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Supplier Selection and Order Allocation Problem Modeling with the Aim of Comparing Incremental Discounts Versus Wholesale Discounts by Using GA and NSGA Algorithms

Mohammad Vardi[1], Mehdi Neyestani[2], Ali Ghorbanian[3*]

[1] Department of Industrial Engineering, Faculty of Engineering, Tarbiat Modares University, Iran
[2] Department of Electrical Engineering, Esfarayen University of Technology, North Khorasan 96619-98195, Iran
[3] Department of Industrial Engineering, Esfarayen University of Technology, North Khorasan 96619-98195, Iran

Corresponding Author Email: a.ghorbanian@esfarayen.ac.ir

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ABSTRACT

In today's competitive world, it is very important for organizations to select suppliers according to price, quality, satisfactory service and timely delivery. Since a considerable portion of production costs is associated with purchasing raw materials from suppliers, selection of the right suppliers and allocation of optimal order quantities plays an important role in the success of an organization. So far, extensive research has been conducted in the context of supplier selection, and multi-criteria decision-making techniques are the common approach used to select the appropriate option. Recently, some studies in the context of supplier selection considered variable assumptions like quantity discount possibility. So, the aim of this study is modeling the supplier selection problem based on incremental and wholesale discounts and comparing the results of them like best selected supplier(s) and optimal order allocation to them. And solve a big problem with GA and NSGA algorithms and comparing with each other's for this an integrated three-stage approach has been proposed by combining fuzzy AHP and Extended Analysis Method for the supplier selection problem and develop a GA&NSGA algorithms. Finally, the performance of the proposed approach and proposed algorithms has been appraised by numerical examples.

1. INTRODUCTION

Supply chain includes all the stage which are involved in satisfying customer's need directly & indirectly. Supply chain not only includes the suppliers, but also involves transportation, stores, retailers & customers, too. The manufacturing firms should decrease the extra costs of supply chain to retain their competitive position. For example, it should be better to outsource parts & services which are not strategic goods of manufacturer. When a firm decides outsourcing, its main challenge is supplier selection problem [1]. Selecting of suppliers is one of the main parts in supply chain as well as it has turned to a strategic decision in supply chain during recent years. In manufacturing industries, procurement of raw materials includes approximately 70 % of the manufacturing costs. In such a condition, firm's purchasing department plays an important role in cost decrement and supplier selection is an important task in purchasing management [2].

Supplier selection problem is two types:

(1) Supplier selection without capacity restrictions. i.e. It can satisfy all the buyer's needs.

(2) Supplier selection with capacity restrictions. It means that, the supplier can't satisfy all the buyer's needs. So, buyer has to supply some of his requirements by another supplier [3].

In supplier selection problem, we are facing with a multi-dimensional problem. Thus, researchers use single or mixed multi-criteria decision-making techniques for supplier selection problem.

Amid et al. used a weighted multi-objective fuzzy model with three objectives including price and lead-time minimization and quality maximization for order allocating while each supplier offer various quantity discount [4, 5]. Have used goal programming approach & Fuzzy TOPSIS for supplier selection. The relationship closeness, quality, delivery ability, guarantee & expire date criteria have been used in their research. Network analysis process and mixed integer linear programming have been applied by Liao and Kao to investigate quantitative & qualitative criteria in supplier selection. They have determined the optimal order allocation to each supplier with the aim of maximizing purchase value, minimizing consuming budget & the least failure rate. 14 criteria have been investigated in 4 clusters; profit, opportunity, cost & risk [6]. Demirtas & Üstün applied a fuzzy approach for supplier selection in a washing machine company among three candidates [7]. A multi-criteria intuitionistic fuzzy group decision making has been exploited by Kilincci & Onal [8], 2011 to rank 5 supplier. Boran et al. [9] proposed an AHP-based approaches for supplier evaluation and they used quality, serving level, innovation & management and financial conditions as selection criteria. Bruno et al. [10] have presented a two-layer model for supplier selection. They proposed a multi-objective mixed integer programming model. Shahroodi & Hassani [11] suggested a mathematical model to select suppliers through using DEA integrated approach and wholesale ownership cost with a case study in construction value chain of Irankhodro industry. They have introduced the most efficient supplier with the least wholesale cost & have presented solutions for achieving to efficiency by the other part makers. Tabriz & Azar [12] have presented a fuzzy decision making process model for strategic supplier selection. The supplier selection & order allocation for the selected suppliers is very complicated when quantity discounts are considered in problem. We can find supplier selection problem & order allocating simultaneously in the researches of Yücel and Güneri [2], Sadrian and Yoon [13]. Recently some other studies like Perić and Babić [14], investigated supplier selection & order allocating problem through using Fuzzy AHP hybrid approach & multi-objective linear programming. Kannan et al. [15] have used a Fuzzy simulation based Fuzzy TOPSIS method for proper suppliers selection by evaluation of 4 criteria; operational strategy, service quality, innovation & risk. Zouggari and Benyoucef [16] have investigated the problem of dynamic supplier selection. Sivrikaya et al. [17] have investigated the problem of supplier selection in textile industry they have used two phases that consist of fuzzy AHP and goal programming. Ayhan and Kilic [18] have presented a two stage approach for supplier section problem, in the first stage, the relative weight of each criterion for each type of item are determined via F-AHP technique and in second stage these output are used as inputs in the MILP model to determine the supplier selection. In this research 4 criteria namely, price, quality, delivery time performance, and after sales performance are used for altenatives evaluation. Like the other research, they applied wholesale discount in their model. New approaches for supply chain coordination problem are developed by Arshinder & Deshmukh [21, 20] and Cardenas & Barron [22]. A multi-objective supplier selection and order allocation problem with fuzzy objective are studied by Kazemi et al. [23].

As it can be seen, former researches mostly consider wholesale discount in their studies and not only don't apply other type of discount, but also there isn't any research that compares the results of these two types of discount. So one of the main contribution of this study is investigating and modeling of incremental discount and also comparing the result of them toward wholesale discount.

The main differences of this study than previous research is:

(1) As much as the authors are aware, this study for the first time considers the incremental discount in the supplier selection problem.

(2) Unlike previous researches that just solve the model just for small size problem, in this work by dealing with large size problem, we have investigated the efficiency of exact solution according to time consuming.

(3) In previous studies, Weighted Method have been used to solve the Multi-Objective optimization problem, however we applied a non-dominated solution for solving the problem.

(4) In spite of previous studies, this is the first work that used meta-heuristic algorithms (*e.g.* NSGA II) to solve multi-objective optimization problems.

This research tries to investigate the supplier selection problem while there are some restrictions on supplier's capacity, quality and so on as well as a supplier can't satisfy all of the buyer's demand lonely. So, in this research, a two-stage approach has been used for modeling & supplier selection Problem Solving as well as allocating order to them in quantitative discount existing condition for various levels. In the first stage, an integrated fuzzy AHP- approach & extent analysis have been used for determining criteria weight. In second stage, the multi-objective problem has changed to a single-objective problem through weight method as well as single-objective modeling & problem solving have been done in two incremental & wholesale discounts mode.

Research structure is as follow; in the second section, a brief description on the used methods by the research such as calculating fuzzy numbers (the reason for fuzzy numbers will be explained), introducing extent analysis method, introducing weight methods have been presented. Then in the third section, problem mathematical modeling in partial & wholesale discounts existing condition for order quantities has been presented. In forth section, model performance in two partial & wholesale discounts mode has been compared by a numerical example to investigate the accuracy of the presented model. Finally, in the fifth section, conclusion & recommendations for future studies have been presented.

2. PRESENTED METHODS

In this section, before modeling & problem solving, a brief description on the used techniques in the research & their way of calculating has been presented. In this part, at first the way of calculating fuzzy numbers by some decision makers has been presented; then, the extent analysis method has been introduced; finally, a brief description has been presented on the weighed method which its weights are being calculated by extent analysis method. The way of calculating fuzzy numbers in group decision making mode In fact, in a group decision making a group of individual comment on a special issue. In such a condition, the way of determining final resulted conclusion from the done decisions by the decision makers is important. Thus, this section tries to represent the way of calculating resulted conclusion from group decision making. It should be point out that the done decisions by the decision makers are being represented lingual. Therefore, the pre-determined triangular fuzzy numbers have been used for each of lingual variables. The way of calculating the resulted fuzzy numbers from group decision making is follow; At first, each of the decision makers are being requested to fill out criteria comparison questionnaire (these decision makers can compare the criteria individually or by group & in interaction with each other). This research has considered that each of decision makers have compared the criteria independently. Equations (1), (2) & (3) are being used for achieving to a fuzzy number resulted from n decision makers while decision makers do compare the criteria independently [16].

Figure (1) illustrates display of triangular fuzzy numbers. In this figure, the horizontal axis indicates triangular fuzzy numbers include three l, *m* & *u* values as well as the vertical axis indicates the related membership function to horizontal axis values and is calculated according to equation (4).

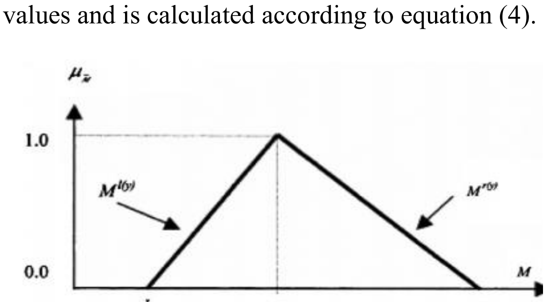


Figure 1. Triangular fuzzy numbers display

$$l_{ij} = min_k(l_{ijk}) \tag{1}$$

$$m_{ij} = \left(\prod_{k=1}^{n} m_{ijk}\right)^{1/n} \tag{2}$$

$$u_{ij} = max_k(u_{ijk}) \quad (3)$$

In above equations, l_{ij}, m_{ij} & u_{ij} are equivalent with the left value, average value & right value of resulted triangular fuzzy number through group decision making by k number for i^{th} value of the j^{th} supplier, respectively. K index represents the made decision by of k^{th} decision maker.

$$\mu_{\tilde{M}} = \begin{cases} 0, \ x < l \\ (x-l)/(m-l), \ l \leq x \leq m, \\ (u-x)/(u-m), \ m \leq x \leq u, \\ 0 \qquad ,x > u. \end{cases} \quad (4)$$

In relation (4), $\mu_{\tilde{M}}$ indicates multi-value membership function by x values.

The fuzzy numbers are intuitively & easily useable to represent decision maker's qualitative assessments.

Each fuzzy number can be indicated by its right & left values of membership degree as follow:

$$\tilde{M} = \left(M^{l(y)}, M^{r(y)}\right) = (l + (m-l)y, u + (m-u)y), \\ y\epsilon[0,1] \quad (5)$$

3. INTRODUCING EXTENT ANALYSIS METHOD IN FUZZY AHP

In AHP method, a cut of 1 to 9 discrete numerical scale is used for decision making on a criterion priority to other criteria while, fuzzy numbers or lingual values are being used in fuzzy AHP. When fuzzy numbers are being used in AHP technique, its way of solving will differ from the way of solving definite AHP. One of the most common methods for solving fuzzy AHP is extent analysis method which has been presented by Chang [17]. In this method, the "extent" is being valued by fuzzy numbers. The value of fuzzy compound degree can be achieved by the resulted fuzzy values from extent analysis for each criterion as follow;

In supplier selection problem, it is assumed that $X = \{x1, x2, \ldots, xn\}$ represents alternatives set as objective set as well as $U = \{u1, u2, \ldots, um\}$ represents set of supplier selection criteria as the goal set. According to extent analysis method, at first each of objective are chosen and the extent analysis is being done for each g_i ideal, respectively. Therefore, m is the extent analysis value for each measurable objective which is represents as follow;

Where All $M_{g_i}^j$ are triangular fuzzy numbers. Generally, extent analysis method can be summarized in below steps;

First stage: Calculating fuzzy compound extent value according to the i^{th} objective.

$$s_i = \sum_{j=1}^{m} m_{g_i}^j \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \quad (6)$$

The below equations represent the way of calculating $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} m_{g_i}^j\right]^{-1}$ & $\sum_{j=1}^{m} m_{g_i}^j$.

$$\sum_{j=1}^{m} m_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (7)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}. \frac{1}{\sum_{i=1}^{n} l_i}\right) \quad (8)$$

Second stage: Determining the possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$.

$$V(M_2 \geq M_1) = \begin{cases} 1, & if \ m_2 \geq m_1 \\ 0, & if \ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2-u_2)-(m_1-l_1)}, & otherwise \end{cases} \quad (9)$$

To compare, M_1 & M_2, the values of $V(M_1 \geq M_2)$ & $V(M_2 \geq M_1)$ should be calculated.

Third stage: Determining objective weight vector.

$$\acute{W} = \left(\left(\acute{d}(A_1), \acute{d}(A_2), \ldots, \acute{d}(A_n)\right)^T, \\ A_i(i = 1,2, \ldots, n), \ \acute{d}(A_i) = min\, V\,(s_i \geq s_k) \\ k = 1,2, \ldots, n; \ k \neq n \quad (10)$$

Fourth stage: Determining normalized weight vector.

$$W = ((d(A_1), (d(A_2), \ldots, (d(A_n))^T \quad (11)$$

4. INTRODUCING WEIGHT METHOD

The weight method is one of the most applicable methods in modeling & solving multi-objective optimization problem in spite of being easy. In this method, a weight is considered for the problem various objective functions. This weight represents the importance & relative-priority of the objectives to each other. Since, the supplier selection problem & allocating order to them is of multi-objective optimization problems; thus, this research tries to use weight method for modeling & solving it. Notable point in weight method is the way of calculating the weights. So, the extent analysis method is used for determining relative weights of criteria to each other. After calculating relative weights of criteria to each other, the multi-objective linear programming modeling & solving it is done by the weight method. In the below part the way of changing the multi-objective problem to single-objective problem through using weight method has been represented.

$$Max(Min) f_i(x), \qquad i = 1,2, \ldots, n \\ S.t. \\ g_i(x) \leq or \geq b_i, \qquad i = 1,2, \ldots, n \\ x_i \geq 0. \quad (12)$$

$$Max(Min)\ w_1.f_1(x) + w_2.f_2(x) + \cdots + w_n.f_n(x) \\ S.t \\ g_i(x) \leq or \geq b_i, \qquad i = 1,2, \ldots, n \\ x_i \geq 0. \quad (13)$$

5. PROBLEM MATHEMATICAL MODEL

This research tries to investigate supplier selection problem in two partial & wholesale discounts mode for order quantity. So, in this section two model have been presented for the possibility of existing partial & wholesale discount.

5.1 Mathematical model with the possibility of existing partial discount for order quantity

Supplier selection problem is a problem with multiple criteria. The considered criteria in this research are cost, quality & delivery time, respectively. These criteria are of the most important criteria which are used in the related researches to supplier selection as well as their application in various researches during recent years has been presented in table (1) in the appendixes. So, these three criteria have been used in this research as the main criteria in selecting proper supplier. Multi-objective integer linear programming modeling in the special partial discount condition for order quantity which has not been presented in the former researches has been presented in this section. Partial discount for order quantity is that the price is different for each determined quantity interval as well as wholesale price is being measured aggregately while in wholesale discount, all of the purchased quantities are being calculated by the related prices to the same price interval.

The model variables & parameters are being described before modeming the problem.

Variables;

X_{ij}: Number of the purchased units from i^{th} supplier in j^{th} price level.

Y_{ij}: Zero & one variable for i^{th} supplier in j^{th} price level.

Parameters;

P_{ij}: Product price for the i^{th} supplier in the j^{th} level.

V_{ij}: The length of the order interval from the i^{th} supplier in the j^{th} price level.

D: the demand of whole period.

M_i: The price levels of the i^{th} supplier.

C_i: The capacity of the i^{th} supplier.

F_i: The percentage of delayed items for the i^{th} supplier.

Q_i: Quality of the i^{th} supplier items.

n: Numbers of the suppliers.

$$\text{MinZ}_1=\sum_{i=1}^{n} p_{i,1}\, x_{i,1} + p_{i,2}\cdot(x_{i,2}) + \cdots + p_{i,m}\cdot(x_{i,m}) \quad (14)$$

$$\text{MaxZ}_2= \sum_{i=1}^{n} Q_i \sum_{j=1}^{mi} x_{i,j} \quad (15)$$

$$\text{MinZ}_3= \sum_{i=1}^{n} F_i \sum_{j=1}^{mi} x_{i,j} \quad (16)$$

S.t.

$$\sum_{i=1}^{n}\sum_{j=1}^{mi} x_{i,j} \geq D \quad (17)$$

$$\sum_{j=1}^{mi} x_{i,j} \leq C_i \quad i = 1,2,\ldots,n \quad (18)$$

$$V_{i,j}Y_{i,j} \leq x_{i,j},\ i = 1,\ldots,n, j = 1,\ldots,m \quad (19)$$

$$x_{i,j} \leq v_{i,j}\cdot Y_{i,j-1} \quad i = 1,2,\ldots,n,\ j = 1,2,\ldots,m_i \quad (20)$$

$$\sum_{j=1}^{m} y_{ij} \leq m, \quad \forall i\epsilon\ i = 1,\ldots,n \quad (21)$$

$$Y_{i,j} = 0 \text{ or } 1 \quad i = 1,2,\ldots,n,\ j = 1,2,\ldots \quad (22)$$

$$x_{i,j} \geq 0, Integer \quad i = 1,2,\ldots,n \quad , j = 1,2,\ldots,m_i \quad (23)$$

In the above model, the (14), (15) & (16) relations which represent objective functions are price minimizing, quality maximizing & lead time minimizing in delivery, respectively. The (17) & (18) relations are limitations for demand & capacity, respectively. The (19) & (20) relations also, are the related limitations to partial discount. Finally, the (21) & (22) relations represent the limitation of variables being zero & one as well as being positive.

5.2 Mathematical model with the possibility of existing wholesale discount for order quantity

In this part, a mathematical model is presented with the wholesale discount existence for order quantity. Since, in wholesale discount unlike partial discount all the purchased items are being purchased with the related price to the same interval; here, instead the parameter of $\acute{V}_{i,j}$ order quantity interval length the parameter of $\acute{V}_{i,j}$ order quantity upper limit is used. So, mathematical model of supplier selection problem & allocating optimum order to them in wholesale discount condition will be as follow;

New parameter;

$\acute{V}_{i,j}$: Upper limit of order interval from the i^{th} supplier in the j^{th} price level

$$\text{MinZ}_1=\sum_{i=1}^{n} p_{i,1}\, x_{i,1} + p_{i,2}\cdot(x_{i,2}) + \cdots + p_{i,m}\cdot(x_{i,m}) \quad (24)$$

$$\text{Max Z2} = \sum_{i=1}^{n} Q_i \sum_{j=1}^{mi} x_{i,j} \quad (25)$$

$$\text{MinZ3} = \sum_{i=1}^{n} F_i \sum_{j=1}^{mi} x_{i,j} \quad (26)$$

S.t.

$$\sum_{i=1}^{n}\sum_{j=1}^{mi} x_{i,j} \geq D \quad (27)$$

$$\sum_{j=1}^{mi} x_{i,j} \leq C_i \quad i = 1,2,\ldots,n \quad (28)$$

$$\acute{v}_{i,j}Y_{i,j} \leq x_{i,j}, \quad i = 1,\ldots,n, j = 1,\ldots,m \quad (29)$$

$$x_{i,j} \leq \acute{v}_{i,j}\cdot Y_{i,j} \quad i = 1,2,\ldots,n \quad , j = 1,2,\ldots,m_i \quad (30)$$

$$\sum_{j=1}^{m} y_{ij} \leq 1, \quad \forall i\epsilon\ i = 1,\ldots,n \quad (31)$$

$$Y_{i,j} = 0 \text{ or } 1 \quad i = 1,2,\ldots,n \ , j = 1,2,\ldots \quad (32)$$

$$x_{i,j} \geq 0 \quad i = 1,2,\ldots,n \quad , j = 1,2,\ldots,m_i \quad (33)$$

All limitations of the above model are the same as the former model except the (29) & (31) which are for wholesale discount.

5.3 Normalization

In multi-objective optimization problem, when we have different objective functions with different scales, normalization of objective functions, play an important role in ensuring the consistency of optimal solutions.

There are different approaches for normalization and one of the simplest (but appropriate) approaches is to optimize each of the objectives individually first, then divide each objective by those optimum values and finally sum up all normalized terms as one objective function

Initially, each objective function is optimized separately and the negative ideal solution (worst solution) and positive ideal solution (best solution) of them are found. Since the values of objective function vary in different scales equation 34 and 35 is used for normalize the objective functions.

For minimization objective function

$$f_i^N = \frac{NIS_f - f}{NIS_f - PIS_f} \quad (34)$$

For maximization objective function

$$f_i^N = \frac{f - NIS_f}{PIS_f - NIS_f} \quad (35)$$

where, f_i^N is the normalized value of the ith objective function, NIS is negative ideal solution of objective function and PIS is best solution or positive ideal solution at the end model is changed to a single-objective function by summing up all weighted functions as shown in Eq. (36).

$$MAX(f) = \sum_{i=1}^{n} w_i f_i^N \quad (36)$$

6. NUMERICAL EXAMPLE

In this part, the implementation stages of supplier selection problem as well as their step by step solving to investigate the presented model validity is presented though giving a numerical example. In this example, three decision makers (to do group decision making), three supplier wilt limited capacity & the presenter of partial & wholesale discount for order quantity have been considered. The considered criteria in this example are cost, quality & lead time. Table 2 indicates the complete related information to price, quality & delivery as well as productive capacity for the three suppliers. The implementation steps of the recommended model for our example are as follow Table 2.

Table 2. Problem information

productive capacity	Percentage lead time in delivery	quality	Purchase interval	cost	
16000	0.1	80	[0-4000]	15	Supplier 1
			[4001- 8000]	14.5	
			[8001-16000]	14	
15000	0.15	70	[0-3000]	17	Supplier 2
			[3001- 10000]	16.5	
			[10001-15000]	16	
17000	0.3	95	[0-5000]	13	Supplier 3
			[5001- 11000]	12.5	
			[11001-17000]	12	

First step: Determining criteria's weight by AHP integrated method & extent analysis method.

- **Filing out the questionnaire by the experts (decision makers)**

In this section, at first a questionnaire is prepared for the experts. This questionnaire includes questions through which the ecision makers are requested to represent their viewpoints on the criteria. Table (3) indicates an example of the filled questionnaire by the decision makers.

Table 3. The pair-wise comparison by the experts

lead time in delivery	**Quality (Q)**	**Cost (C)**	**First decision maker**
Very very imporant	Equal importance	1	Cost (C)
Very very imporant	1		Quality(Q)
1			lead time

- **Changing lingual variables to corresponding fuzzy numbers**

In the next section, after filling the questionnaire by the experts the lingual values are changed to corresponding fuzzy numbers with them according to table (2) in the appendix. Table (5) indicates related fuzzy numbers to resulted lingual values from decision makers' viewpoints. In this table C, Q & F represent cost, quality & lead time, respectively as well as D1, D2 & D3 represent decision maker 1, 2 & 3, respectively.

Table 4. Lingual values & their corres

Importance	**values**
The same importance	(1,1,1)
more Important portion	(2/3,1,3/2)
More Important	(3/2,2,5/2)
More & more important	(5/2,3,7/2)
Completely Important	(7/2,4,9/2)

Table 5. Corresponding fuzzy numbers with each decision makers' preferences

	D1	**D2**	**D3**
C/Q	(1,1,1)	(5/2,3,7/2)	(1,1,1)
C/F	(5/2,3,7/2)	(1,1,1)	(3/2,2,5/2)
Q/F	(5/2,3,7/2)	(2/7,1/3,2/5)	(3/2,2,5/2)

In the next section, resulted values of decision makers are being replaced with a fuzzy number through using (1), (2) & (3) equations.

Table (6) indicates these values.

Table 6. Fuzzy values of resulted mean from three decision makers

	Lij	**Mij**	**Uij**
C/Q	1	1.44	3.5
C/F	1	1.96	3.5
Q/F	0.28	1.26	3.5

Table (7) indicates resulted triangular numbers from paired comparisons.

Table 7. Paired comparisons values resulted from table (6)

	C	**Q**	**F**
C	(1,1,1)	(1,1.44,3.5)	(1,1.96,3.5)
Q	(1/3.51/1.44.,1/1)	(1,1,1)	(0.28,1.26,3.5)
F	(1/3.5,1/1.96,1/1)	(1/3.5,1/1.26,1/0.28)	(1,1,1)

- **Determining criteria's weight by extent analysis method**

$S_{cost} = (3, 4.4, 8) \otimes (\frac{1}{19.071}, \frac{1}{11.42}, \frac{1}{6.137}) = (0.157, 0.385, 1.303)$

$S_{quality} = (1.56, 2.954, 5.5) \otimes (\frac{1}{19.071}, \frac{1}{11.42}, \frac{1}{6.137}) = (0.82, 0.258, 0.896)$

$S_{delivery} = (1.571, 4.068, 5.57) \otimes (\frac{1}{19.071}, \frac{1}{11.42}, \frac{1}{6.137}) = (0.082, 0.356, 0.9078)$

$V(S_{cost} \geq S_{quality}) = 1$, $V(S_{quality} \geq S_{cost}) = 0.854$

$V(S_{cost} \geq S_{delivery})=1$, $V(S_{delivery} \geq S_{cost})=0.963$
$V(S_{quality} \geq S_{delivery})=0.893$, $V(S_{delivery} \geq S_{quality})=1$
$\acute{d}(cost) = \min(1,1) = 1$
$\acute{d}(Quality) = \min(0.893,854) = 0.854$
$\acute{d}(Delivery\ ) = \min(0.963,1) = 0.963$
$\acute{w} = (1,0.854,0.963)$

The normalized resulted weight is as follow:

$$WG = (0.36, 0.3, 0.34)$$

Second step: Changing multi-objective optimizing model to single-objective model.

In this section, after determining the weight significance of each objective functions, multi-objective linear programming model is changed to single-objective model. The single-objective model is as follow for the example of partial & wholesale discount mode;

So in this section, we intend to normalize objective functions according to above mentioned approach. For the first step, we solve the single objective optimization problem for each objective function, to obtain the optimum value of them. Table (8), show the optimum value of objective functions.

Table 8. PIS and NIS for z1 to z3

Function	PIS	NIS
Z1(min is best)	249000	313000
Z2(max is best)	1855000	1450000
Z3(min is best)	22	55.5

- **Integer linear programming model in partial discount mode**

$$\text{MAX Z} = 0.36 * \Big(\big(313000 - (15x_{11} + 14.5x_{12} + 14x_{13} + 17x_{21} + 16.5x_{22} + 16x_{23} + 13x_{31} + 12.5x_{32} + 12x_{33})\big)\Big) / (313000 - 249000) + 0.3 * \Big(\big(80\ (x_{11} + x_{12} + x_{13}) + 70\ (x_{21} + x_{22} + x_{23}) + 95(x_{31} + x_{32} + x_{33})\big) - 1450000\Big) / (1855000 - 1450000) + 0.34 * (55.5 - (0.001(x_{11} + x_{12} + x_{13}) + 0.0015(x_{21} + x_{22} + x_{23}) + 0.003(x_{31} + x_{32} + x_{33})))/(55.5\text{-}22)$$

S.t.
$x_{11} + x_{12} + x_{13} + x_{21} + x_{22} + x_{23} + x_{31} + x_{32} + x_{33} = 20000$
$x_{11} + x_{12} + x_{13} \leq 16000$
$x_{21} + x_{22} + x_{23} \leq 15000$
$x_{31} + x_{32} + x_{33} \leq 17000$
$4000 * Y_{11} - x_{11} \leq 0$
$x_{11} - 4000 \leq 0$
$4000 * y_{12} - x_{12} \leq 0$
$x_{12} - 4000 * Y_{11} \leq 0$
$8000 * y_{13} - x_{13} \leq 0$
$x_{13} - 8000 * Y_{12} \leq 0$
$3000 * y_{21} - x_{21} \leq 0$
$x_{21} - 3000 \leq 0$
$7000 * y_{22} - x_{22} \leq 0$
$x_{22} - 7000 * Y_{21} \leq 0$
$5000 * y_{23} - x_{23} \leq 0$
$x_{23} - 5000 * Y_{22} \leq$
$5000 * y_{31} - x_{31} \leq 0$
$x_{31} - 5000 \leq 0$
$6000 * y_{32} - x_{32} \leq 0$
$x_{32} - 6000 * Y_{31} \leq 0$
$6000 * y_{33} - x_{33} \leq 0$
$x_{33} - 6000 * Y_{32} \leq 0$
$Y_{11} + Y_{12} + Y_{13} \leq 3$
$Y_{21} + Y_{22} + Y_{23} \leq 3$
$Y_{31} + Y_{32} + Y_{32} \leq 3$
$Y_{i,j} = 0,1 \quad , i = 1,2, \dots, n \quad j = 1,2, \dots, m_i$
$x_{ij} \geq 0, i = 1,2, \dots, n, j = 1,2, \dots, m_i, \quad x_{ij} = \text{INTEGER}$

- **Integer linear programming model in wholesale discount mode**

$$\text{MAX Z} = 0.36 * \Big(\big(313000 - (15x_{11} + 14.5x_{12} + 14x_{13} + 17x_{21} + 16.5x_{22} + 16x_{23} + 13x_{31} + 12.5x_{32} + 12x_{33})\big)\Big) / (313000 - 249000) + 0.3 * \Big(\big(80\ (x_{11} + x_{12} + x_{13}) + 70\ (x_{21} + x_{22} + x_{23}) + 95(x_{31} + x_{32} + x_{33})\big) - 1450000\Big) / (1855000 - 1450000) + 0.34 * (55.5 - (0.001(x_{11} + x_{12} + x_{13}) + 0.0015(x_{21} + x_{22} + x_{23}) + 0.003(x_{31} + x_{32} + x_{33})))/(55.5\text{-}22)$$

S.t.
$x_{11} + x_{12} + x_{13} + x_{21} + x_{22} + x_{23} + x_{31} + x_{32} + x_{33} = 20000$
$x_{11} + x_{12} + x_{13} \leq 16000$
$x_{21} + x_{22} + x_{23} \leq 15000$
$x_{31} + x_{32} + x_{33} \leq 17000$
$x_{11} - 4000 * Y_{11} \leq 0$
$4001 * Y_{12} - x_{12} \leq 0$
$x_{12} - 8000 * Y_{12} \leq 0$
$8001 * y_{13} - x_{13} \leq 0$
$x_{13} - 16000 * Y_{13} \leq 0$
$x_{21} - 3000 * Y_{21} \leq 0$
$3001y_{22} - x_{22} \leq 0$
$x_{22} - 10000 * Y_{22} \leq 0$
$10001 * y_{23} - x_{23} \leq 0$
$x_{23} - 15000 * Y_{23} \leq$
$x_{31} - 5000 * Y_{31} \leq 0$
$5001y_{32} - x_{32} \leq 0$
$x_{32} - 11000 * Y_{31} \leq 0$
$11001 * y_{33} - x_{33} \leq 0$
$x_{33} - 16000 * Y_{32} \leq 0$
$Y_{11} + Y_{12} + Y_{13} \leq 1$
$Y_{21} + Y_{22} + Y_{23} \leq 1$
$Y_{31} + Y_{32} + Y_{32} \leq 1$
$Y_{i,j} = 0,1 \quad , i = 1,2, \dots, n \quad j = 1,2, \dots, m_i$
$x_{ij} \geq 0, i = 1,2, \dots, n, j = 1,2, \dots, m_i, \quad x_{ij} = INTEGER$

Third step: Running the model & finding the optimum solution.

The optimum values have been achieved through running the two above mentioned model in GAMS software (Table 8);

As it can be seen in above Table, 1 & 3 supplies have been selected for demand supply in both partial & wholesale discount mode. But, way of order allocating is different in both modes. As it has been stated, in partial discount mode each order interval has its own special price as well as only the values of this interval will have this discount While in wholesale discount, all of the related order to the mentioned supplier are sold with the price of this order quantity in the same interval. Generally, the results indicate that both discounts have selected the same suppliers for order allocation as well as the order quantity for them is the same. The only difference in these two discounts is the way of calculating order wholesale price. This has been shown well in table (9) in the part of calculating the first objective function value (ZI). The cause of the second & third objective functions being the same in both kinds of the discounts is order quantity being the same for suppliers is both kinds of discount.

Table 9. Optimum values of objective functions & resulted variables from model solving

Variables	Partial discount	Normalized value	Wholesale discount	Normalized value
Z1	257000	1	256002	0.89059375
Z2	1855000	1	1779985	0.814777778
Z3	54	0.045	43.998	0.343343284
X11	3000		0	
X12	0		0	
X13	0		8001	
X21	0		0	
X22	0		0	
X23	0		0	
X31	5000		0	
X32	6000		0	
X33	6000		11999	
0.36*Z1+0.3*Z2+0.34*Z3		0.675		0.682

7. GA AND NSGA ALGORITHMS

Srinivas and Deb [24] have instructed NSGA method for optimization multi objective problems. This algorithm use Darwin's principle of natural selection for to find the formula or optimal solution. But NSGA algorithm is highly sensitive to share fitness and other parameters. So for the second version of NSGA algorithm called NSGA-II was introduced in [25] by Deb et al. in the NSGA algorithm some of answer selected by using tournament selection from answer of each generation. note in this method the answer that there isn't any answer better than it is best answer and has more point. Answers ranked and sorted based on how many answers there are better than them [26]. Fitness allocated to answer based on their ranks and not overcome of other answers. In the first, rank of answer and second, compaction distance are criteria for selecting in NSGA –II algorithm. The answer is more favorable that rank answer is less and has more compaction distance. The not overcome answer that obtained archived and sorted as elite.

Table 10. Parameters levels of algorithms

algorithms	parameters	Symbols	levels
NSGAII	Crossover rate	P_c	0.4-0.6-0.8
	Mutation rate	P_m	0.1-0.3-0.5
	Pop size	*pop*	20-50-100
	iteration	*It*	100-200-300
GA	Crossover rate	P_c	0.4-0.6-0.8
	Mutation rate	P_m	0.1-0.3-0.5
	Pop size	*pop*	20-50-100
	iteration	*It*	100-200-300

Table 11. Taguchi results to adjust parameter's NSGA algorithm

Number of experiments	P_c	P_m	*pop*	*It*	Practical discount	Wholesale discount
1	0.4	0.1	20	100	0.624179	0.60199
2	0.4	0.3	50	200	0.635072	0.65644
3	0.4	0.5	100	300	0.667806	0.66566
4	0.6	0.1	50	300	0.642662	0.64461
5	0.6	0.3	100	100	0.644928	0.66679
6	0.6	0.5	20	200	0.620905	0.64456
7	0.8	0.1	100	200	0.663939	0.66269
8	0.8	0.3	20	300	0.645692	0.61330
9	0.8	0.5	50	100	0.61057	0.66295

Adjusting parameter's algorithms

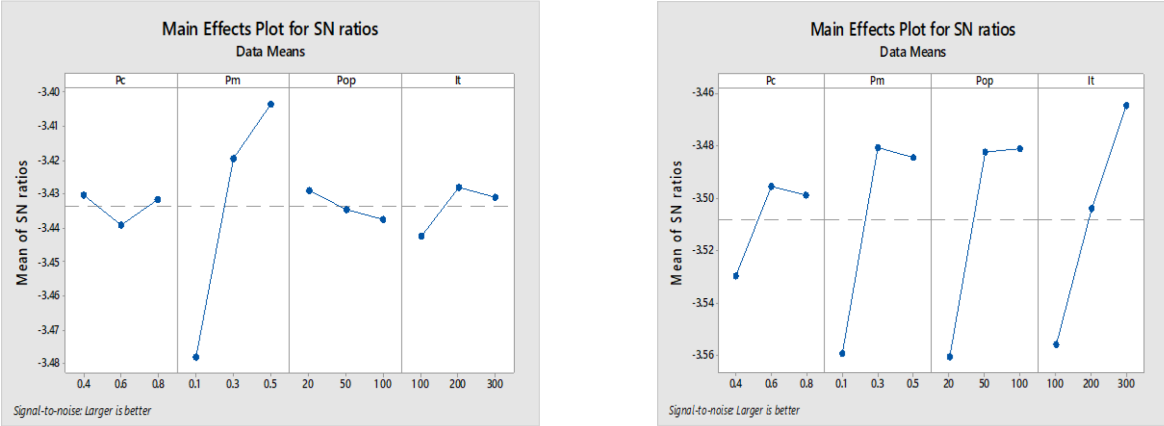
In this study used Taguchi method to adjust the parameters of the proposed algorithms. In this way at the first different levels of parameters be determined. Related parameters and values of GA& NSGA II algorithms are given in Table 10.

It is available of the value of parameters after running using the signal to noise. This graph is available for GA&NSGA algorithms that is showed in Figures 2 and 3.

At the end of each replication, a final answer has calculated by using weights that are obtained from fuzzy AHP method. The GA and NSGA run for 10 times and averaged for value can be seen in table 11 the final answer of Pareto solution is shown in Z.

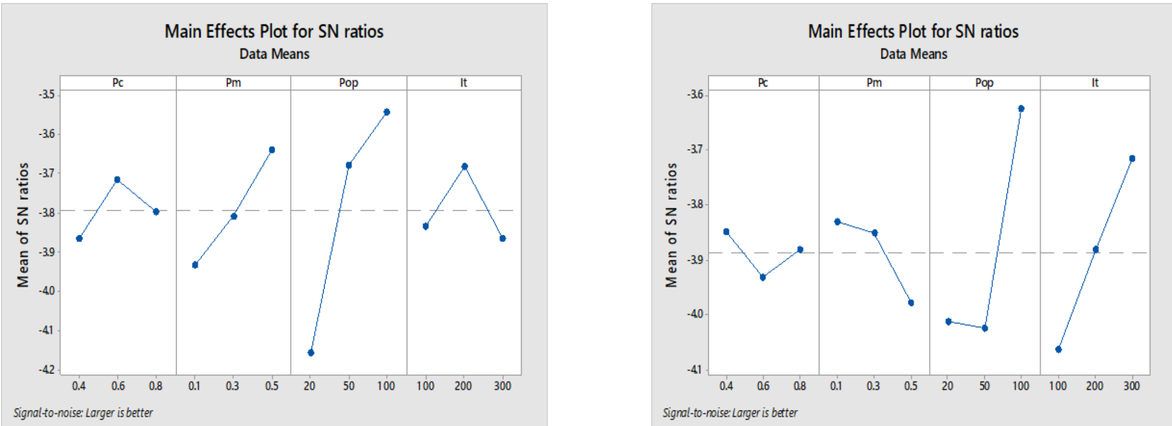
Table 12. Taguchi results to adjust parameter's GA algorithm

Number of experiment	P_c	P_m	*pop*	*It*	Practical discount	Wholesale discount
1	0.4	0.1	20	100	0.65481	0.67001
2	0.4	0.3	50	200	0.67045	0.67522
3	0.4	0.5	100	300	0.67332	0.67599
4	0.6	0.1	50	300	0.67007	0.66974
5	0.6	0.3	100	100	0.66916	0.67318
6	0.6	0.5	20	200	0.66679	0.67621
7	0.8	0.1	100	200	0.66691	0.67036
8	0.8	0.3	20	300	0.66982	0.67531
9	0.8	0.5	50	100	0.66855	0.67525



Wholesale discount **Practical discount**

Figure 2. Signal to noise for GA algorithm



Wholesale discount **Practical discount**

Figure 3. Signal to noise for NSGA algorithm

Table 13. Best value for parameters of GA and NSGA algorithms

algorithms	parameters	Symbol	Value of parameter (practical discount)	Value of parameter (wholesale discount)
NSGAII	Crossover rate	P_c	0.4	0.6
	Mutation rate	P_m	0.1	0.5
	Pop size	***pop***	100	100
	iteration	***It***	300	200
GA	Crossover rate	P_c	0.6	0.4
	Mutation rate	P_m	0.3	0.5
	Pop size	***pop***	100	20
	iteration	***It***	300	200

Table 14. Value of GA and NSGA

	NSGA for wholesale	GA for wholesale	GA for practical	NSGA for practical
X1	8093	8838	3555	3586
X2	5	100	93	60
X3	11904	11067	16361	16355
Z1	256235	258236	259238	259070
Z2	1778670	1765405	1845205	1844805
Z3	43.812	42.189	52.7775	52.7400
X1+ X2+ X3	20000	20000	20000	20000
Normalized SAW	0.681	0.677	0.667	0.668

Table 15. GA and NSGA error parentage

	Optimal Normalized value	Value of NSGAII	Value of GA	NSGA Error Parentage	GA Error Parentage
Practical discount	0.675	0.668	0.667	1.03	1.18
Wholesale discount	0.682	0.681	0.677	1.02	0.73

Appropriate values for the parameters of algorithm NSGAII and GA have been reported in Table 13.

Then the given example has solved by using the optimal value is obtained that has shown in table 14. Compared the obtained value with the optimal value is known as a very low percentage of errors, especially in the NSGA algorithm that this reflects the accurate of algorithms are used. Table 15 Shows value of errors.

Now given that accuracy of algorithms is evaluated then a big size problem has solved in both wholesale and practical discount. This problem can be seen in appendix 2. In this problem number of supplier is 35. The best solution for each of discount is shown in Table 16.

Table 16. Best value for big problem

	NSGA for wholesale	GA for wholesale	GA for practical	NSGA for practical
X1	11633	7394	8014	880
X2	4531	13000	4434	1006
X3	5201	1438	5379	3237
X4	2949	1201	2234	5766
X5	10530	2292	5259	15315
X6	9995	12166	8769	5839
X7	10840	625	11293	5731
X8	11027	14413	8014	880
X9	332	1347	4434	1006
X10	3200	2560	5379	3237
X11	3158	3205	2234	5766
X12	8246	1048	5259	15315
X13	100	5377	8769	5839
X14	10872	9618	11293	5731
X15	4211	15693	8014	880
X16	343	6371	4434	1006
X17	5087	164	5379	3237
X18	254	3643	2234	5766
X19	8334	795	5259	15315
X20	157	8461	8769	5839
X21	4509	7654	11293	5731
X22	14972	1701	8014	880
X23	758	5622	4434	1006
X24	14945	15579	5379	3237
X25	412	4695	2234	5766
X26	6445	3342	5259	15315
X27	1877	3919	8769	5839
X28	3704	12405	11293	5731
X29	1657	2853	8014	880
X30	9449	1080	4434	1006
X31	4638	9008	5379	3237
X32	5914	7672	2234	5766
X33	5326	9213	5259	15315
X34	9817	304	8769	3256842
X35	4581	4143	11293	16473804
Z1	3120360	3173353	3143148	231
Z2	16281954	-15979768	16316710	200001
Z3	247	243	254	0.65
$\sum x_i$	200004	200001	200004	880
Normalized SAW	0.729	0.682	0.550	1006

8. CONCLUSION & RECOMMENDATIONS FOR FUTURE STUDIES

In this research step by step has been used for solving the supplier selection problem & determining order quantity to them in the condition which both partial & wholesale discounts are valid for order quantity. A three-stage approach has been used for modeling & problem solving. In the first stage, the criteria's weight has been determined by an integrated AHP method & extent analysis. In the second stage, supplier selection problem modeming has been done by multi-objective integer linear programming technique which has been solved by weight method and the third stage has developed a GA and NSGA algorithms then a big problem has solved with algorithms and compared with each other. This research innovation is 1- presenting mathematical model for supplier selection problem in the partial discount exiting condition for order quantity; 2- comparing & investigating the role of partial & wholesale discount in the way of selecting optimum supplier & allocating order to them optimally. In the following, supplier selection problem has been investigated through giving a numerical example as well as results have indicated that both discounts select the same suppliers. However, the way of allocating order to selected supplier & way of calculating order wholesale price are different in wholesale & partial discount.

The recommendations for future studies are:

1. Using other methods to solve multi-objective problem & comparing its results with this research results.
2. In this research. It has been assumed that the decision makers evaluate the criteria independently, although it can be seen that some of the decision makers affect by the others. So, this such condition can be investigated & be investigated with the result of the mentioned condition.

Finally, another objective functions can be added to the problem & their results to be analyzed.

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APPENDIX

Table 1. Supplier selection criteria for 1966 to 2013

	Dicson	Evans	Shipley	Ellram	Weber et.al	Tam and tummada	Pi and low	Chen et.al	In and chen	Wang et.al	Perić	Lee et al.	Yücel and Güneri
Selection criteria													
Price (Cost)	√	√	√	√	√		√				√	√	√
Product Quality	√	√	√	√	√	√	√	√		√	√		√
On-Time Delivery	√	√	√	√	√		√						√
Warranty And Claims	√												
After Sales Service	√					√							

Technical Support/Expertise						√							
Attitude	√												
Total Service Quality				√			√						
Training Aids	√												
Performance History	√				√	√							
Financial Stability	√				√			√		√			
Location	√				√								
Labor Relations	√												
Relationship Closeness								√	√				
Management And Organization	√				√								
Conflict/Problem Solving Capability						√		√	√				
Communication System	√								√				
Respond To Customer Request													
Technical Capability	√				√			√					
Production Capability	√				√								
Packaging Capability	√												
Operational Controls	√												
Amount Of Past Business	√												
Reputation And Position In Industry	√				√	√			√	√			
Reciprocal Managements	√												
Impression	√												
Business Attempt	√												
Maintainability	√												
Reliability											√		
Size	√				√					√			

	cost	Purchase interval	quality	Percentage lead time in delivery	productive capacity
S1	15	[0-4000]	80	0.1	16000
	14.5	[4001- 8000]			
	14	[8001-16000]			
S 2	17	[0-3000]	70	0.15	15000
	16.5	[3001-10000]			
	16	[10001-15000]			
S 3	13	[0-5000]	95	0.3	17000
	12.5	[5001-11000]			
	12	[11001-17000]			
S 4	17	[0-2500]	97	0.33	12000
	16.5	[2501- 5500]			
	16	[5501-12000]			
S 5	14	[0-4500]	65	0.15	14000
	13.5	[4501- 9000]			
	13	[9001-14000]			
S 6	15.5	[0-3500]	85	0.12	12500
	14.5	[3501- 7000]			
	14	[7001-12500]			
S 7	18	[0-5000]	98	0.05	16000
	17.5	[5001- 8000]			
	17	[8001-16000]			
S 8	15.25	[0-3000]	83	0.07	16000
	15	[3001- 9000]			
	14.75	[9001-16000]			

	cost	Purchase interval	quality	Percentage lead time in delivery	productive capacity
S 18	20	[0-3500]	96	0.11	15550
	19	[3501-10000]			
	19.5	[10001-15550]			
S 19	16	[0-3250]	70	0.21	15000
	15.5	[3251-7550]			
	14.5	[7551-15000]			
S 20	18.5	[0-4250]	84	0.15	15500
	18	[4250-9500]			
	17.5	[9501-15500]			
S 21	13	[0-6200]	60	0.23	18000
	12.5	[6201-11000]			
	12	[11001-18000]			
S 22	21	[0-3250]	85	0.09	15000
	19	[3250-8500]			
	17	[8501-15000]			
S 23	16.25	[0-3000]	73	0.13	14500
	16	[3001-9000]			
	15.5	[9001-14500]			
S 24	18	[0-4500]	84	0.07	16500
	17.5	[4501-9500]			

S 9	19	[0-5000]	95	0.11	16000
	18.5	[5001-12000]			
	18	[12001-16000]			
S 10	13	[0-5500]	60	0.25	16500
	12	[5501- 9000]			
	11	[9001-16500]			
S 11	18.5	[0-2250]	90	0.12	13500
	18	[2251- 9500]			
	17.5	[9501-13500]			
S 12	15.5	[0-6000]	85	0.18	17000
	15	[6001-10500]			
	14.5	[10501-17000]			
S 13	17.5	[0-4000]	75	0.11	145000
	17	[4001- 7000]			
	16.5	[7001-14500]			
S 14	13	[0-3250]	68	0.15	12000
	12.5	[3251- 9500]			
	11.5	[9501-12000]			
S 15	15.25	[0-5000]	75	0.17	16500
	15	[5001-10500]			
	14	[10501-16500]			
S 16	18	[0-4250]	80	0.09	15000
	17.5	[4251- 7250]			
	17	[7251-15000]			
S 17	19	[0-5500]	85	0.10	14500
	18.25	[5501- 9500]			
	17.75	[9501-14500]			

	17	[9501-16500]			
S 25	15.75	[0-4300]	76	0.10	16250
	15	[4301-9550]			
	14.25	[9551-16250]			
S 26	16.75	[0-5250]	78	0.12	14500
	16.5	[5251-9500]			
	15.75	[9501-14500]			
S 27	20	[0-3500]	86	0.08	14000
	19.75	[3501-8500]			
	18.5	[8501-14000]			
S 28	19	[0-4000]	82	0.12	15000
	18.25	[4001-7500]			
	17.75	[7501-15000]			
S 29	14	[0-4200]	72	0.18	15000
	13.5	[4201-9750]			
	13.25	[9751-15000]			
S 30	15.5	[0-5500]	78	0.12	18000
	14.5	[5501-12000]			
	13.5	[12001-18000]			
S 31	16	[0-5300]	78	0.12	18000
	15.25	[5301-9500]			
	14.5	[9501-15000]			
S 32	17.5	[0-27500]	82	0.10	15000
	17	[27501-6000]			
	16.25	[6001-15500]			
S 33	19.25	[0-5400]	85	0.09	15500
	19	[5401-9750]			
	18.75	[9751-15000]			
S 34	18.75	[0-4250]	96	0.05	15000
	18	[4250-9800]			
	17.25	[9801-14000]			
S 35	19.5	[0-1500]	90	0.08	14000
	19.25	[1501-7500]			
	18.75	[7501-12500]			