.3},\frac{m_4}{0.3}\right\}\right),\left(e_6,\emptyset\right)\end{array}\right\}$$

then (F,E) is a fuzzy soft set on X, where

$$(F,E)=\{\left(e_j,\frac{m_i}{\mu_i(m_i)}\right):i\in\{1,2,3,4,5\},$$
$$j\in\{1,2,3,4,5,6\},\mu_i(m_i)\in[0,1]\}$$

and $\mu_i(m_i)$ denotes the value of membership m_i on X. The value of membership which is not written in (F,E) is 0.

Definition 1.9. [1] Let (F,E) and (G,E) be two fuzzy soft sets on a universal set X. A relation R of (F,E) on (G,E) is defined as a mapping $R:E\times E\to P(U\times U)$ such that for each $e,f\in E$ and $x\in F(e)$, $y\in G(f)$, the relation R is characterized by the following membership function

$$\mu_R(x,y)=\mu_{F(e)}(x)\times\mu_{G(f)}(y).$$

It is important to produce some solutions for encountered difficulties. Then using the above notions, some applications have been obtained for some daily life problems. For example, Kalaichelvi and Malini studied an application of a fuzzy soft set to investment decision making problem [5]. In [2], it was given an application of a fuzzy EOQ model to the stock management. In [3], it was proposed Fuzzy Logic to model human behavior and used the existing data from an experimental study on Stock Management Model and comes up with Fuzzy Logic players to mimic the behaviors of three different types of players. Kong et al. presented two methods in decision making problems in fuzzy soft sets and constructed a new algorithm to solve the two problems [6]. In [12], it was introduced a soft expert system (SES) as a prediction system for prostate cancer by using the prostate specific antigen (PSA), prostate volume (PV) and age factors of patients based on fuzzy sets and soft sets. Yüksel et al. defined soft covering based rough set and presented an example in medicine [13]. Özgür and Taş obtained a new application of investment decision making problem using the notions of matrix theory, period and soft set theory [11]. Recently, Kong et al. applied the particle swarm optimization to reduce parameters in a soft set [7]. Then, in [4], Han proposed a linear programming mathematical representation for normal parameter reduction problems of soft sets.

By the motivation of the above studies, in this paper we give an application of soft sets (resp. fuzzy soft sets) to the management of stock-out situations. To do this we use the soft sets to determine the stock-out situations of a company. For this purpose we use the Excel program by constructing a model of stock control. Then using the notion of a fuzzy soft set and MATLAB [14] we can easily track the most affected raw material by various conditions. As a consequence one can easily observe and manage the stock-out situations. The stock-out situations can be easily followed on a table by means of our "soft set modelling". Also the most affected raw materials can be easily controlled using our "fuzzy soft set modelling". Consequently, the stock-out situations of these raw materials can be observed using our two models together. If we consider the study given in [3], we see that the obtained model was constructed using fuzzy logic without parameter. In our models, we use both of the notions of a soft set and a fuzzy soft set and so the considered problem is modelled comprehensively by appropriate parameters.

2. An Application of Soft Sets to the Stock-Out Situations

In this section, an excel program is constructed by the notion of a soft set in order to control the stock-out situations in a company. This program shows raw materials which is out of stock for giving order.

Now we explain the program for five-day working week. Firstly, we determine a universal set of raw materials and a parameter set of the stock-out situations. For five-day working week, daily usage data of every raw materials is entered manually on the table in the excel program. At the end of the first week, we define a bound for each of raw materials by considering the remaining raw materials at the end of fifth day to predict the remaining raw materials are adequate or not for the next week (each bound are determined by some factors such as weekly usage, lead time, storage capacity etc.). For the first week, the amount of ordered raw materials is written as a line for the first week in the table of weekly used raw materials. Remaining amounts of raw materials can be easily seen with the codes at the end of any day for the first week. By the boundary of raw materials, the information of the stock-out situations follows easily:

According to the amount of remaining raw materials at the end of first week;

• If the amount of remaining raw materials $\geq$ boundary of raw materials, they are in stock and showed with "1".

• If the amount of remaining raw materials $<$ boundary of raw materials, they are out of stock and showed with "0".

Raw materials which are out of stock are ordered after the information of the stock-out situations. Also, order quantity of raw materials should be at least the amount of weekly usage. After raw materials which are out of stock are ordered, the amount of raw materials ordered for the second week is written as the line of the second week in the table of weekly used raw materials. Raw materials which are in stock are not ordered and the remaining of them are used for the next week. Then "0 (zero)" is written instead of raw materials which are in stock. For the raw materials which are out of stock, the amount of raw materials staying in the previous week and the amount of ordered raw materials are collected and this amount is used for the second week. If the raw materials are in stock, then remaining raw materials in the last week are used for the next week. For the second week, remaining of raw materials can be easily seen with the codes at the end of any day. At the end of fifth day, remaining of raw materials determines remaining of raw materials of the second week. According to the amount of remaining raw materials at the end of the second week;

• If the amount of remaining raw materials $\geq$ boundary of raw materials, they are in stock and showed with "1".

• If the amount of remaining raw materials $<$ boundary of raw materials, they are out of stock and showed with "0".

Raw materials which are out of stock are ordered after the information of the stock-out situations. These process are the same as the first and second weeks for the third and fourth weeks. As a consequence, remaining of raw materials can be easily seen with the codes for first month. Then the column graph of remaining raw materials is obtained. Using the constructed table with "0" and "1", we obtain the soft sets (F_i,E) $(i \in \{1,2,3,4\})$, where $E = \{e_1 = \text{in stock}, e_2 = \text{out of stock}\}$ is a parameter set and $F_i : E \to P(X)$ is a function (X is a set of raw materials). By the above process, we have some information about the stock-out situations of raw materials which are used by the company as weekly and monthly. We can easily seen the stock-out situations of raw materials in single line by means of the soft sets (F_i,E).
Now we give an example of this program using a soft set.

Example 2.1. Let

$X = \{m_1,m_2,m_3,m_4,m_5\}$ be the set of raw materials

and

$E = \{e_1,e_2\}$ be the set of parameters,

where $e_1 =$ in stock and $e_2 =$ out of stock. The parameter "e_1" is denoted by "1" and the parameter "e_2" is denoted by "0" in the Excel program.
Now we see how this Excel program operates for the sets "X" and "E". At first, the amount of daily usage for the raw materials are entered in the program (see Table 1).

Table 1. The amounts of daily usage of raw materials.

	m_1	m_2	m_3	m_4	m_5
First day	175	250	125	100	200
Second day	200	50	75	25	200
Third day	100	160	90	60	150
Fourth day	80	100	150	130	120
Fifth day	200	75	150	100	50

Then the amount of daily use for raw materials are demonstrated our the minimum amount of stock (see Table 2, where s_i denotes the minimum amount of stock of m_i for $i \in \{1,2,3,4,5\}$).

Table 2. The bounds for the raw materials for one week.

s_1	s_2	s_3	s_4	s_5
755	635	590	415	720

The amount of raw materials which are ordered are entered in the program for each week (see Table 3).

Table 3. The amount of ordered raw materials.

	m_1	m_2	m_3	m_4	m_5
First week	1500	1250	1000	2000	1800
Second week	1000	1250	900	0	0
Third week	0	0	0	0	750
Fourth week	1000	500	750	0	750

Hence we can easily see the table of weekly remaining raw materials after our program is run (see Figure 1).

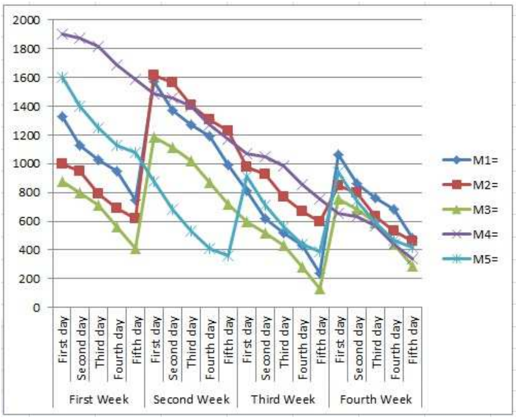

Figure 1. Daily remaining raw materials for each week of a month.

Consequently, the following table and graph show the remaining raw materials at the end of a month (see Table 4 and Figure 2).

Table 4. Remaining raw materials for each week in the first month.

	m_1	m_2	m_3	m_4	m_5
First week	745	615	410	1585	1080
Second week	990	1230	720	1170	360
Third week	235	595	130	755	390
Fourth week	480	460	290	340	420

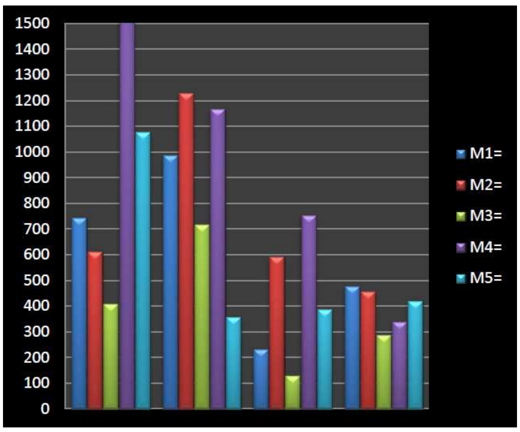

Figure 2. The remaining raw materials graph.

Finally, we can obviously see the stock-out situations of raw materials using parameters (see Table 5, Table 6, Table 7 and Table 8).

Table 5. The stock-out situations for the first week.

	m_1	m_2	m_3	m_4	m_5
e_1	0	0	0	1	1
e_2	1	1	1	0	0

Table 6. The stock-out situations for the second week.

	m_1	m_2	m_3	m_4	m_5
e_1	1	1	1	1	0
e_2	0	0	0	0	1

Table 7. The stock-out situations for the third week.

	m_1	m_2	m_3	m_4	m_5
e_1	0	0	0	1	0
e_2	1	1	1	0	1

Table 8. The stock-out situations for the fourth week.

	m_1	m_2	m_3	m_4	m_5
e_1	0	0	0	0	0
e_2	1	1	1	1	1

In the above tables we have seen the amounts of raw materials which are in stock or out of stock at the end of the first week (resp. second week, third week, fourth week). For example, the raw materials m_1, m_2 and m_3 are out of stock at the end of the first week. Similarly, the raw materials m_1, m_2, m_3, m_4 and m_5 are out of stock at the end of a month and so all raw materials have to be ordered.
Using the above tables, we construct the following soft sets (F_1,E), (F_2,E), (F_3,E), (F_4,E) for first week, second week, third week, fourth week, respectively.

$$\begin{aligned}
(F_1,E) &= \{(e_1,\{m_4,m_5\}),(e_2,\{m_1,m_2,m_3\})\},\\
(F_2,E) &= \{(e_1,\{m_1,m_2,m_3,m_4\}),(e_2,\{m_5\})\},\\
(F_3,E) &= \{(e_1,\{m_4\}),(e_2,\{m_1,m_2,m_3,m_5\})\},\\
(F_4,E) &= \{(e_1,\emptyset),(e_2,\{m_1,m_2,m_3,m_4,m_5\})\}.
\end{aligned}$$

These soft sets show the raw materials which are in stock and out of stock at the end of a month for each week in single line. We can easily control the stock-out situations of raw materials using these soft sets.

3. The Effective Stock Management via Fuzzy Soft Sets

In this section we give another approach to stock management using the concept of a fuzzy soft set. To do this we give an algorithm. The following algorithm can be presented for an application of "fuzzy soft sets" to stock management.

Step 1. Define a universal set X and a parameter set E.
Step 2. Construct the fuzzy soft sets $(f_i,e_i)=F_i$ for $i\in\{1,2,...,n\}$.
Step 3. Using MATLAB, choose appropriate functions through all of the membership values.
Step 4. Using the functions chosen in Step 3, define the membership functions.
Step 5. Determine the parameters which are influence on stock management for the company.
Step 6. Compute the fuzzy soft sets for our company using the relation R given in Definition 1.9 among the membership values related to parameters.
Step 7. Determine the raw material which is most affected by parameters.

Now we give an example. We define the following notations:

Raw materials:

m_1 : First raw material,
m_2 : Second raw material,
m_3 : Third raw material,
m_4 : Fourth raw material,
m_5 : Fifth raw material.

Factors influencing stock management:

e_1 : The amount of planned product,
e_2 : Season,
e_3 : Hygiene,
e_4 : The source of the raw materials,
e_5 : Time,
e_6 : Service life,
e_7 : Storage capacity,
e_8 : Temperature.

A universal set and a parameter set are defined as follows, respectively:

$$X=\{m_1,m_2,m_3,m_4,m_5\}$$

and

$$E=\{e_1,e_2,e_3,e_4,e_5,e_6,e_7,e_8\}.$$

Then we construct the following fuzzy soft sets for each parameter.

$$\begin{aligned}
(f_1,e_1) &= F_1=\left\{\frac{m_1}{0.5},\frac{m_2}{0.75},\frac{m_3}{1},\frac{m_4}{0.25},\frac{m_5}{0.3}\right\},\\
(f_2,e_2) &= F_2=\left\{\frac{m_1}{0.2},\frac{m_2}{0.4},\frac{m_3}{0.1},\frac{m_4}{0.6},\frac{m_5}{0.7}\right\},\\
(f_3,e_3) &= F_3=\left\{\frac{m_1}{1},\frac{m_2}{0.75},\frac{m_3}{0.5},\frac{m_4}{0.8},\frac{m_5}{1}\right\},\\
(f_4,e_4) &= F_4=\left\{\frac{m_1}{0.3},\frac{m_2}{0.2},\frac{m_3}{0.45},\frac{m_4}{0.64},\frac{m_5}{0.9}\right\},\\
(f_5,e_5) &= F_5=\left\{\frac{m_1}{0.7},\frac{m_2}{1},\frac{m_3}{0.5},\frac{m_4}{0.54},\frac{m_5}{1}\right\},\\
(f_6,e_6) &= F_6=\left\{\frac{m_1}{0.39},\frac{m_2}{0.71},\frac{m_3}{1},\frac{m_4}{0.45},\frac{m_5}{0.6}\right\},\\
(f_7,e_7) &= F_7=\left\{\frac{m_1}{1},\frac{m_2}{0.4},\frac{m_3}{0.8},\frac{m_4}{0.2},\frac{m_5}{0.01}\right\},\\
(f_8,e_8) &= F_8=\left\{\frac{m_1}{1},\frac{m_2}{1},\frac{m_3}{1},\frac{m_4}{1},\frac{m_5}{1}\right\}.
\end{aligned}$$

Using MATLAB and the membership values of the above fuzzy soft sets, we define the membership functions for each of the fuzzy soft sets. At first we construct the following functions ξ_i for $i \in \{1,2,3,4,5,6,7,8\}$.

$$\begin{aligned}
\xi_1(x) &= 0.1167x^4 - 1.3333x^3 + 5.0833x^2 \\
&\quad -7.4167x + 4.05, \\
\xi_2(x) &= -0.1042x^4 + 1.2583x^3 - 5.1958x^2 \\
&\quad +8.5417x + 4.3, \\
\xi_3(x) &= -0.0875x^4 + 0.9667x^3 - 3.6125x^2 \\
&\quad +5.1333x - 1.4, \\
\xi_4(x) &= 0.0225x^4 - 0.2933x^3 + 1.3725x^2 \\
&\quad -2.5017x + 1.7, \\
\xi_5(x) &= -0.0608x^4 + 0.8317x^3 - 3.8692x^2 \\
&\quad +6.9983x - 3.2, \\
\xi_6(x) &= 0.0979x^4 - 1.1142x^3 + 4.2221x^2 \\
&\quad -6.0158x + 3.2, \\
\xi_7(x) &= 0.1421x^4 - 1.7542x^3 + 7.4729x^2 \\
&\quad -12.8708x + 8.01, \\
\xi_8(x) &= 1,
\end{aligned}$$

where $x \in \{1,2,3,4,5\}$. The membership functions $\mu_{f_i(e_i)}(m_x)$ (see Figure 3, the x axis shows raw materials) be defined as

$$\mu_{f_i(e_i)}(m_x) = \xi_i(x).$$

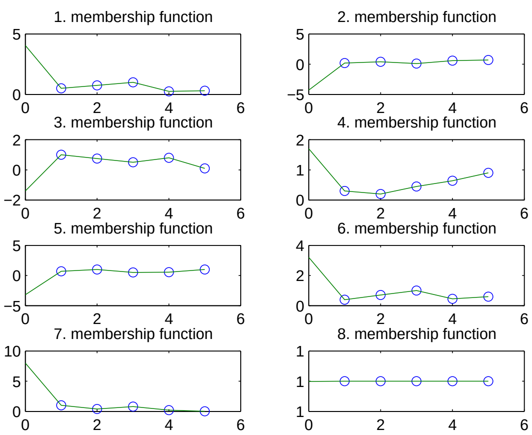

Figure 3. The membership functions of the fuzzy soft sets.

This fuzzy soft set model is developed using a relation R among the fuzzy soft sets for three companies as follows:

First Company (A): The factors influencing stock management of this company are season (e_2), hygiene (e_3), time (e_5), service life (e_6) and temperature (e_8). Then the fuzzy soft set F_A shows both of the most affected and the least affected raw materials by factors as follows:

$$F_A = \left\{ \frac{m_1}{0.0546}, \frac{m_2}{0.213}, \frac{m_3}{0.025}, \frac{m_4}{0.1166}, \frac{m_5}{0.42} \right\}.$$

By the fuzzy soft set F_A, we say that the raw material m_3 is the least affected and m_5 is the most affected by factors. Consequently, the stock-out situations of the raw material m_5 should be frequently controlled.

Second Company (B): The factors influencing stock management of this company are the amount of planned products (e_1), the source of the raw materials (e_4), time (e_5) and storage capacity (e_7). Then the fuzzy soft set F_B shows both of the most affected and the least affected raw materials by factors as follows:

$$F_B = \left\{ \frac{m_1}{0.105}, \frac{m_2}{0.06}, \frac{m_3}{0.18}, \frac{m_4}{0.0173}, \frac{m_5}{0.0027} \right\}.$$

By the fuzzy soft set F_B, we say that the raw material m_5 is the least affected and m_3 is the most affected by factors. Consequently, the stock-out situations of the raw material m_3 should be frequently controlled.

Third Company (C): The factors influencing stock management of this company are hygiene (e_3), time (e_5) and storage capacity (e_7). Then the fuzzy soft set F_C shows both of the most affected and the least affected raw materials by factors as follows:

$$F_C = \left\{ \frac{m_1}{0.7}, \frac{m_2}{0.3}, \frac{m_3}{0.2}, \frac{m_4}{0.0864}, \frac{m_5}{0.01} \right\}.$$

By the fuzzy soft set F_C, we say that the raw material m_5 is the least affected and m_1 is the most affected by factors. Consequently, the stock-out situations of the raw material m_1 should be frequently controlled.

Now we give an algorithm for the above companies using MATLAB programme as follows:

```
e1 = [0.5 0.75 1 0.25 0.3];
e2 = [0.2 0.4 0.1 0.6 0.7];
e3 = [1 0.75 0.5 0.8 1];
e4 = [0.3 0.2 0.45 0.64 0.9];
e5 = [0.7 1 0.5 0.54 1];
e6 = [0.39 0.71 1 0.45 0.6];
e7 = [1 0.4 0.8 0.2 0.01];
e8 = [1 1 1 1 1];
enb = 0;
for i = 1 : length(e1)
  A(i) = e2(i) * e3(i) * e5(i) * e6(i) * e8(i);
% the matrix A is calculated as the number of selected parameters for each company.
end
disp(A);
for i = 1 : length(A)
  if A(i) > enb
      enb = A(i);
  else enb = enb;
  end
end
[amount, rawmaterial] = max(A);
disp('For company A, the number of the most affected, raw material is'),
disp (rawmaterial)
% i can be considered as the raw materials m_{i}
disp ('the amount of the affected raw material'),
disp (enb)
```

```
>> company A
  0.0546   0.2130   0.0250   0.1166   0.4200
```

For company A, the number of the most affected raw material is
5
the amount of the affected raw material
0.4200

Similarly, two algorithms can be written for companies B and C, respectively. As seen in the above examples of companies, the most affected raw materials of each company is different.
Using the “fuzzy soft set model” we can easily seen the most affected raw materials by parameters. Then we use the “soft set model” defined in Section 2 to control the stock-out situations of this affected raw materials. Consequently, if we use these two models at the same time, we can more accurately track the stock-out situations of raw materials.

4. Conclusion

In this paper, we introduce two new applications of a soft set theory and fuzzy soft set theory to the effective management of stock-out situations. Our applications are developed using excel program and MATLAB. Companies may be use these methods for accurate data. For example, the “soft set model” defined in Section 2 is constructed using only the amount of raw materials. So the amount of ordered raw materials depends only the amounts of daily usage (or weekly usage). But these quantities can be changed using the lead time, storage capacity etc.

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