A decision-making technique for solving order allocation problem using a genetic algorithm

Ijaz Ahmad¹, Yan Liu*,¹, Danish Javeed¹, Shahab Ahmad²

¹School of Computer Science and Technology, Changchun University of Science and Technology, Changchun 130022, China.
²School of Economics & Management, Chongqing University of Post & Telecommunication, Chongqing, 400065, China.

*e-mail: yanl@cust.edu.cn, engeerijaz04@gmail.com

Abstract. The selection of proper suppliers is one of the most complicated works of the purchasing department. Today, supplier selection includes different conflicting objectives. Because of contradictory multi-objective supplier selection is solving by using the decision-making technique. This paper is presented a modified genetic algorithm by using a combination of crossover operators, Order crossover (OX), Simulated binary crossover (SBX) to assign the optimal order quantities to each supplier, with criteria of transportation cost, product quality, and delivery time with a quantity discount. The result shows that the modified genetic algorithm is an allocated optimal order for multi vendors with improves quality as well as less computational times.

Keywords. Genetic Algorithm; Multi-objective; Order crossover, Simulated Binary Crossover

1. Introduction

Today fierce competitive environment, many industries the product cost is related to the cost of raw material and parts because, for example, the industries of automotive/textile machinery have more than 70% revenues due to purchasing components and parts from external sources that's why the literature of supplier selection is focused from the previous three decades. In Supplier selection, the appropriate supplier is selected to supply the sources and allocate optimal order for each vendor. Additionally, the multi-objective nature of vendor selection, select more suppliers based on different criteria is an issue, because due to various contradictory multi-objective factors [22][23][24].

Supplier selection can be categorized into four sections. (1) Acquiring the desired aspects through supplier selection (2) description of product criteria (3) appropriate supplier (4) select proper supplier based on supplier criteria[21]. The criteria of modern supplier selection are transportation cost, product quality, and timely delivery. Under these criteria, the vendors have a different level of performance. For example, a vendor that has less price may have less quality or poor delivery given by industries. Besides this, due to multi-objective supplier selection, the appearance of a pricing discount is also a difficult task for purchasing managers to make the best policy of purchasing. At present, there are different models for various product discount models that represent the different range of price breaks for each vendor. Quantity discounts depend on the sale of volume. The issue of purchasing is solved by using the MP(Mathematical Programming) techniques. It represents various order quantities for each vendor with different discounts provided by the supplier. In this research, a mathematical model is evaluated to various order quantities, a quantity discount, with constraints of each vendor for
the selection of appropriate suppliers. By solving such complex multi-object optimization problems is needed meta-heuristic technique (Genetic algorithm). In this paper, a Multi-object genetic algorithm is used to select proper suppliers based on various criteria. This research has the following sections; section 3 contains the Mathematical model to represents objectives function with constrains, section 5 methodology part, which have an explanation of the multi-object genetic algorithm, section 6 described experimental results, section 7 represents the conclusion and future work.

2. Literature review

Regarding the decision-making technique for order allocation problem with price discounts in supplier selection, there exists a wide literature. In the literature of [1], [2], [3], highlighted supplier selection problem with decision-making technique based on multi-objective optimization problems (MOPs). These articles provided systematic approaches for the purchasing department to estimate and achieve the suppliers with optimal order allocations base on multiple various criteria.

In the literature of Nourmohamadi Shalke, Paydar [4], have developed the idea of a multi-objective model to address supplier selection, order allocation in a multi-period, multi-item, and multi-supplier problem. In another study, Tavana, Yazdani, and Di Caprio [5] explained an integrated multi-criteria decision making(MCDM) approach for the selection of proper vendors with optimal order. A review of decision-making techniques in order allocation is as follows [6-17].

| Literature                  | DM techniques                                      | Order allocation |
|-----------------------------|----------------------------------------------------|------------------|
| Arunkumar, N. L.           | Genetic algorithm (GA)                             | ✔                |
| Karunamoorthy. [6]          |                                                    |                  |
| Hamdan, Sadeque. [7]        | analytic hierarchy process (AHP)                   | ✔                |
| Scott, James, et al. [8]    | analytic hierarchy process (AHP)                   | ✔                |
| Lee et al. [10].            | Multi-objective decision analysis                  | ✔                |
| Tsai & Hung. [11]           | Multi-objective programming                        | ✔                |
| Yeh and Chuang. [12]        | Multi-objective genetic algorithm                  | ✔                |
| Kannan et al. [13]          | FAHP, FTOPSIS, multi-objective programming         | ✔                |
| Nourmohamadi, Parvin. [14] | multi-choice goal programming                      | ✔                |
| Azadnia et al. [15]         | analytic hierarchy process (AHP)                   | ✔                |
| Zhang, Ju-liang. [16]       | branch-bound algorithm                             | ✔                |
| Hamdan, Sadeque. [17]       | analytic hierarchy process (AHP)                   | ✔                |
| Jadidi, O. M. I. D. [18]    | normalized goal programming                        | ✔                |
| Govindan, Kannan. [19]      | Fuzzy TOPSIS                                       | ✔                |

Recently, quantity discount schemes have received substantial attention from researchers. When a purchaser places a large order, quantity discounts are considered, and the unit purchase price is decreased by the supplier under a predetermined scheme. Hence, studies have been done that consider the problems of supplier selection, order allocation, and lot sizing, each affecting supply chain activities (Azadnia et al.[13], Mohave, Emadikhiav, & Parsa, [18], Rezaei, Davoodi, Tavasszy, & Davarynejad,[19]).

From quantity discount strategies,[6] under different business volume discounts schedules a mathematical model to represents the mathematical formulation of a single item. Most realistic optimization problems, like supplier selection, have more than one objective need for simultaneous optimization. Frequently, the conflict in the objectives. For example, the lowest per-unit price of the vendor would not have the optimal delivery. Hence the company must analyze in the making decisions the tradeoffs among the relevant criteria. The multi-objective approach allows different criteria in the evaluated process with their natural units instead of using a common unit for measurement [20]. In order allocation problems to select proper vendors needs decision-making techniques. This paper presents a multi_objective programming model for select vendors.
3. MOP: formulation Objectives, Various constraints
The problems of supplier selection have appropriate constraints, multiobjective with various settings. This paper proposes a multiobjective programming model to demonstrate the supplier data of textile machinery, which consists of various components, such as a heater, feed. Each component represents by there mathematical notation are as follows [6],

N Entire number of vendors.

n Entire number of components.

γij Percentage of defective of the ith component from vendor j.

βij Percentage of late delivery for the ith component from vendor j.

λij Cost of ith component per uni from vendor j.

Xij Number of i purchased components from vendor j.

Cij Capacity of j vendor for the ith component.

Wij Vendor j minimum order supply to ith component.

Bij Minimum business for the vendor j for the ith component.

Mij Vendor j maximum trade for the ith component.

η'ij ith component of cost per unit from vendor j with no discount.

η''ij ith component of cost per from vendor j with no discount.

Mij ith component of middle-order quantity of vendor j.

Φi Upper boundary desired from the purchase manager for the number of defective items for the ith component.

Ωi An Upper boundary desired from the purchase manager for the number of late delivery for the ith component.

ξij selection of vendor j for supplying the ith component shows by A binary variable.

3.1 Objectives function
In this problem of appropriate selection of vendors the objective function is to minimize multi factors, total cost, late deliveries, and defective items, represented by mathematical notation Y1, Y2, Y3 as follows [31],

Objective 1: Minimize no of defective items (Quality )

\[
\min Y1 = \sum_{j=1}^{n} \gamma_{ij}X_{ij} \quad j = 1, 2 \ldots . n
\] (1)

Objective 2: Minimize time delivery

\[
\min Y2 = \sum_{j=1}^{n} \beta_{ij}X_{ij} \quad j = 1, 2 \ldots . n
\] (2)

Objective 3: Minimize product cost
\[
\min Y_3 = \sum_{j=1}^{n} \lambda_{ij}X_{ij} \quad j = 1, 2 \ldots n \quad (3)
\]

3.2 Vendor constraints
At the point of view of the capacity of vendors, it has some business constraints, by which the capacity of vendors would not be exceeded during order allocation. As a business policy, the number of components should meet the requirements of manufacturers, as min order and max order.

Constraint 1: (Vendors Capacity)

\[
X_{ij} \leq (C_{ij} \times \xi_{ij}) \quad \forall i=1,2,\ldots,n \quad j=1,2,\ldots,N. \quad (4)
\]

Constraint 2: (Min Quantity):

\[
X_{ij} \geq (Q_{ij} \times \xi_{ij}) \quad \forall i=1,2,\ldots,nj=1,2,\ldots,N. \quad (5)
\]

4. Methodology
A multi-criteria supplier selection problem with considers to objectives is solved by using a step-by-step procedure one by one. By using real coded multi_object genetic algorithms to get an optimal order quantity for each supplier. The solution of MOGA is compared with other techniques. It examined that GA provides an optimal solution. This will be helpful for the purchase department manager to find the alternate set of suppliers. The problems of combinatorial optimization are involved with the optimal allocation of restricted resources to satisfy the desired objectives. The possible alternatives constraints on basic resources restrict all the various possible solutions that considered being feasible. These supplier selection problems the combinations of the vendor are input to the Multi-object GA optimize the optimal order allocation based on constraints, objectives, and business values.

![Figure 1. Evolution of multi-object genetic algorithm.](image)

4.1 The evolution process of the Multi_object Genetic algorithm
The evolution process of the multi_object genetic algorithm is just like the guidance system. In Figure 2.shows, the evaluation process of MOGA.In the given below the figure, use the ratio of several needless chromosomes in each generation to the population size. The values of D>0.7, the number of needles chromosomes will be high. So the population will show a very less the desired solution, then
for a satisfactory solution mutation operator is used, and this way, GA randomly searches the space to get the optimal solution, if the values of D<0.4, then the number of needless chromosomes is very low, the chance is more to select a satisfactory solution. If the value of D is very small, say <= 0.3, its shows that ratio of the optimal is high in the population, and combination of order crossover with simulated binary crossover (OX, SBX) operator apply to produce different solutions. The value of D found out mined in( trial /error approach, for the suitability of the problem.

4.2 Combination of order & simulated Binary crossovers (OX, SBX)
Crossover operators in one of the most important processes of genetic algorithms. The process of crossover is convergence operation by which the population of the given problem leads towards local minima or maxima. This paper presents the combination of two crosses over operators (simulated binary cross over & order crossover. In figure 2. represents the combination of (OX, SBX).

4.5 Mutation operator
A random way is thereby eliminating the local minima, which the problem being stuck. A general way to represents the mutation operator would change one or more bit or genes values. Mutation operators perform a vital role in genetic algorithm, by changes or eliminating the genes in the population to provide divergence or premature convergence. The mutation is the opposite process of crossover. For this problem, the rate mutation is 0.07; if the total order exceeds the demand, then the mutation takes place.

4.6 Fitness function
This section represents the fitness value of each chromosome by using the mathematical model. The fitness function shows how much the solution is fit or the approaches to compare the given solution with the optimal solution in the given problem. In this problem, the first fitness function of multi_objectives converts into a single objective of the combination of the objective function, e.g., \( F=F_1+F_2 \). We can obtain objective function values quality, time, and cost and also with their weights. Therefore, the objective function is the total weighted sum of these three objectives.

![Figure 2. Combination of (SBX,OX) operators.](image-url)
5. Case study: Experimental results

In this section, the models evaluate the data of the textile industry of India, having seven vendors and demands of 2000 components, as given in Table 2.

5.1 Manufacturer details

The demand for Textile machinery-manufacturing is a maximum of 2000 components. The minimum and maximum range with considering to business values of order quantities are between 100 and 1200, respectively [23].

Table 2. Vendor’s details

| Vendors | Min Order | Max order | Defective % | Cost1 Rs. B/discount | Late | Delivery% Cost2 after discount |
|---------|-----------|-----------|-------------|----------------------|------|------------------------------|
| V1      | 100       | 600       | 2.5         | 2.5                  | 3.25 | 9                            |
| V2      | 200       | 750       | 4.5         | 4.5                  | 5.25 | 10                           |
| V3      | 250       | 800       | 5           | 5                    | 6.25 | 11                           |
| V4      | 350       | 750       | 3.5         | 3.5                  | 15   | 9                            |
| V5      | 100       | 700       | 1.5         | 1.5                  | 0.2  | 10                           |
| V6      | 300       | 950       | 6           | 6                    | 2.5  | 11.5                         |

5.2 Selection of vendors with quantity discounts

In this problem in Figure 3, explain various combinations set of vendors besides their multi-objectives, defectives/Late delivery & cost with include of various rang of price discounts. The set (1,2,3,5,6) represents vendors group, V1, V2, V3, V5 and V6. The combination set of V4 and V7 is not mentioned in the given graph because of there defective percentage is very high as compared to the product cost. In this graph, the combination set of vendors (1,2,3,5,6) represents the values of defective., time delivery with product cost which is minimum; the values of the given set are (69,47,22386), so from this graph, it is evident that the combined set of vendors (1,2,3,5,6) is best and has an optimal solution of multicriteria defectives/Late delivery & costs, price discount in supplier selection problem.

Figure 3. Combination set of vendors with their defectives/Late delivery & cost

Figure 4 showed the fitness values of the vendor in this problem. It is originated that when increases the no of generations, the feasible solutions goes towards an optimal. Figure 4 already that the optimal values to be found (151, 99.8154) with generation number is 151, against their fitness values 99.8154. This program was implemented and executed on Intel Pentium P6, 2.80 GHz of PC. from feasible solutions towards an optimal solution, the program took 30 seconds.
When GA compared to Exact, the solution of GA can be more effective and optimal for incremental quantity discounts. As given in figure 5.

As order allocation quantity of (V1,V2,V3,V5,V6) with respect to genetic algorithm the values is (454,324,539,448,304) and demand is 2000 so ,and the defective are (10,22,12,10,15) which total is 69.and vendors order are 2069.

Figure 4. Fitness values Against generations.

Figure 5. Comparison of genetic algorithm vs. Exact methods contains order allocation

Total Vendor Order=V1+V2+V3+V5+V6 ,Order – Defectives = 2069 – 69 = 2000 = Demand

6. Conclusion
This paper examined the use of MOGA selection of vendors with various quantity discounts, which is a combinatorial and multi-objective problem in nature. The previous methodology, do not define the defectives present in the supply selection while allocating order quantity to each vendor when satisfying the firm demand. One of the novel approaches planned in this model is that it define defectives during order alocation so that the accurate demand will always be fulfilled. In the supplier selection problem. The product demand given by industries would always be equal to the total order of the vendors. Besides this, the benefit of the given model is to find out the best solution. The benefit of applying MOGA as a design tool of their capability to get solutions, which is free of preconceptions that what is best or not. The results obtained by applying MOGA were found to make a competitive conclusion to that using conventional techniques. This approach will be very helpful for the purchase
manager to find an alternate set of suppliers. For the future, various extensions possibility of this research follows, (1) improve the computational time, (2) improve the quality of the solution, especially when implementing big data of suppliers given by enterprises.

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