AN OPTIMIZATION TECHNIQUE FOR SELECTION AND RATING OF SUPPLIERS WITH INCENTIVE & PENALTY SYSTEM USING GENETIC ALGORITHM

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ABSTRACT

The incentive & penalty system is for giving reward for exceptional work and penalty for low standard work of suppliers. The supplier selection process is very critical process, more complicated due to consideration of multi objective criteria in the decision making process. This research paper proposes a multi objective suppliers selection model based on genetic algorithm by considering incentive & penalty system. This proposed method evaluated and validated with a case study approach under Indian context to select and rate most appropriate suppliers from the group of suppliers.

Keywords: *Genetic algorithm, incentive, multi objective, penalty, supplier selection.*

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1. INTRODUCTION

In today's competitive business environment each company is focusing for steep reduction of final product costs and the cost of raw materials, component parts and services may account up to 70% - 80% of the final product costs in most of the industries (Weber *et al*, 1991; Ding *et al*., 2005; Shen and Yu, 2009). This has initiated a detailed understanding of the supplier side and selection of supplier viz cost of sourcing, quality and timely supplies etc. Hence area of supplier selection and their management has not only caught the attention of academicians in the area of operations management, supply chain management and logistics but recently, it has also attracted the attention of industrial people.

Supplier selection is a critical, cumbersome and lengthy process in which a company selects a supplier on the basis of various factors based on business' priorities and strategy. The overall objective of the supplier selection process is to reduce risk and maximize overall value to the manufacturer. Supplier selection often follows a rigorous, structured approach through the use of a survey of market. An effective supplier survey should have certain characteristics such as comprehensiveness, objectiveness, reliability, flexibility and finally, has to be mathematically straightforward. Researchers are using the genetic algorithm approach for this purpose.

Indian automobile sector is growing rapidly and its contribution in Indian economy is quite high. There are large numbers of unorganized suppliers and there are many challenges which demand that the industry needs to be explored. In automobile sector the cost of raw materials, component parts and services constitutes the main cost of a product. This clearly indicates the requirement of additional research for getting new strides and further advancement of this area. This paper is structured as follows: literature review on supplier selection process is presented in Section 2. Briefly overviews of genetic algorithm are presented in Section 3. Supplier selection model based on GA is discussed in Section 4. A case study is discussed in Section 5. Incentive & Penalty system is discussed in section 6. Finally Result and conclusion & future research issues are discussed in last Section.

2. LITERATURE REVIEW

Supplier selection an important element in supply chain management, has been gaining attention in both academic literature and industrial practice (Kouvelis *et al*., 2004). The role of a manufacturer, in the past decade has evolved from the manufacturer to one that coordinates or manages the supply chain entities (Choy and Lee, 2003). This greatly increases a firm's dependency on suppliers which, in turn, increases the need for effective

supplier or partner selection. Narasimhan *et al*. (2001) states "supplier evaluation is a complex process that involves the consideration of numerous factors". Talluri and Narasimhan (2004) emphasize that managing the supply base by identifying, selecting and managing suppliers for strategic, long term partnerships is a "key ingredient to the success of a supply chain". The main objective of supplier selection process is to reduce purchase risk, maximize overall value to the purchaser and develop closeness and long-term relationships between manufacturer and suppliers (Li *et al*., 1997). However, selecting the right supplier is always a difficult task for many purchasing managers (Liu and Hai, 2005). Different researcher use deferent methods to get the best supplier. Ding *et al*. (2005) presented a genetic algorithm (GA) based optimization methodology for supplier selection. The proposed method provided possible configurations of the selected suppliers, including transportation modes. Each configuration was then evaluated with respect to the key performance indicators. Jain *et al*. (2004) proposed a fuzzy based approach for supplier selection. According to them, it might be difficult for an expert to define a complete rule set for evaluating the supplier performance. GA was therefore integrated to generate a number of rules inside the rule set according to the nature and type of the priorities associated with the products and their supplier's attributes. Mohammad *et al*., (2007) presents a hybrid intelligent algorithm based on the push SCM, which uses a fuzzy neural network and a genetic algorithm to forecast the rate of demand, determine the material planning and select the optimal supplier. They test the proposed algorithm in a case study conducted in Iran. Lau *et al*. (2006) used an integrated approach of ANN and GA for supplier selection. ANN was responsible for benchmarking the potential suppliers with respect to four evaluating factors and GA was deployed to determine the best combination of suppliers. Liao and Rittscher (2007) developed multi-objective programming model for supplier selection under stochastic demand conditions. Four objective functions were incorporated into the model. After finding the optimality, GA was deployed to select the optimal supplier in an efficient manner.

3. MULTI OBJECTIVE GENETIC ALGORITHM

The earliest instances of what might today be called genetic algorithm appeared in the late 1950's and early 1960's, programmed on computers by evolutionary biologists who were explicitly seeking to model aspects of natural evolution. A more successful development in this area came in 1965, when Ingo Rechenberg, then of the technical university of Berlin introduced a technique called evolution strategy. In this technique there was no population or

crossover, one parent was mutated to produce one offspring and the better of the two was kept and became the parent for the next round of mutation.

Genetic algorithm is a powerful tool, it has multiple offspring they can explore the solution space in multiple direction at once. It is particularly well suited to solving problems where the space of all potential solutions is truly huge. It can perform well in problems for which the fitness landscape is complex. It has ability to manipulate many parameters simultaneously. Genetic algorithm is weak in certain areas like, the problem of how to write the fitness function must be carefully considered so that higher fitness is attainable and actually does equate to a better solution for the given problem. The other parameters of genetic algorithm – size of the population, the rate of mutation and crossover, the type and strength of selection must be also chosen with care.

Genetic algorithm technique can be used for solving supplier selection problem. Genetic algorithm is different from other techniques in following ways [1]:

1. GA deals with chromosomes that encode decisions related to the selection or not such supplier and the corresponding percentage of assigned demand, when more Than one supplier is selected.
2. GA searches from one population of solutions to another rather than from individual to individual.
3. GA use only objective function information to guide themselves through the solution Space and not derivative. When compared to other technique where it need variety of information to guide them. GA needs only the measure of fitness (objective function Values) about a configuration in the space of the solutions.
4. GA uses probabilistic transition rules rather than deterministic rules.

4. MULTI OBJECTIVE SUPPLIER SELECTION MODEL BASED ON GENETIC ALGORITHM:

For selection of suppliers, we have considered the multi objective criteria, by taking the case of an automobile parts manufacturing company in India. This company manufactures the sheet metal products, so it requires a large no. of materials and supplies them to leading manufacturers of automobile in India. This model is formulated considering the objective functions and constraints that could be used by the company to select suppliers. Each supplier has its own capacity, minimum quantity, maximum quantity, percentage late delivery, percentage defective, cost per unit, financial condition in market. The manufacturer has to consider all the criteria and its demand for selecting the appropriate suppliers.

Let us consider supplier j supplying component i to this manufacturer. The notation used in the model is as follows

N = Total no. of suppliers.

n = Total no. of components.

αij = Defective percentage of ith component produced by supplier j

βij = Late delivery percentage of ith component produced by supplier j

γij = Cost per unit for ith component produced by supplier j

λij = Quantity percentage of ith component produced by supplier j

ηij = Financial Position for producing ith component by supplier j

Xij = Number of component of type i purchased from supplier j

Φi = upper limit desired by purchase manager for no. of defective items for ith component.

ωi = upper limit desired by purchase manager for no. of late delivery for ith component.

μi = upper limit desired by purchase manager for cost per unit for ith component.

mi =Lower limit desired by purchase manager for quantity of ith component.

fi = Lower limit desired by manager for financial position for ith component.

4.1 Objective Function:

In this supplier selection process, the objectives are to minimizing or maximizing , the total no. of defective items, total no. of late deliveries , the total financial position of supplier purchasing multiple component from multiple suppliers.

Let us consider

Z1 = Quality Objective; Z2 = Delivery Objective; Z3 = Cost Objective

Z4 = Quantity Objective; Z5 = Financial Objective;

[Z1] Quality Objective

Minimize Zi1 = $\sum_{j=1}^{N} \alpha ij * Xij \quad ,i = 1,2,3 \dots \dots n$

[Z2] Delivery Objective

Minimize Zi2 = $\sum_{j=1}^{N} \beta ij * Xij \quad ,i = 1,2,3 \dots \dots n$

[Z3] Cost Objective

Minimize Zi3 = $\sum_{j=1}^{N} \gamma ij * Xij \quad ,i = 1,2,3 \dots .. n$

[Z4] Quantity Objective

Maximize Zi4 = $\sum_{j=1}^{N} \lambda ij * Xij \quad ,i = 1,2,3 \dots \dots n$

[Z5] Financial Objective

Maximize Z5 = $\sum_{j=1}^{N} \eta ij * Xij \quad ,i = 1,2,3 \dots \dots n$

Constraints

Minimize Zi1

Subjected to: $\sum_{j=1}^{N} (\alpha ij * Xij) \leq \emptyset i \quad ,i = 1,2,3 \dots \dots n$

Minimize Zi2

Subjected to: $\sum_{j=1}^{N} (\beta ij * Xij) \leq \omega i \quad ,i = 1,2,3 \dots \dots n$

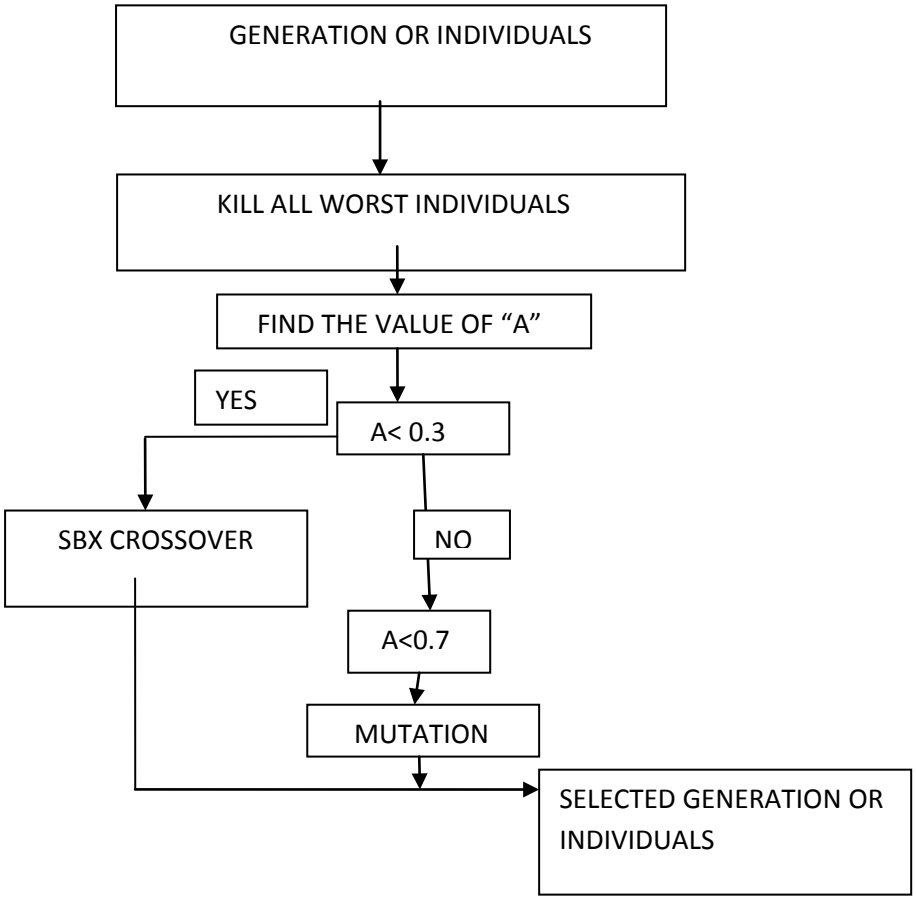
Minimize Zi3
Subjected to: $\sum_{j=1}^{N}(\gamma ij * Xij) \leq \mu i \quad ,i = 1,2,3 \ldots \ldots n$

Maximize Zi4
Subjected to: $\sum_{j=1}^{N}(\lambda ij * Xij) \geq mi \quad ,i = 1,2,3 \ldots \ldots n$

Maximize Zi5
Subjected to: $\sum_{j=1}^{N}(\eta ij * Xij) \geq fi \quad ,i = 1,2,3 \ldots \ldots n$

4.2 G.A. Process:

The selection mechanism works like the guidance system. In this figure "A" Is the ratio of number of worst individuals to the total no. of individuals. The value of "A" Determines how G.A. proceed.



5. MODEL VALIDATION THROUGH CASE STUDY:

For the study of multi objective supplier selection model, we went to an automobile parts manufacturing company "X" , established in 1995 in India. The company is engaged in manufacturing of sheet metal automobile parts at a very large scale, we met with the personals of B.O.P. section i.e. brought out part section which deals with the suppliers and their supplies. We got the data of ten suppliers from the B.O.P. section, they provided us data according to their company rules and regulations.

The data for ten suppliers collected from an automobile parts manufacturing firm as shown in this table1.

Suppliers	Min. Qty.	Max. Qty.	% Defective	%Late Dlvry	Cost/Unit	Order Qty.	Fin.Cond. (Lakhs)
S1	2000	18000	0.65	2.5	58	18000	300
S2	5000	15000	0.98	3.1	62	15000	330
S3	14000	28000	1.56	3.7	75	28000	280
S4	10000	20000	0.85	2.6	55	20000	290
S5	15000	32000	1.35	2.9	73	32000	350
S6	24000	48000	1.79	3.5	80	48000	400
S7	7000	17500	0.78	1.9	60	17500	325
S8	25000	53000	0.82	2.2	67	53000	450
S9	11000	24500	1.12	2.8	72	24500	250
S10	16000	35500	1.09	3.3	78	35500	380

Table 1. Suppliers Data

SOLUTION METHODOLOGY

CASE I : Considered order quantity > 20000.,

No. of worst individuals =3,

"A"=3/10= 0.3,

Therefore, **SBX crossover (stimulated binary crossover):**

When the ratio of the no. of worst individuals to the total no. of individuals is less than or equal to 0.3, then SBX crossover is used. The SBX crossover operator is μ, which is a random value selected between 0 and 1, during each cycle.

Order quantity of supplier 2 for child 2 is calculated as follows:

Table2. SBX Crossover

S2	S4	S5	S7	S9	TOTAL	PARENT 1
4200	4800	2000	4000	5000	20000	
S2	S4	S5	S7	S9	TOTAL	PARENT 2
4000	4500	3500	4800	5800	22600	

The random variable μ = 0.85

S2 ch2=S2P1Xμ + S2P2X(1-μ)

= 4000X0.85+ 4200X(1-0.85)

= 4030

Similarly,

S2ch1= S2P2Xμ + S2P1X (1-μ)

= 4200X0.85 + 4000X (1-0.85)

= 4170

Therefore, we get values,

S2	S4	S5	S7	S9	TOTAL	CHILD 1
4170	4755	2225	4120	5120	20390	
S2	S4	S5	S7	S9	TOTAL	CHILD 2
4030	4545	3275	4680	5680	22210	

Table3. SBX Crossover

CASE II: Considered order quantity < 20000

No. of worst individuals= 6,

"A"= 6/10= 0.6,

Therefore, **Mutation :**

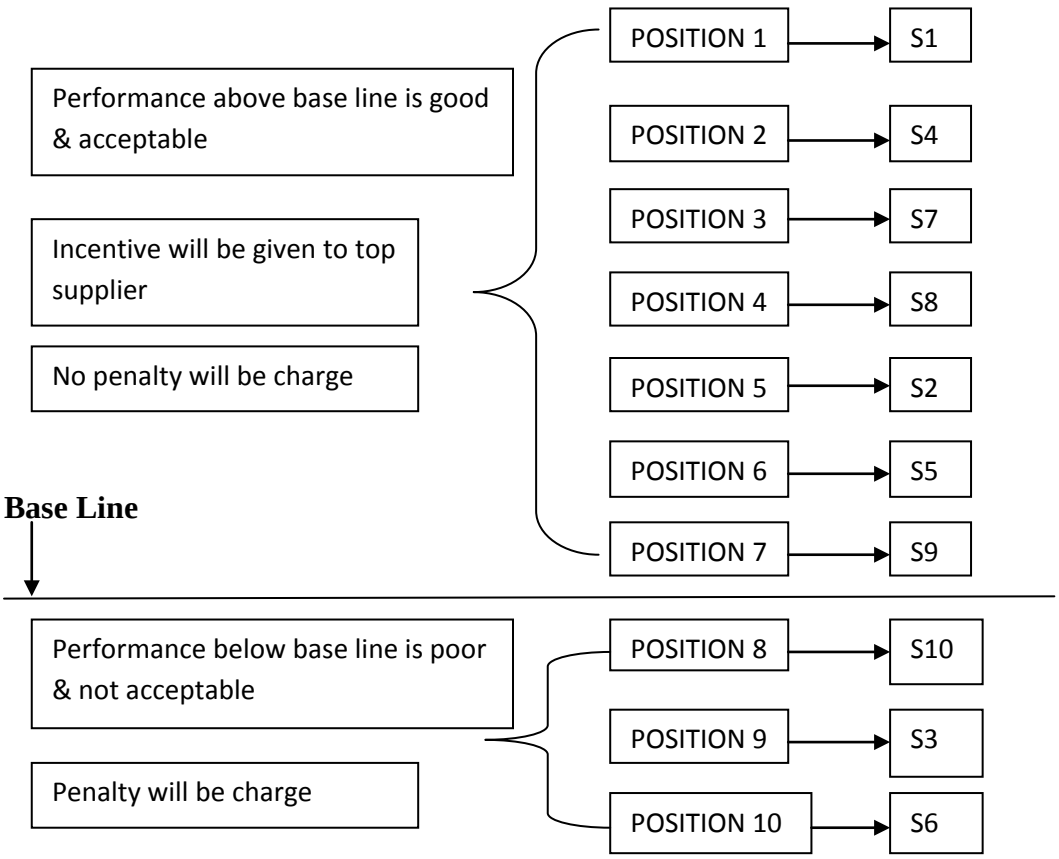
When the ratio of the no. of worst individual to the total no. of individuals

Is less than 0.7 i.e. "A"< 0.7, then mutation operator is chosen.

Table 4. Mutation

S2	S4	S5	S7	S9	TOTAL	PARENT 1
4200	4800	2000	4000	5000	20000	
		↓				
S2	S4	S5	S7	S9	TOTAL	PARENT 2
4200	4800	3500	4000	5000	21500	

6. INCENTIVE & PENALTY SYSTEM:



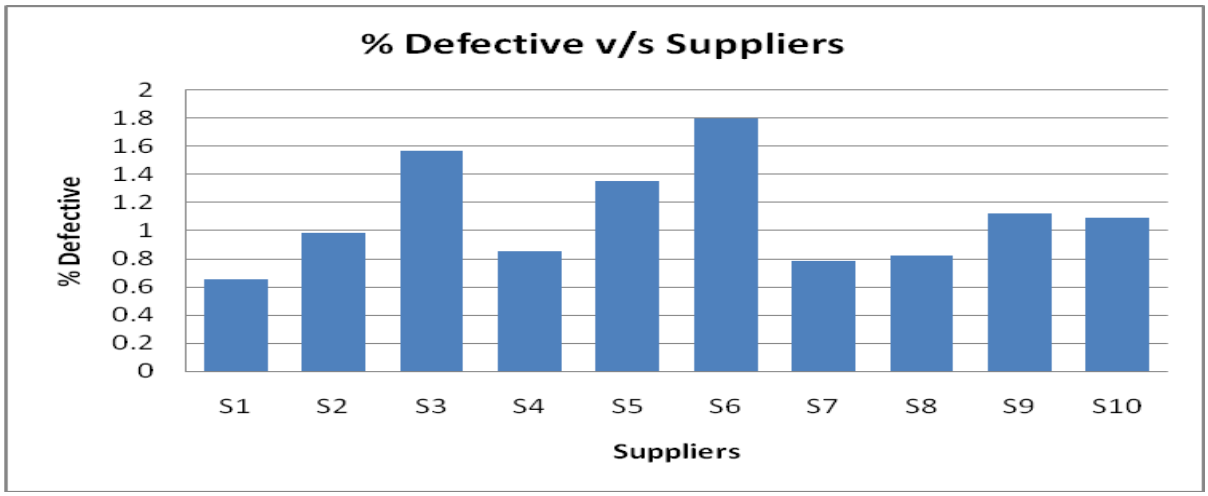
In Supplier selection procedure in Industries, the introduction of incentive & penalty system is a good and workable approach and provides good result and also serve as an important tool in the hands of manager. This system works in following ways:

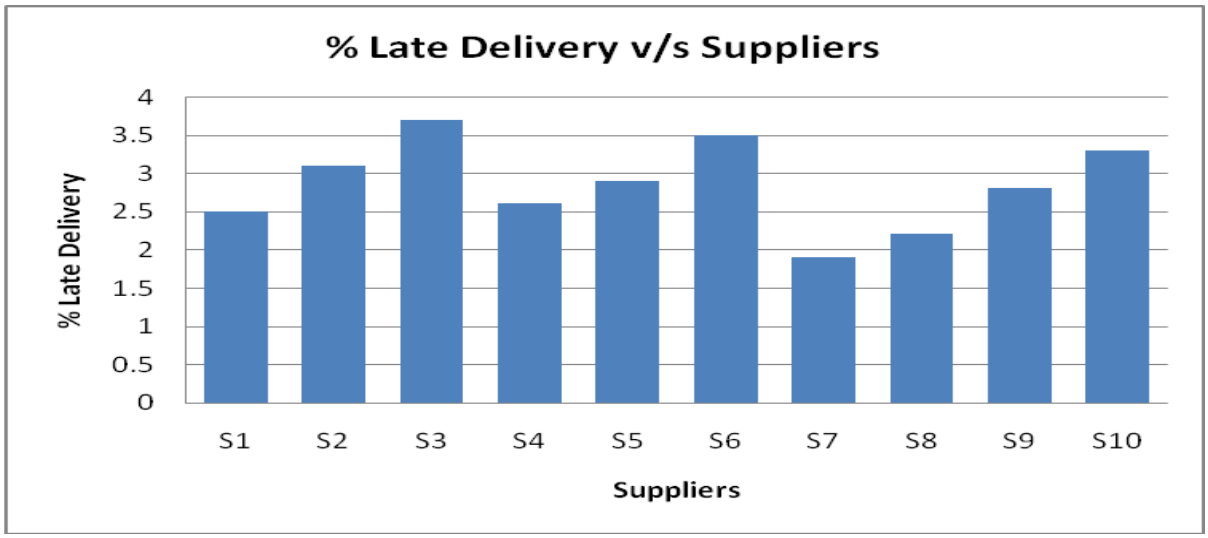
(a.) If one supplier is providing the materials on time, with good quality and is serving best as compared to other suppliers then the organization can give him reward in the form of incentive of 1 or 2% at the end of financial year and also increase its order.

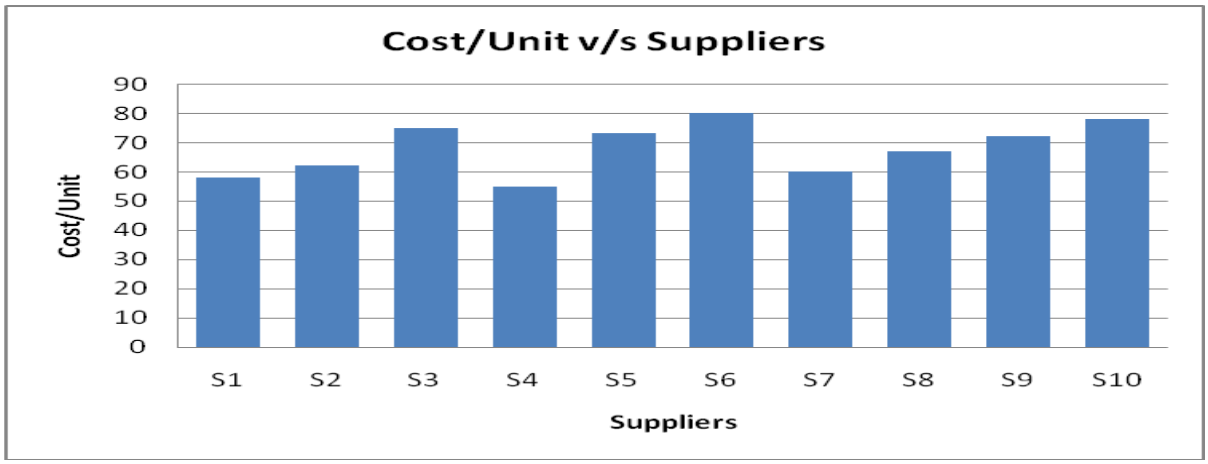
(b.) If from the group of suppliers, the supplier which is at the least position in supplies and performance compared to others , then the organization can charge penalty on the supplier of 1 or 2% and the same penalty can be given to the top supplier as its incentive with no extra burden on the organization.

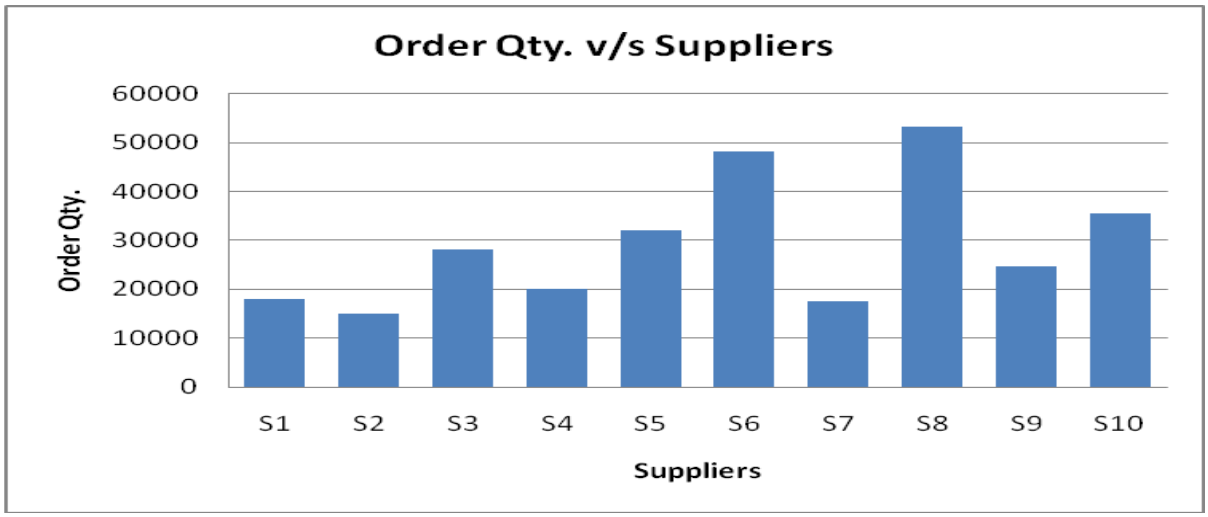
(c.) By adopting this system competition between suppliers will increase and their performance will be better.

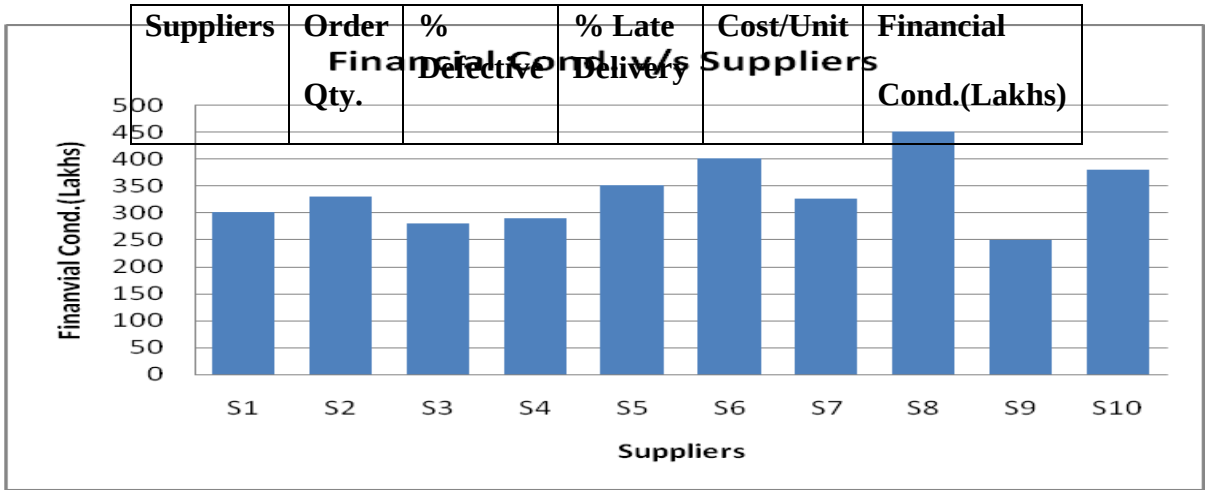
(d.) Chances of rejection of materials and customer complaints will reduce.


% Defective v/s Suppliers
% Defective
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
Suppliers


% Late Delivery v/s Suppliers
% Late Delivery
4
3.5
3
2.5
2
1.5
1
0.5
0
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
Suppliers


Cost/Unit v/s Suppliers
Cost/Unit
90
80
70
60
50
40
30
20
10
0
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
Suppliers





Suppliers	Order Qty.	% Defective	% Late Delivery	Cost/Unit	Financial Cond.(Lakhs)

RESULT & DISCUSSION:

This paper comprises and used the G.A. technique in selecting suppliers by considering multi objective factors like defective factor, late delivery factor, cost factor,order quantity factor , financial status. The result of this paper is obtained by studying quantitative factors and incentive & penalty system by using genetic algorithm. This approach provides the best suppliers on which the organization can rely and hence very helpful to the manager for selecting suppliers From this study suppliers from each category are selected and by analyzing this study, it gives four suppliers which are most reliable and best from the group. It is evident from the study and result that four suppliers i.e. S1, S4, S7, S8 are the best suppliers.

S1	18000	0.65	2.5	58	300
S4	20000	0.85	2.6	55	290
S7	17500	0.78	1.9	60	325
S8	53000	0.82	2.2	67	450

Table 5. Selected Suppliers

CONCLUSION & FUTURE SCOPE:

This research provide solution to the selection and rating of suppliers by using genetic algorithm by considering multi objective criteria with incentive & penalty system, this is one of the unique approach proposed in this model, in the existing scenario, the firms basically not consider the large no. of objectives, they select the suppliers by considering two or three most common criteria but they are not enough for appropriate selection. With the result of this study, we went to the manufacturing firm again the manager showed interest in the study and was satisfied with the approach and result, and said this study will help them to select supplier by considering multi objective criteria and to improve the customer satisfaction and reduce the no. of complaints from customer.

There are various possible extension to this study, like costing of each activity can be done so that unnecessary activities can be remove, time and cost can be saved which improve the profit of organization. Number of factors can be increase for more accurate selection of suppliers.

REFERENCES:

(1) N. Arunkumar, L.Karunamurthy & N. Uma Makeshwara, 2007, An Optimization technique for vendor selection with quantity discount using G.A. International Journal of industrial engineering. Vol 3, No.4, pp 1-13.

(2)N. Arunkumar, L.Karunamoorthy & S.Anand and T. Ramesh Babu, 2006, Linear Approach for solving a piecewise linear vendor selection problem of quantity Discounts using lexicographic method. International Journal of Advanced Manufacturing Technology.

(3)K.Bhutta, 2003, Supplier selection problem: A classification of methodology Literature . Proceedings, Southwest Decision Sciences Institue, Houston TX.

(4)K. Bhutta and F.Huq, 2002, Supplier selection problem: A comparision of the Total cost of ownership and analytic hierarchy process. Supply chain management: An International Journal.

(5)K.Cengiz, C. Ufuk and U.Ziya, 2003, Multi criteria supply selection using fuzzy, AHP. Logistics Information Management.

(6)S.S. Chaudhry, F.G.Forst and L.J. Zydiak, 1993, Vendor selection with price breaks. European Journal of Operational Research.

(7)C.M.Fonseca and P.J.Fleming, 1993, Genetic Algorithms for Multi-objective Otimization: Formulation , Discussion and Generalization.

(8)T.Gary and J.Hector, 2005, A model for evaluation and selection of suppliers in global Textile and apparel supply chains. International Journal of physical distribution & Logistics management.

(9)M.E. Gonzalez, G. Quesada and Monge Mora, C.A, 2004, Determining the importance Of the supplier selection process in manufacturing: A case study. International Journal of Physical Distribution and logistics management.

(10)Kalyanmoy Deb,2002, Optimization for Engineering Design: Algorithm and examples. Prentice- Hall of India pvt ltd. New Delhi. ISBN-81-203-0943-X.

(11)B.Karpak, E.Kumcu and R.Kasuganti, 1999, An application of visual interactive goal programming: A case in vendor selection decisions. Journal of Multi-Criteria Decision Analysis.

(12)Shahadat Khan, 2003, Supplier choice criteria of executing agencies in developing countries. The International Journal of public sector management.

(13)W.E.Patton, 1996, Use of human judgement models in industrial buyers Vendor selection decisions, Industrial marketing management.

(14) Weber C. A., Current J. R. and Benton W. C., 1991 "Vendor Selection Criteria and Methods", *European Journal of Operational Research*. Vol. 50, No. 1, pp. 2-18.

(15.) Ding H., Benyoucef L. and Xie X.,2005 "A Simulation Optimization Methodology for Supplier Selection Problem", *International Journal Computer Integrated Manufacturing*. Vol.18, No. 2/3, pp. 210-224.

(16)Shen Chun-Ying and Yu Kun-Tzu,2009 "Enhancing the Efficacy of Supplier Selection Decision-Making on the Initial Stage of New Product Development: A Hybrid Fuzzy Approach Considering the Strategic and Operational Factors Simultaneously", *Expert Systems with Applications*. Vol. 36 No. 8, pp. 11271-11281.

(17)Kouvelis Panos, Rosenblatt Meir J. and Munson C. L.,2004 "A Mathematical Programming Model for Global Plant Location Problems: Analysis and Insights" *IIE Transactions.* Vol. 36, No. 2, pp. 127–144.

(18)Choy K. L. and Lee W. B., 2003"A Generic Supplier Management Tool for Outsourcing Manufacturing", *Supply Chain Management: An International Journal.* Vol. 8, No. 2, pp. 140-154.

(19)Narasimhan R., Jayaram J. and Carter J. R., 2001"An Empirical Examination of the Underlying Dimensions of Purchasing Competence", *Production and Operations Management.* Vol. 10, No.1, pp. 1-15.

(20)Talluri S. and Narasimhan R.,2004 "A Methodology for Strategic Sourcing", *European Journal of Operational Research.* Vol. 154, No.1, pp. 236-250.

(21)Liu F. H. F. and Hai H. L.,2005 "The Voting Analytic Hierarchy Process Method for Selecting Supplier", *International Journal of Production Economics.* Vol. 97, No. 3, pp. 308–317.

(22)Sarfaraz Ahmad, 2011"An Integrated Multi-Objective Decision Making Process for Supplier Selection with Volume Discounts", Proceedings of the International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia., January 22 – 24, pp. 978-983.

(23)Zohrehbandian Majid and Saen Reza Farzipoor, 2010"A Mathematical Model for Supplier Selection in Quantity Discount Environments", *International Journal of Mathematics in Operational Research*. Vol. 2, No. 4, pp. 456-466.

(24)Ho William, Xu Xiaowei and Dey Prasanta K.,2010 "Multi-Criteria Decision Making Approaches For Supplier Evaluation And Selection: A Literature Review", *European Journal of Operational Research*. Vol. 202, No. 1, pp. 16-24.

(25)Lau H. C. W., Lee C. K .M., Ho G. T. S., Pun K. F. and Choy K. L.,2006 "A Performance Benchmarking System to Support Supplier Selection" , *International Journal of Business Performance Management*. Vol. 8, No. 2/3, pp. 132–151.

(26)Liao Z. and Rittscher J.,2007 "A Multi-Objective Supplier Selection Model under Stochastic Demand Conditions", *International Journal of Production Economics*. Vol. 105, No.1, pp. 150-159.

(27)Weber C. A. and Current J. R.,1993 "A Multiobjective Approach To Vendor Selection", *European Journal of Operational Research*. Vol. 68, pp. 173-184.

(28)Ding H., Benyoucef L. and Xie X.,2004 "A Multi-Objective Optimization Method for Strategic Sourcing and Inventory Replenishment", *IEEE International Conference on Robotics and Automation*. Vol. 3, pp. 2711-2716.