Fuzzy Expected Value Based Model to Solve Integrated Supplier Selection and Inventory Control Problem in Fuzzy Environment

Sutrisno #1, Widowati #2, R. Heru Tjahjana #3

Department of Mathematics, Diponegoro University
Semarang, Indonesia

1tresno.math@undip.ac.id
2widowati_math@undip.ac.id
3heru_tjahjana@undip.ac.id

***Abstract*—In a production and inventory planning management, the future parameters like future demand, future product buying cost, future transport cost and future holding cost are obviously unknown/uncertain. To determine the optimal strategy in uncertain condition, a method that can handle the uncertainty of parameters is needed. If the historical data of the uncertain parameters are known then they can be approached by using probability distribution, but if there is no historical data then it cannot be used. In this paper, we propose a new mathematical optimization model with fuzzy parameters to solve an integrated supplier selection problem and inventory control problem in fuzzy environment where fuzzy variables are used to approach the uncertain parameters. To solve the corresponding optimization problem, we use fuzzy expected value based integer quadratic programming where the fuzzy variables are approximated by fuzzy expected value. From the numerical experiment results, the optimal strategy i.e. the optimal supplier and the optimal stored product volume were obtained and the actual inventory level followed the desired level with minimal total expected cost.**

***Keywords*—** *Fuzzy Environment, Fuzzy expected value, Fuzzy programming, Inventory Control, Supplier selection*

1. Introduction

A supplier selection problem is finding the optimal supplier(s) from many alternative supplier to supply some product(s) or material to satisfy the demand so that the procurement cost is minimal [1]. Some researchers were formulated some mathematical models to solve supplier selection problem corresponds to the specification of the each model such as linear programming [2, 3]. Another problem in industrial manufacturer and retail which commonly occurred is inventory control problem. This problem is refer to how to meet the future demand where the decision can be storing the product in the storage surely it will occur some holding cost or buy the product in the future period. The advanced problem of inventory control is how to decide the product buying so that the volume of the stored product is as close as possible to a level decided by the decision maker. In system and control theory, this problem is obviously called as trajectory tracking control problem.

The existing model commonly can handle only with known parameter values. In industrial manufacturer or retile, commonly there are many parameter values which are unknown especially for future time period such as the future demand. Other parameters like future transport cost, future purchase cost, future holding cost, etc. are also commonly unknown. So, the model that can handle an unknown/uncertain parameter is needed to be developed.

To handle an unknown value of parameters, people obviously use probability theory but to formulate the probability distribution, it will need historical data of each parameter. Another approach that can be used to solve a problem with uncertain parameter without having historical data is by using fuzzy variable approach based on possibility theory. Possibility theory was developed in [4] that can be used to solve a fuzzy optimization. The basic idea to solve a fuzzy programming is by finding the expected value for the occurred fuzzy parameters [5]. Some researchers were successfully used fuzzy theory to optimize some industrial processes likes envelopment analysis [6 - 8], industrial grinding process [9, 10] and portfolio optimization [11-13].

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In this paper, we formulate a new mathematical model to solve an integrated supplier selection and inventory trajectory tracking control problem with some unknown parameters approached by using fuzzy variable. The proposed model is in the form of quadratic programming with fuzzy parameters. We solve the occurred optimization by using expected value based fuzzy quadratic programming.

2. Mathematical Model

Suppose a manufacturer/retailer faces a problem which will determine the optimal supplier from several alternatives and it will control the inventory level so that the stored product level as close as possible to a desired level. We deal with multi-product, multi supplier and multi time period problem. Let

T : Set of time period;
S : Set of supplier;
P : Set of product;

Let the known/certain parameters are denoted by

SC_{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 period $t \in T$ from supplier $s \in S$;
M_p : Storage capacity of product $p \in P$;
B_t : Cost budget at time period $t \in T$.

Let the unknown/uncertain parameters approximated by fuzzy variables in the problem are denoted by

UP_{tsp} : Fuzzy unit price of product $p \in P$ from supplier $s \in S$ at time period $t \in T$;
TC_{ts} : Fuzzy transportation cost of all product from supplier $s \in S$ at time period $t \in T$;
HC_{tp} : Fuzzy holding cost of product $p \in P$ at time period $t \in T$.

Let the decision variables are denoted by

X_{tsp} : Volume of product $p \in P$ 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);
I_{tp} : Inventory level of product $p \in P$ at time period $t \in T$.

The procedure of the problem solving is illustrated by Fig. 1. The first step is defining the problem then identifying the fuzzy parameters in the problem. The next step is the decision maker defining the membership function for each fuzzy parameter. Formulating a fuzzy integer quadratic programming based on the expected value of each fuzzy parameter is the next step. The last step is solving the corresponding optimization.

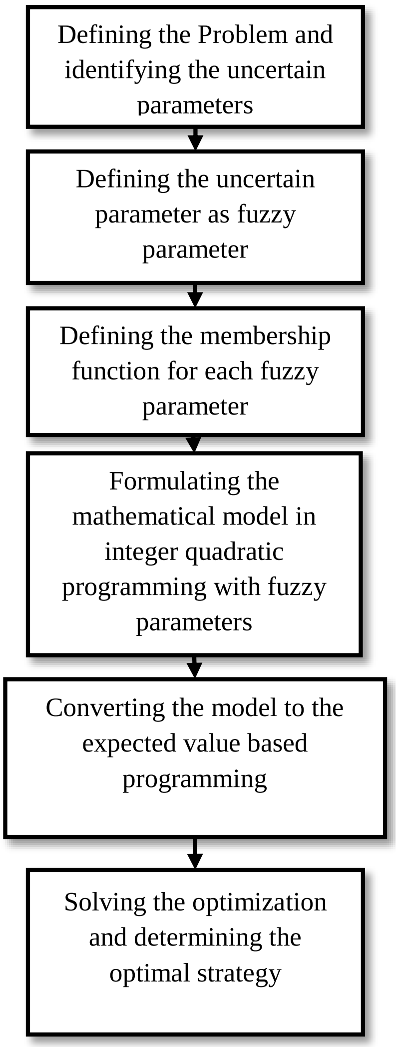

Figure 1. Problem solving procedure

The general form of the expected value based nonlinear fuzzy programming can be expressed as follows

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

where $f\left(x,\xi\right)$ is the fuzzy objective function and $g_i\left(x,\xi\right)$ are fuzzy constraint functions, x is the decision vector and ξ is a fuzzy vector containing the fuzzy parameters in the problem. By following the fuzzy expected value model proposed in [5], we solve (1) by converting it into

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

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

$$E\left[\xi\right] = \int_0^\infty Cr\left\{\xi \geq r\right\} dr - \int_{-\infty}^0 Cr\left\{\xi \leq r\right\} dr \quad (3)$$

provided at least one of these two integrals in (3) is finite where $Cr\left[\cdot\right]$ denotes the credibility value. For independent fuzzy variables ξ and ς with finite expected values,

$$E\left[a\xi + b\varsigma\right] = aE\left[\xi\right] + E\left[\varsigma\right] \quad (4)$$

where a and b are arbitrary real number.

The model that we are proposed is formulated as follows. The fuzzy parameters that we are using in the model are the fuzzy unit price denoted by UP_{tsp}, the fuzzy transport cost denoted by TC_{ts}, the fuzzy holding cost denoted by HC_{tp} and the fuzzy demand denoted by $\tilde{D}_{tp}$. The fuzzy objective function that has to be minimized is the total cost which is

$$\begin{aligned} &\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} UP_{tsp}\cdot X_{tsp} + \sum_{t=1}^{T}\sum_{s=1}^{S} TC_{ts}\cdot TR_{ts} \\ &+\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P}(1-Q_{tsp})\cdot UPC_{tsp}\cdot X_{tsp} \\ &+\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} UDC_{tsp}\cdot DLT_{tsp}\cdot X_{tsp} \\ &+\sum_{t=1}^{T}\sum_{p=1}^{P} HC_{tp}\cdot I_{tp} + \sum_{t=1}^{T}\sum_{p=1}^{P} k\left(I_{tp}-r_{tp}\right)^2 \end{aligned}$$

where k is arbitrary positive real number denoting the weight of the trajectory tracking term $\left(I_{tp}-r_{tp}\right)^2$. The constraints of the model will be explained later. By using fuzzy expected value approach model (2) and by using formula (4) to simplify objective function, our mathematical model in fuzzy expected value based integer quadratic programming is completely stated as

$$\begin{aligned} \min Z = E&\left[\begin{aligned} &\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} UP_{tsp}\cdot X_{tsp} + \sum_{t=1}^{T}\sum_{s=1}^{S} TC_{ts}\cdot TR_{ts} \\ &+\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P}(1-Q_{tsp})\cdot UPC_{tsp}\cdot X_{tsp} \\ &+\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} UDC_{tsp}\cdot DLT_{tsp}\cdot X_{tsp} \\ &+\sum_{t=1}^{T}\sum_{p=1}^{P} HC_{tp}\cdot I_{tp} + \sum_{t=1}^{T}\sum_{p=1}^{P} k\left(I_{tp}-r_{tp}\right)^2 \end{aligned}\right] \\ &= \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} E\left[UP_{tsp}\right]\cdot X_{tsp} \\ &+\sum_{t=1}^{T}\sum_{s=1}^{S} E\left[TC_{ts}\right]\cdot TR_{ts} \\ &+\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P}(1-Q_{tsp})\cdot UPC_{tsp}\cdot X_{tsp} \\ &+\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} UDC_{tsp}\cdot DLT_{tsp}\cdot X_{tsp} \\ &+\sum_{t=1}^{T}\sum_{p=1}^{P}\left[HC_{tp}\right] I_{tp} \\ &+\sum_{t=1}^{T}\sum_{p=1}^{P} k\left(I_{tp}-r_{tp}\right)^2 \end{aligned} \quad (5)$$

subject to:

$$\begin{aligned} &\sum_{s=1}^{s} X_{tsp} - \sum_{s=1}^{s} DLT_{tsp}\cdot X_{tsp} \\ &-\sum_{s=1}^{S}(1-Q_{tsp})\cdot UPC_{tsp}\cdot X_{tsp} \\ &-I_{tp} \geq \tilde{D}_{tp}, \text{ for } t=1, \forall p \in P; \\ &I_{t-1,p} + \sum_{s=1}^{s} DLT_{(t-1)sp}\cdot X_{(t-1)sp} \\ &-\sum_{s=1}^{s} DLT_{tsp}\cdot X_{tsp} - \sum_{s=1}^{S}(1-Q_{tsp})\cdot UPC_{tsp}\cdot X_{tsp} \\ &+\sum_{s=1}^{s} X_{tsp} - I_{tp} \geq \tilde{D}_{tp}, \text{ for } t>1, t\in T, \forall p \in P. \end{aligned} \quad (6)$$

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

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

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

$$I_{tp} \le M_{tp}, \forall t \in T, \forall p \in P, \quad (10)$$

$$E\left[\sum_{s=1}^{S}\sum_{p=1}^{P} X_{tsp} \cdot UP_{tsp} + \sum_{s=1}^{S} TC_{ts} \cdot Y_{ts}\right] + \sum_{s=1}^{S}\sum_{p=1}^{P}(1-Q_{tsp}) \cdot UPC_{tsp} \cdot X_{tsp} \cdot Y_{ts} + \sum_{s=1}^{S}\sum_{p=1}^{P} UDC_{tsp} \cdot DLT_{tsp} \cdot X_{tsp} \cdot Y_{ts} \quad (11)$$
$$+\sum_{p=1}^{P} HC_{tp} \cdot I_{tp} + \sum_{t=1}^{T}\sum_{p=1}^{P}\left(I_{tp} - r_{tp}\right)^2 \le B_t, \forall t \in T,$$

$$X_{tsp} \ge 0, \forall t \in T, \forall s \in S, \forall p \in P, \quad (12)$$

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

The model can be explained as follows. The objective function Z is the fuzzy expected value of the total cost where the first term presented the expected total purchase cost for all product, all supplier and all time period, the second term presented the expected total transport cost, the third term presented the total penalty cost for unqualified product, the fourth term presented the total penalty cost for product with late delivery, the fifth term presented the expected total holding cost and the last term presented the trajectory tracking objective for inventory level. The constraints of the model are explained respectively as the expected demand satisfying, supplier assignment determining, supplier capacity limit, supplier assignment as binary variable determining, storage capacity limit, budget limit, non-negativity constraint and integer value constraint.

2. Numerical Experiment

To evaluate and demonstrate how the model solves the problem, we simulate the model with three products said P1, P2, P3, four suppliers said S1, S2, S3, S4 for 8 future time periods. Let the initial stored product is 0 unit. Suppose that the decision maker defining the membership function for fuzzy unit price for product p from supplier s at time period t as follows

$$\mu_{UP_{tsp}} = \begin{cases} \mu_{\mathrm{UP}_{tsp(i)}} & \text{if } \mathrm{UP}_{tsp} = \mathrm{UP}_{tsp(i)} \\ 0, & \text{others} \end{cases} \quad (14)$$

and the membership function for fuzzy transport cost is

$$\mu_{TC_{ts}} = \begin{cases} \mu_{TC_{ts(i)}} & \text{if } TC_{ts} = TC_{ts(i)} \\ 0, & \text{others} \end{cases} \quad (15)$$

where the values of $\mathrm{UP}_{tsp(i)}$, $\mu_{UP_{tsp(i)}}$, $TC_{ts(i)}$ and $\mu_{TC_{ts(i)}}$ are available in Appendix. The expected value of UP_{tsp} and TC_{ts} are

$$E\left[\mathrm{UP}_{tsp}\right] = \sum_{i=1}^{10} w_{UPtsp(i)}\left(\mathrm{UP}_{tsp(i)}\right) \quad (16)$$

and

$$E\left[TC_{tsp}\right] = \sum_{i=1}^{10} w_{TCtsp(i)}\left(TC_{tsp(i)}\right) \quad (17)$$

respectively where the values of $w_{UPtsp(i)}$ and $w_{TCtsp(i)}$ are available on appendix. The other parameter values are also available on appendix. Due to computers memory capacity limit, the holding cost is assumed to be known, in other words, the fuzzy holding cost parameter is assumed to be have a value with 1 membership value and 0 membership value for others. We solve the expected value based integer quadratic programming (5) by using branch and bound algorithm in LINGO® 17.0 with Windows 8 Operating System, 4 GB of memory and AMD A6 2.7 GHz of processor. The solution is shown in Fig. 2 and Fig. 3. Fig. 2 shows the optimal values of $X_{tsp}, \forall t \in T, \forall s \in S, \forall p \in P,$ which is the optimal volume for each of products P1, P2 and P3 that should be purchased from each supplier S1, S2, S3 and S4 for time periods 1 to 8. The reference inventory level, or desired inventory level of products P1, P2 and P3 which decided by the decision maker are shown in Fig. 3. In Fig. 3, it also shown the optimal value of $I_{tp}, \forall t \in T, \forall p \in P,$ which is the optimal volume of products P1, P2 and P3 that should be stored in the warehouse so that the actual inventory/stock level will be closest to its desired level.

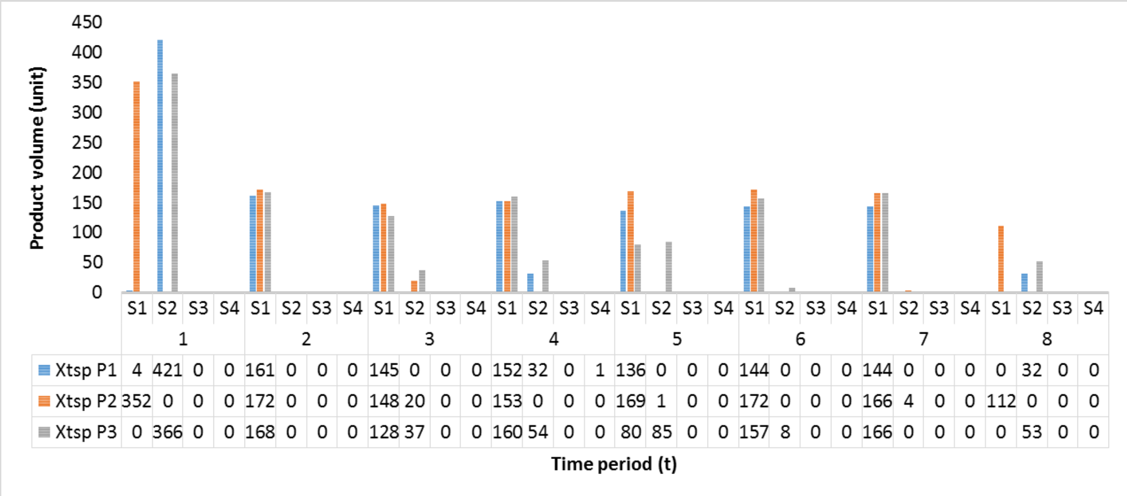

Figure 2. The optimal strategy i.e. the optimal purchased product volume for the discussed problem

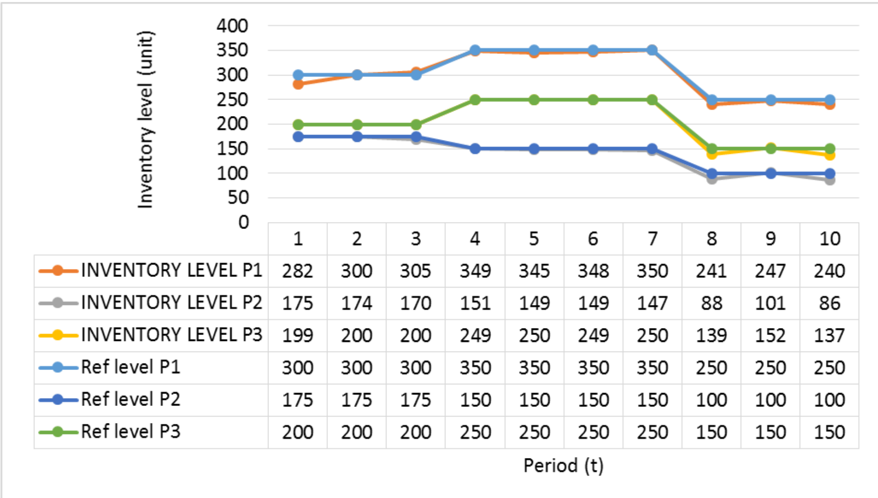

Figure 3. Actual inventory level and its reference/desired level

From Fig. 2, it can be explained that at time period 1, 4 units of product P1 and 352 units of product P2 should be purchased from supplier S1 whereas 421 units of product P1 and 366 units of product P3 should be purchased from supplier S2 and no product has to be purchased from supplier S3 and S4. Furthermore, at time period 1, 282 units of product P1, 175 units of product P2 and 199 units of product P3 should be stored in the warehouse to be used for the future time periods. The optimal decision for time period 2 to 8 can be derived analogously. If this scenario is run, then the expected total cost is 118040.

3. Conclusions

In this paper, a mathematical optimization model in fuzzy expected value based integer quadratic programming that can be used to determine the optimal strategy for integrated supplier selection problem and inventory control problem was considered. A numerical experiment was performed to evaluate the proposed model. From the result, for each time period, the optimal supplier was determined and the optimal decision about how many product that has to be stored in the inventory was also determined with minimal total cost. Furthermore, the actual inventory/stock level was sufficiently closed to its desired level.

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Appendix. Parameter values for numerical experiment

MEMBERSHIP VALUE of Dtp(i)											
Time Period	Product	i									
		1	2	3	4	5	6	7	8	9	10
all	P1	0.1	0.4	0.7	0.9	1	0.85	0.75	0.6	0.2	0.15
	P2	0.2	0.3	0.4	0.95	1	0.95	0.8	0.4	0.3	0.15
	P3	0.15	0.2	0.5	0.8	0.95	1	0.9	0.6	0.2	0.1
WEIGHT VALUE (w_Dtp(i))											
Time period	Product	i									
		1	2	3	4	5	6	7	8	9	10
all	P1	0.05	0.15	0.15	0.1	0.125	0.05	0.075	0.2	0.025	0.075
	P2	0.1	0.05	0.05	0.275	0.05	0.075	0.2	0.05	0.075	0.075
	P3	0.075	0.025	0.15	0.15	0.075	0.075	0.15	0.2	0.05	0.05
DEMAND VALUE (Dtp(i))											
Time period	Product	i									
		ss1	ss2	ss3	ss4	ss5	ss6	ss7	ss8	ss9	ss10
all	P1	100	110	120	130	140	150	160	170	180	190
	P2	80	100	120	140	160	180	200	220	240	260
	P3	120	130	140	150	160	170	180	190	200	210

HOLDING COST (HCtp)			
Period	Products		
	P1	P2	P3
all	0.75	1.25	1

Period	Budget
1	500000
2	550000
3	500000
4	500000
5	750000
6	600000
7	650000
8	450000

Membership value (miu_TCts(i))											
Time period	Supplier	i									
		1	2	3	4	5	6	7	8	9	10
all	S1	0.1	0.25	0.5	0.75	0.85	1	0.95	0.55	0.2	0.1
	S2	0.25	0.55	0.75	0.85	1	0.95	0.8	0.55	0.25	0.1
	S3	0.2	0.5	0.74	0.92	0.99	1	0.79	0.58	0.42	0.35
	S4	0.1	0.3	0.75	0.8	1	0.85	0.7	0.65	0.35	0.3

WEIGHT VALUE (w_TCts(i))											
Time period	Supplier	i									
		1	2	3	4	5	6	7	8	9	10
all	S1	0.05	0.075	0.125	0.125	0.05	0.1	0.2	0.175	0.05	0.05
	S2	0.125	0.15	0.1	0.05	0.1	0.075	0.125	0.15	0.075	0.05
	S3	0.1	0.15	0.12	0.09	0.035	0.11	0.105	0.08	0.035	0.175
	S4	0.05	0.1	0.225	0.025	0.175	0.075	0.025	0.15	0.025	0.15

TCts(i)											
Time period	Supplier	i									
		1	2	3	4	5	6	7	8	9	10
all	S1	250	270	290	310	330	350	370	390	410	430
	S2	300	305	310	315	320	325	330	335	340	345
	S3	300	310	320	330	340	350	360	370	380	390
	S4	220	230	240	250	260	270	280	290	300	310

LATE RATE (DLTtsp)				
Period	Supplier	P1	P2	P3
all	S1	0.015	0.001	0.015
	S2	0.000	0.000	0.002
	S3	0.000	0.000	0.000
	S4	0.003	0.002	0.001

DEFECT RATE (Qtsp)				
Period	Supplier	P1	P2	P3
all	S1	0.000	0.025	0.005
	S2	0.001	0.015	0.000
	S3	0.002	0.012	0.025
	S4	0.011	0.005	0.025

LATE RATE (DLTtsp)				
Period	Supplier	P1	P2	P3
all	S1	0.015	0.001	0.015
	S2	0.000	0.000	0.002
	S3	0.000	0.000	0.000
	S4	0.003	0.002	0.001

MEMBERSHIP VALUE of UPtsp(i)											
Supplier	Product	i									
		1	2	3	4	5	6	7	8	9	10
S1	P1	0.20	0.30	0.40	0.95	1.00	0.90	0.75	0.30	0.20	0.10
	P2	0.20	0.25	0.40	0.80	1.00	0.90	0.70	0.50	0.30	0.10
	P3	0.30	0.40	0.50	0.90	1.00	0.90	0.75	0.50	0.40	0.20
S2	P1	0.01	0.45	0.50	0.90	1.00	0.75	0.65	0.40	0.20	0.10
	P2	0.20	0.50	0.70	0.95	1.00	0.80	0.70	0.45	0.25	0.15
	P3	0.20	0.45	0.50	0.90	1.00	0.75	0.65	0.40	0.20	0.10
S3	P1	0.20	0.20	0.45	0.55	0.75	0.90	1.00	0.65	0.40	0.20
	P2	0.10	0.40	0.46	0.55	0.75	1.00	0.85	0.65	0.30	0.10
	P3	0.30	0.20	0.45	0.55	0.80	1.00	0.75	0.65	0.40	0.20
S4	P1	0.10	0.20	0.45	0.55	0.75	1.00	0.65	0.40	0.25	0.16
	P2	0.20	0.30	0.40	0.50	0.90	0.95	1.00	0.60	0.25	0.15
	P3	0.10	0.20	0.45	0.55	0.75	1.00	0.65	0.40	0.25	0.15

WEIGHT VALUE (w_UPtsp(i))											
Supplier	Product	i									
		1	2	3	4	5	6	7	8	9	10
S1	P1	0.100	0.050	0.050	0.275	0.075	0.075	0.225	0.050	0.050	0.050
	P2	0.100	0.025	0.075	0.200	0.150	0.100	0.100	0.100	0.100	0.050
	P3	0.150	0.050	0.050	0.200	0.100	0.075	0.125	0.050	0.100	0.100
S2	P1	0.005	0.220	0.025	0.200	0.175	0.050	0.125	0.100	0.050	0.050
	P2	0.100	0.150	0.100	0.125	0.125	0.050	0.125	0.100	0.050	0.075
	P3	0.100	0.125	0.025	0.200	0.175	0.050	0.125	0.100	0.050	0.050
S3	P1	0.100	0.000	0.125	0.050	0.100	0.075	0.225	0.125	0.100	0.100
	P2	0.050	0.150	0.028	0.048	0.100	0.200	0.100	0.175	0.100	0.050
	P3	0.150	0.000	0.075	0.050	0.125	0.225	0.050	0.125	0.100	0.100
S4	P1	0.050	0.050	0.125	0.050	0.100	0.300	0.125	0.075	0.045	0.080
	P2	0.100	0.050	0.050	0.050	0.200	0.025	0.225	0.175	0.050	0.075
	P3	0.050	0.050	0.125	0.050	0.100	0.300	0.125	0.075	0.050	0.075

UPtsp(i)											
Supplier	Product	i									
		ss1	ss2	ss3	ss4	ss5	ss6	ss7	ss8	ss9	ss10
S1	P1	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5
	P2	20	21	22	23	24	25	26	27	28	29
	P3	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5
S2	P1	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5
	P2	20	21.5	23	24.5	26	27.5	29	30.5	32	33.5
	P3	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5
S3	P1	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5
	P2	20	21.5	23	24.5	26	27.5	29	30.5	32	33.5
	P3	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5
S4	P1	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5
	P2	20	21.5	23	24.5	26	27.5	29	30.5	32	33.5
	P3	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5

Supplier Capacity (SCtsp)				
Periode	Suppliers	Products		
		P1	P2	P3
all	S1	1250	1100	1200
	S2	1300	1050	950
	S3	1200	950	1150
	S4	1350	900	1000

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

DELAY PENALTY COST (UDCtsp)				
Period	Supplier	Products		
		P1	P2	P3
all	S1	1	0.55	1.25
	S2	0.75	1	1
	S3	1	0.75	1
	S4	0.85	0.5	0.85

DEFECT RATE (Qtsp)				
Period	Supplier	P1	P2	P3
all	S1	0.000	0.025	0.005
	S2	0.001	0.015	0.000
	S3	0.002	0.012	0.025
	S4	0.011	0.005	0.025

Storage capacity (Mtp)			
Period	P1	P2	P3
all	700	650	800