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Expected Value Analysis for Integrated Supplier Selection and Inventory Control of Multi-product Inventory System with Fuzzy Cost

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Abstract. The future cost in many industrial problem is obviously uncertain.Then a mathematical analysis for a problem with uncertain cost is needed. In this article, we deals with the fuzzy expected value analysis to solve an integrated supplier selection and supplier selection problem with uncertain cost where the costs uncertainty is approached by a fuzzy variable. We formulate the mathematical model of the problems fuzzy expected value based quadratic optimization with total cost objective function and solve it by using expected value based fuzzy programming. From the numerical examples result performed by the authors, the supplier selection problem was solved i.e. the optimal supplier was selected for each time period where the optimal product volume of all product that should be purchased from each supplier for each time period was determined and the product stock level was controlled as decided by the authors i.e. it was followed the given reference level.

INTRODUCTION

In logistic and supply chain management (LSCM), commonly a manufacturer faces supplier selection problem which can be presented as an optimal supplier finding to supply some raw material or product to the manufacturer with minimal total cost [1]. The most developed method to find the optimal supplier is mathematical model method in a mathematical optimization form such as mixed-integer linear programming that was developed in [2], [3] . To meet the demand for the future period, the manufacturer can store some product in the storage where the holding cost is charged. Commonly, the stored product is to be minimized in order to minimize the holding cost, but for some cases like retail manufacture, the decision maker is deciding to store the product as many he want which can be called set point inventory level. To minimize the total cost so that the inventory level as close as possible to a set point level, a reference tracking control method is needed. The most published articles was developed a method to solve the supplier selection with known demand value i.e. the demand value of all product at each time period is certainly measured. Unfortunately, there are many case that the demand value is unknown which can be called uncertain demand. To solve this problem, the uncertainty theory is needed. Since it was introduced in [4], possibility theory was being powerful tool to solve many problems in uncertain environment mainly in fuzzy optimization. Inspired by expected value of a random variable in probabilistic theory, the expected value of a fuzzy variable was introduced in [5] to solve a fuzzy programming. Many researchers were successfully utilized fuzzy expected value approach to solve many problems like data envelopment analysis [6]-[8], industrial grinding process [9], [10], portfolio optimization [11]-[13] and many more. In this paper, we propose a mathematical model in quadratic programming with fuzzy parameter to determine the optimal strategy for integrated inventory control and supplier selection problem with fuzzy demand where the corresponding optimization will be solved by using expected value based fuzzy programming approach. Numerical experiment will be performed to evaluate the proposed model and to analyze the optimal strategy for this problem.

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MATHEMATICAL MODEL

We are assuming that the inventory control problem that will be solved is covering multi-product, multi supplier and multi period. Let the variables and parameters that we are used for mathematical model formulation are :

T	:	Set of time period;
S	:	Set of supplier;
P	:	Set of product;
X_{tsp}	:	Volume of product $p \in P$ from supplier $s \in S$ at time period $t \in T$;
$\widetilde{UP}_{tsp}$	:	Fuzzy unit price of product $p \in P$ from supplier $s \in S$ at time period $t \in T$;
$\widetilde{TC}_{ts}$	:	Fuzzy transportation cost of all product from supplier $s \in S$ at time period $t \in T$;
Y_{ts}	:	Supplier assignment $s \in S$ at time period $t \in T$ (1 if X_{tsp}¿0 exist, 0 if none);
C_{tsp}	:	Supplying capacity of supplier $s \in S$ for product $p \in P$ at time period $t \in T$;
UPC_{tsp}	:	Unit penalty cost for defect product unit $p \in P$ from supplier $s \in S$ at time period $t \in T$;
UDC_{tsp}	:	Unit delay cost for delayed product unit $p \in P$ from supplier $s \in S$ at time period $t \in T$;
DLT_{tsp}	:	Delay lead time of product $p \in P$ from supplier $s \in S$ at time period $t \in T$;
Q_{tsp}	:	Quality level of product $p \in P$ at time period $t \in T$ from supplier $s \in S$;
I_{tp}	:	Inventory level of product $p \in P$ at time period $t \in T$;
M_p	:	Storage capacity of product $p \in P$;
B_t	:	Cost budget at time period $t \in T$;
C_{tp}	:	Holding cost of product $p \in P$ at time period $t \in T$.

The mathematical model that we are modeling will follow the general form of expected value based fuzzy programming model. The general form of expected value based fuzzy programming fuzzy objective and fuzzy constraint can be expressed as follows

$$\begin{cases} \min f(x,\xi) \\ \text{s.t. } g_i(x,\xi) \geqslant 0, i = 1, 2, \ldots, p, \end{cases} \tag{1}$$

where $f(x,\xi)$ is the objective function and $g_i(x,\xi)$ are constraint functions,x is the decision vector and ξ is a fuzzy vector. Note that both of the objective and constraint functions in (1) are not produce a crisp feasible set. To determine the optimal decision x in (1), a fuzzy expected value model was proposed by Liu and Liu [14] as follows

$$\begin{cases} \min E[f(x,\xi)] \\ \text{s.t. E}[g_i(x,\xi)] \geq 0, i = 1, 2, \ldots, p, \end{cases} \tag{2}$$

where $E[\cdot]$ denotes the expected value defined by

$$E[\xi] = \int_0^{\infty} Cr\{\xi \geq r\}\, dr - \int_{-\infty}^{0} Cr\{\xi \leq r\}\, dr \tag{3}$$

provided that at least one of the two integrals is finiteand $Cr[\cdot]$ denotes the credibility value.An important result in fuzzy expected value theory is the expected value of linear function of fuzzy variable. Suppose independent fuzzy variables$\xi$and ς with finite expected values, then

$$E[a\xi + b\varsigma] = aE[\xi] + E[\varsigma] \tag{4}$$

where a and b are arbitrary real number. With fuzzy variables $\widetilde{UP}_{tsp}$ and $\widetilde{TC}_{ts}$, we proposethe following mathematical model to solve an integrated supplier selection and inventory control:

$$
\begin{aligned}
\min Z = E & \left[\begin{array}{l} \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} X_{tsp}\cdot \widetilde{UP}_{tsp} + \sum_{t=1}^{T}\sum_{s=1}^{S} \widetilde{TC}_{ts}\cdot Y_{ts} + \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} (1-Q_{tsp})\cdot UPC_{tsp}\cdot X_{tsp}\cdot Y_{ts} \\ + \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} UDC_{tsp}\cdot DLT_{tsp}\cdot X_{tsp}\cdot Y_{ts} + \sum_{t=1}^{T}\sum_{p=1}^{P} HC_{tp}\cdot I_{tp} + \sum_{t=1}^{T}\sum_{p=1}^{P}\left(I_{tp}-r_{tp}\right)^2 \end{array} \right] \\
&= \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} X_{tsp}\cdot E\left[\widetilde{UP}_{tsp}\right] + \sum_{t=1}^{T}\sum_{s=1}^{S} E\left[\widetilde{TC}_{ts}\right]\cdot Y_{ts} + \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} (1-Q_{tsp})\cdot UPC_{tsp}\cdot X_{tsp}\cdot Y_{ts} \\
&+ \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} UDC_{tsp}\cdot DLT_{tsp}\cdot X_{tsp}\cdot Y_{ts} + \sum_{t=1}^{T}\sum_{p=1}^{P} HC_{tp}\cdot I_{tp} + \sum_{t=1}^{T}\sum_{p=1}^{P}\left(I_{tp}-r_{tp}\right)^2
\end{aligned} \tag{5}
$$

subject to:

$$\sum_{s=1}^{s} X_{tsp} - I_{tp} \geq D_{tp},\ \text{for } t=1, \forall p \in P,\ \text{and } V_{t-1,p} + \sum_{s=1}^{s} X_{tsp} - V_{tp} \geq D_{tp},\ \text{for } t>1, t \in T, \forall p \in P. \tag{6}$$

$$\left(\sum_{p=1}^{P} D_{tp}\right) Y_{ts} \geq \sum_{p=1}^{P} X_{tsp}, \forall t \in T, \forall s \in S, \tag{7}$$

$$X_{tsp} \leq SC_{tsp}, \forall t \in T, \forall s \in S, \forall p \in P, \tag{8}$$

$$Y_{ts} = \begin{cases} 1, \text{ if } \sum_{p=1}^{P} X_{tsp} > 0 \\ 0, \text{ others} \end{cases}, \forall t \in T, \forall s \in S, \tag{9}$$

$$I_{tp} \leq M_{tp}, \forall t \in T, \forall p \in P, \tag{10}$$

$$
\begin{aligned}
& E\left[\sum_{s=1}^{S}\sum_{p=1}^{P} X_{tsp}\cdot \widetilde{UP}_{tsp} + \sum_{s=1}^{S} \widetilde{TC}_{ts}\cdot Y_{ts}\right] + \sum_{s=1}^{S}\sum_{p=1}^{P} (1-Q_{tsp})\cdot UPC_{tsp}\cdot X_{tsp}\cdot Y_{ts} \\
& + \sum_{s=1}^{S}\sum_{p=1}^{P} UDC_{tsp}\cdot DLT_{tsp}\cdot X_{tsp}\cdot Y_{ts} + \sum_{p=1}^{P} HC_{tp}\cdot I_{tp} + \sum_{t=1}^{T}\sum_{p=1}^{P}\left(I_{tp}-r_{tp}\right)^2 \leq B_t, \forall t \in T,
\end{aligned} \tag{11}
$$

$$X_{tsp} \geq 0, \forall t \in T, \forall s \in S, \forall p \in P, \tag{12}$$

$$X_{tsp}, I_{tp}, \forall t \in T, \forall s \in S, \forall p \in P \text{ integer}, \tag{13}$$

where the objective function Z is the fuzzy expected value of total cost which contains the fuzzy product buying cost for all product from all supplier for all time period, fuzzy transportation cost, penalty cost for under quality service level product, penalty cost for delayed product and holding cost. Furthermore, the last term in Z is used for inventory level reference tracking objectives. Constraint (6) is used to manage the inventory where as constraint (7) is used to obtain the suppliers assignment value. Constraints (8) - (13) are used for supplier capacity bound, suppliers assignment purposes, storage capacity bound, budget bound, non-negativity bound and integer constraint respectively.

NUMERICAL EXAMPLE

Suppose a manufacturer will purchase three products P1, P2, P3 from four suppliers S1, S2, S3, S4 for 10 future time periods. Let the initial inventory level is 0. Given that the unit price for product p from supplier s at time period t is a fuzzy variable whose membership function

$$\mu_{\widetilde{UP}_{tsp}} = \begin{cases} \mu_{\widetilde{\mathrm{UP}}_{tsp(1)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(1)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(2)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(2)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(3)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(3)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(4)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(4)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(5)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(5)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(6)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(6)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(7)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(7)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(8)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(8)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(9)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(9)} \\ \mu_{\widetilde{\mathrm{UP}}_{tsp(10)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(10)} \\ 0, & \text{others} \end{cases} = \begin{cases} \mu_{\widetilde{\mathrm{UP}}_{tsp(i)}} & \text{if } \widetilde{\mathrm{UP}}_{tsp} = \widetilde{\mathrm{UP}}_{tsp(i)} \\ 0, & \text{others} \end{cases} \tag{14}$$

and

$$\mu_{\widetilde{TC}_{ts}} = \begin{cases} \mu_{\widetilde{TC}_{ts(i)}} & \text{if } \widetilde{TC}_{ts} = \widetilde{TC}_{ts(i)} \\ 0, & \text{others} \end{cases} \tag{15}$$

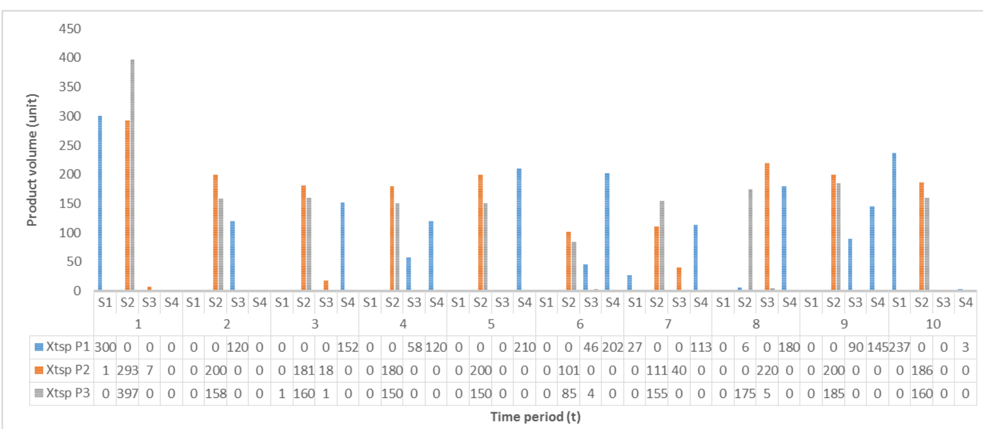
wherethe values of $\widetilde{\mathrm{UP}}_{tsp(i)}$, $\mu_{\widetilde{UP}_{tsp(i)}}$,$\widetilde{TC}_{ts(i)}$ and $\mu_{\widetilde{TC}_{ts(i)}}$ are available in Appendix 2. The expected value of $\widetilde{\mathrm{UP}}_{tsp}$ and $\widetilde{\mathrm{TC}}_{ts}$ are

$$E\left[\widetilde{\mathrm{UP}}_{tsp}\right] = \sum\nolimits_{i=1}^{10} w_{\widetilde{UP}tsp(i)} \left(\widetilde{\mathrm{UP}}_{tsp(i)}\right) \tag{16}$$

and

$$E\left[\widetilde{TC}_{tsp}\right] = \sum\nolimits_{i=1}^{10} w_{\widetilde{TC}tsp(i)} \left(\widetilde{TC}_{tsp(i)}\right) \tag{17}$$

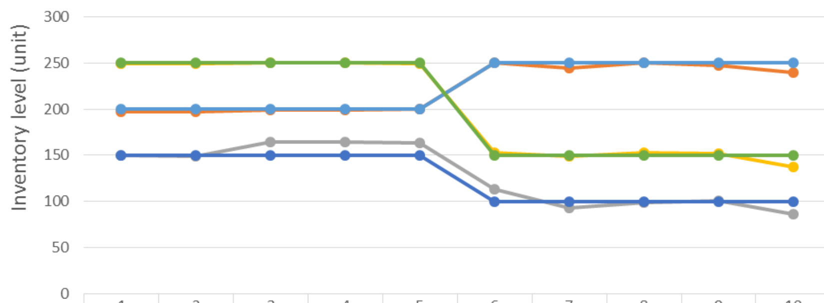
respectively where the values of $w_{\widetilde{UP}tsp(i)}$ and $w_{\widetilde{TC}tsp(i)}$ are available in Appendix 2. We solve (5) in LINGO 16.0 with Windows 8 Operating System, 4 GB of memory and AMD A6 2.7 GHz of processor. The solution is given in Fig. 1-Fig. 2. Figure 1 shows the optimal values of $X_{tsp}, \forall t \in T, \forall s \in S, \forall p \in P$, which is the optimal volume of product P1, P2 and P3that should be purchased each from supplier S1, S2, S3 and S4for time periods 1 to 10. The reference inventory level of product P1, P2 and P3 decided by the decision maker are shown by Fig. 2. Fig. 2 also shows optimal values of $I_{tp}, \forall t \in T, \forall p \in P$, which is the optimal volume of product P1, P2 and P3 that should be stored in the warehouse the inventory level is as close as possible to the reference level.



t	1				2				3				4				5			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Xtsp P1	300	0	0	0	0	0	120	0	0	0	0	152	0	0	58	120	0	0	0	210
Xtsp P2	1	293	7	0	0	200	0	0	0	181	18	0	0	180	0	0	0	200	0	0
Xtsp P3	0	397	0	0	0	158	0	0	1	160	1	0	0	150	0	0	0	150	0	0

t	6				7				8				9				10			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Xtsp P1	0	0	46	202	27	0	0	113	0	6	0	180	0	0	90	145	237	0	0	3
Xtsp P2	0	101	0	0	0	111	40	0	0	0	220	0	0	200	0	0	0	186	0	0
Xtsp P3	0	85	4	0	0	155	0	0	0	175	5	0	0	185	0	0	0	160	0	0

FIGURE 1. Optimal product volume that should be purchased from each supplier for time periods 1 to 10



	1	2	3	4	5	6	7	8	9	10
INVENTORY LEVEL P1	197	197	199	199	200	250	244	250	247	240
INVENTORY LEVEL P2	150	149	164	164	163	113	93	99	101	86
INVENTORY LEVEL P3	249	249	250	250	249	153	149	153	152	137
Ref level P1	200	200	200	200	200	250	250	250	250	250
Ref level P2	150	150	150	150	150	100	100	100	100	100
Ref level P3	250	250	250	250	250	150	150	150	150	150

Period (t)

FIGURE 2. Inventory level and reference level in the first example

From Fig. 1, the optimal strategy for each time period is decided as follows. At time period 1, 300 unit of product P1 and 1 unit of product P2 are should be purchased from supplier S1 whereas 293 units of product P2 and 397 units of product P3 are should be purchased from supplier S2 and finally 7 unit of product P2 is should be purchased from supplier S3. The optimal decision for other time periods are can be derived analogously.Fig. 2 shows the product volume of all product that should be stored in the warehouse so that the inventory level of all product follows the desired (reference) level decided by the decision maker. From Fig 2, it can be conclude that the inventory level follows the reference level well.

CONCLUSIONS

The integrated inventory reference control and supplier selection of multi-product multi-supplier multi-period with fuzzy purchase cost and fuzzy transportation cost was considered. A mathematical model was formulated in fuzzy expected value based quadratic programming by approaching the fuzziness of the purchase cost and transportation cost as fuzzy variable and using fuzzy expected value to formulate the corresponding crisp optimization. LINGO 16.0 was used to solve the corresponding optimization with integer quadratic programming of the model class. From the performed numerical example, it was concluded that the optimal strategy i.e. the product volume of all product that should be purchased from each supplier at each time period was determined and the stock level of the product followed the reference level given by the decision maker.

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Appendix 1. Parameter values for numerical experiment

Supplier Capacity (SCtsp)				
Periode	Suppliers	Products		
		P1	P2	P3
all	S1	1100	1200	1300
	S2	1400	1200	1100
	S3	1400	800	1200
	S4	1200	1000	850

DELAY PENALTY COST (UDCtsp)				
Period	Supplier	Products		
		P1	P2	P3
all	S1	0.75	0.1	1
	S2	0.5	0.85	1
	S3	0.85	1	0.85
	S4	1	0.9	0.95

DEFECT RATE (Qtsp)				
Period	Supplier	P1	P2	P3
all	S1	0.010	0.000	0.010
	S2	0.020	0.001	0.010
	S3	0.000	0.020	0.025
	S4	0.015	0.005	0.020

LATE RATE (DLTtsp)				
Period	Supplier	P1	P2	P3
all	S1	0.000	0.000	0.002
	S2	0.000	0.000	0.010
	S3	0.020	0.010	0.001
	S4	0.025	0.000	0.000

DEFECT PENALTI COST (UPCtsp)				
Period	Supplier	Products		
		P1	P2	P3
all	S1	0.50	0.50	0.70
	S2	0.75	1.00	0.80
	S3	0.75	0.25	0.75
	S4	0.55	1.00	0.85

HOLDING COST (HCtp)			
Period	Products		
	P1	P2	P3
all	1	1	1.5

Period	Budget
1	450000
2	450000
3	400000
4	500000
5	450000
6	400000
7	550000
8	450000
9	500000
10	500000

DEMAND			
Period	P1	P2	P3
1	100	150	140
2	120	200	160
3	150	180	160
4	180	180	150
5	210	200	150
6	200	150	185
7	150	170	155
8	180	210	175
9	240	200	185
10	250	200	175

Storage capacity (Mtp)			
Period	P1	P2	P3
all	500	550	650

Appendix 2. Membership functions for $\widetilde{\mathrm{UP}}_{tsp}$ and $\widetilde{\mathrm{TC}}_{ts}$

Uptsp(i)											
Supplier	Product	i									
		ss1	ss2	ss3	ss4	ss5	ss6	ss7	ss8	ss9	ss10
S1	P1	17	17.5	18	18.5	19	19.5	20	20.5	21	21.5
	P2	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5
	P3	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5
S2	P1	17	17.5	18	18.5	19	19.5	20	20.5	21	21.5
	P2	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5
	P3	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5
S3	P1	17	17.5	18	18.5	19	19.5	20	20.5	21	21.5
	P2	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5
	P3	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5
S4	P1	17	17.5	18	18.5	19	19.5	20	20.5	21	21.5
	P2	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5
	P3	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5

MEMBERSHIP VALUE of Uptsp(i)											
Supplier	Product	i									
		1	2	3	4	5	6	7	8	9	10
S1	P1	0.1	0.2	0.4	0.8	1	0.9	0.8	0.5	0.2	0.01
	P2	0.1	0.2	0.4	0.8	1	0.9	0.8	0.5	0.2	0.01
	P3	0.1	0.2	0.4	0.8	1	0.9	0.8	0.5	0.2	0.01
S2	P1	0.02	0.45	0.5	0.9	1	0.75	0.65	0.4	0.2	0.1
	P2	0.02	0.45	0.5	0.9	1	0.75	0.65	0.4	0.2	0.1
	P3	0.02	0.45	0.5	0.9	1	0.75	0.65	0.4	0.2	0.1
S3	P1	0.1	0.2	0.45	0.55	0.75	0.85	1	0.65	0.4	0.2
	P2	0.1	0.2	0.45	0.55	0.75	0.85	1	0.65	0.4	0.2
	P3	0.1	0.2	0.45	0.55	0.75	0.85	1	0.65	0.4	0.2
S4	P1	0.1	0.2	0.45	0.55	0.75	1	0.65	0.4	0.25	0.15
	P2	0.1	0.2	0.45	0.55	0.75	1	0.65	0.4	0.25	0.15
	P3	0.1	0.2	0.45	0.55	0.75	1	0.65	0.4	0.25	0.15

WEIGHT VALUE (w_UPtsp(i))											
Supplier	Product	i									
		ss1	ss2	ss3	ss4	ss5	ss6	ss7	ss8	ss9	ss10
S1	P1	0.05	0.05	0.1	0.2	0.15	0.05	0.15	0.15	0.095	0.005
	P2	0.05	0.05	0.1	0.2	0.15	0.05	0.15	0.15	0.095	0.005
	P3	0.05	0.05	0.1	0.2	0.15	0.05	0.15	0.15	0.095	0.005
S2	P1	0.01	0.215	0.025	0.2	0.175	0.05	0.125	0.1	0.05	0.05
	P2	0.01	0.215	0.025	0.2	0.175	0.05	0.125	0.1	0.05	0.05
	P3	0.01	0.215	0.025	0.2	0.175	0.05	0.125	0.1	0.05	0.05
S3	P1	0.05	0.05	0.125	0.05	0.1	0.05	0.25	0.125	0.1	0.1
	P2	0.05	0.05	0.125	0.05	0.1	0.05	0.25	0.125	0.1	0.1
	P3	0.05	0.05	0.125	0.05	0.1	0.05	0.25	0.125	0.1	0.1
S4	P1	0.05	0.05	0.125	0.05	0.1	0.3	0.125	0.075	0.05	0.075
	P2	0.225	0.025	0.075	0.075	0.075	0.1	0.05	0.075	0.025	0.275
	P3	0.225	0.025	0.075	0.075	0.075	0.1	0.05	0.075	0.025	0.275

Membership value (miu_TCts(i))											
Time period	Supplier	i									
		1	2	3	4	5	6	7	8	9	10
all	S1	0.15	0.35	0.75	0.92	1	0.95	0.82	0.55	0.3	0.1
	S2	0.25	0.55	0.75	0.85	1	0.95	0.8	0.55	0.25	0.1
	S3	0.35	0.62	0.74	0.92	1	0.98	0.79	0.58	0.42	0.35
	S4	0.25	0.55	0.75	0.95	1	0.95	0.72	0.68	0.25	0.1

WEIGHT VALUE (w_TCts(i))											
Time period	Supplier	i									
		1	2	3	4	5	6	7	8	9	10
all	S1	0.075	0.1	0.2	0.085	0.065	0.065	0.135	0.125	0.1	0.05
	S2	0.125	0.15	0.1	0.05	0.1	0.075	0.125	0.15	0.075	0.05
	S3	0.175	0.135	0.06	0.09	0.05	0.095	0.105	0.08	0.035	0.175
	S4	0.125	0.15	0.1	0.1	0.05	0.115	0.02	0.215	0.075	0.05

TCts(i)											
Time period	Supplier	i									
		1	2	3	4	5	6	7	8	9	10
all	S1	300	310	320	330	340	350	360	370	380	390
	S2	300	310	320	330	340	350	360	370	380	390
	S3	300	310	320	330	340	350	360	370	380	390
	S4	300	310	320	330	340	350	360	370	380	390