Innovative Heuristics Modeling for Dynamic Supply Base Optimization

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Abstract

Efficient and effective management of supply-base throughout the supply chain significantly improves the ultimate service provided to the customer. Dynamic changes in demand patterns play a vital role in the optimization of supply-base throughout the supply chain in order to minimize the total supply chain cost. Efficient supply-base management is a complex process as it has to capture the dynamic nature of the requirements of Raw materials based on demand level occurring from multiple sources. In addition, the complexity of the problem increases when more number of, suppliers, products, distribution centers, agents and customers are involved in the process. In this paper, an innovative heuristic methodology is proposed to generate essential predictive analytics to optimize supply-base based on supplier quality, on time delivery and fill rate indices in alignment with the dynamic demand patterns emerging from multiple sources.

Keywords: *Supply Chain Management, Supply-base Optimization, Particle Swarm Algorithm*

1. Introduction

Global competition, Dynamic changes of demand patterns, global competition, shorter product life cycles, and product varieties and environmental standards cause remarkable changes in the market environment forcing the manufacturing enterprises to deliver their best in order to strive [Sarmiento Rabelo, Lakkoju, Moraga, 2007]. Decrease in lead times and expenses, enrichment of customer service levels and advanced product quality are the characteristics that determine the competitiveness of a company in the contemporary market place [Mileff, Peter, Nehez, Karoly, 2006]. The above mentioned factors have made the business enterprises to contemplate more along their supply chains for gaining competitive advantage. The effective management of the supply chain has become unavoidable these days due to the firm increase in customer service levels [Beamon, 1998]. The supply chain cost was immensely influenced by the overload or shortage of inventories. Thus supply optimization has transpired into one of the most recent topics as far as supply chain management is considered [Joines & Thoney, K, Kay, 2008]

Purchasing managers usually keep a sharp eye on purchasing cost savings and especially their compliance rate. The primary objective of supplier management is the continuous development and performance improvement of suppliers. [Adams, 2004] Unless companies are able to improve their supply base up to world-class levels, they will be at the mercy of competitors who can take market share with in short period of time. The process of identifying the proper mix and number of suppliers to maintain is known as the supply base optimization. Effective supplier management and development begins with a determination of the correct number of suppliers an organization should maintain. It involves eliminating suppliers who are not meeting the world-class requirements either currently or in the near future. Eliminating the un-qualified vendors from the list is the first step in optimizing the supply base. Subsequent optimization requires the replacement of qualified suppliers with the better performing suppliers. Supply-base optimization should result in improvements in costs, quality, delivery and information sharing between buyer and seller. Suppliers are required to deliver with zero defects, so that incoming inspection can be omitted. The right products must be delivered at the right quantities at exactly the right moment. Quality, On-time and Fill rate are the main criteria on which suppliers are assessed. Various purchasing strategies are used to optimize the purchasing activities and supplier evaluation is of greater importance in identifying the good supplier source. The overall objective of the supplier evaluation process is to reduce purchase risk and maximize overall value to the purchase. The supply-base management techniques are advantageous when applied to a relatively larger pool of possible suppliers. [Arjan Van Weele, 2014]. In this paper, an innovative heuristic methodology is proposed to generate essential predictive analytics to optimize supply-base in alignment with the dynamic demand patterns emerging from multiple sources. Particle Swarm Optimization (PSO) is a population-based stochastic global optimization algorithm and the robust performance of the proposed method over a variety of difficult optimization problems has been proved (Alberto Moraglio, Cecilia Di Chio,Julian Togelius and Riccardo Poli, 2008). In accordance with PSO, either the best local or the best global individual affects the behavior of each individual in order to help it fly through a hyperspace (Lu, 2003). The ability of the particles to remember the best position that they have seen is an advantage of PSO. An evaluation function that is to be optimized evaluates the fitness values of all the particles (Ling-Feng Hsieh, Chao-Jung Huang and Chien-Lin Huang, 2007).

2. Model

An organization usually manufacture one or more products for which they are required to source many raw materials from multiple suppliers. For the purpose of supply-base optimization , the Suppler Quality Index(SQI), On time delivery Index(TDI) and Fill rate index(FRI) indices need to be calculated:

Suppose, a supplier makes 20 shipments in a certain time period. In this time period, 3 shipments are returned, 5 shipments are found to be conditionally acceptable and the rest of the shipments are in line with specifications. Then, the Suppler Quality Index(SQI) is calculated as follows:

Suppler Quality Index(SQI) is based on the frequency and gravity of defects related to a specific supplier's deliveries as given below:

Decision with regard to delivery	Weight factor
Return :	15
Conditional Rejection :	10
Conditional Acceptance :	8
Functionally acceptable :	5
In line with specification :	0

Then SQI is calculated as follows:

SQI= 100-[(15x3) + (8x5)]/20= 95.75

(subject to a maximum of 100)

TDI is calculated as follows:

TDI=(Actual score delivery time/Maximum score delivery time)X100

(subject to a maximum of 100)

FRI is calculated as follows:

FRI= (Actual number of units delivered/ Actual number of units ordered)X100

(subject to a maximum of 100)

Supplier selection is based upon criteria that are vital to a particular process and indicative of future success. The criteria are weighted and some attribute may be more important for one process than another. Based on the importance of the 3 factors, appropriate weightage may be assigned and weighted average involving the normalized weights are used to arrive at the Suppler Selection Index(SSIij) for each supplier i for each period j.

A database consisting of these data values is created for each period and for each supplier during the course of manufacturing planning period.. Particle Swarm optimization methodology is developed to generate predictive analytics to move towards dynamic supply-base management and optimization.

The PSO methodology is outlined below.

In PSO, the potential solutions, called particles follow the current optimum particles to fly through the problem space. Every particle represents a candidate solution to the optimization problem. The best position visited by the particle and the position of the best particle in the particle's neighborhood influence its position. Particles would retain part of their previous state using their memory. The particles still remember the best positions they ever had even as there are no restrictions for particles to know the positions of other particles in the multidimensional spaces. An initial random velocity and two randomly weighted influences: individuality (the tendency to return to the particle's best previous position), and sociality (the tendency to move towards the neighborhood's best previous position) form each particle's movement .PSO uses individual and group experiences to search the optimal solutions. Nevertheless, previous solutions may not provide the solution of the optimization problem. The optimal solution is deformed by adjusting certain parameters and putting random variables. The ability of the particles to remember the best position that they have seen is an advantage of PSO. An evaluation function that is to be optimized evaluates the fitness values of all the particles. For every individual particle, a comparison is made between its evaluation value and its. The indicates the best evaluation value among. This serves as an index that points to the best individual generated so far.

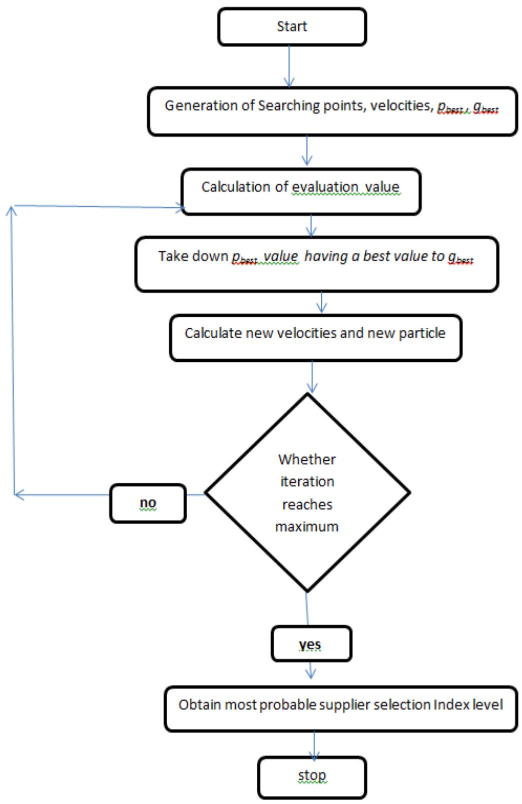

Figure 1:Particle Swarm Optimization Methodology

As an initialization step the individuals of the population including searching points, velocities, and are initialized randomly but within the lower and upper bounds of the CPI values.

The individuals of the population including searching points, velocities, and are initialized randomly but within the lower and upper bounds of the CR values which have to be specified in advance.

Determination of Evaluation function

$$f(i) = -\log\left(1-\frac{n_{occ}(i)}{n_{tot}}\right); \qquad i = 1,2,3,\cdots,n$$

This formulated function is used to capture the most probable suppler selection index levels from the data base as well as the convergence criteria for stopping the algorithm.

$n_{occ}(i)$ is the number of occurrences of the particle in the record set

n_{tot} is the total number of records that have been collected from the past or total number of data present in the record set.

n is the total number of particles for which the fitness function is to be calculated.

For every individual, a comparison is made between its evaluation value and its p_{best} .The g_{best} indicates the most excellent evaluation value among the p_{best} . This g_{best} is an index that points to the best individual generated so far.

Subsequently the adjustment of the velocity of each particle a is as follows:

$$v_{new}(a,b) = w * v_{cnt}(a) + c_1 * r_1 * [p_{best}(a,b) - I_{cnt}(a,b)] \\ + c_2 * r_2 * [g_{best}(b) - I_{cnt}(a,b)]$$

where, $a = 1,2,\cdots\cdots,N_p$ (Number of particles)

$b = 1,2,\cdots\cdots,d$ (Dimension of the particle)

This is done to diversify the search space as well as to intensify the search towards better feasible solutions

Here, $v_{cnt}(a)$ represents current velocity of the particle, $v_{new}(a,b)$ represents new velocity of a particular parameter of a particle r_1, and r_2 are arbitrary numbers in the interval $[0,1]$, c_1 and c_2 are acceleration constants (often chosen as 2.0), w is the inertia weight that is given as

$$w = w_{\max} - \frac{w_{\max} - w_{\min}}{iter_{\max}} \times iter$$

where, $w_{\max}$ and $w_{\min}$ are the maximum and minimum inertia weight factors respectively that are chosen randomly in the interval $[0,1]$. Also and are the minimum and maximum limit for velocities respectively

$iter_{\max}$ is the maximum number of iterations

$iter$ is the current number of iteration

Such newly obtained particle should not exceed the stated limits. This would be checked and corrected before proceeding further as follows,

If $v_{new}(a,b) > v_{\max}(b)$, then $v_{new}(a,b) = v_{\max}(b)$

if $v_{new}(a,b) < v_{\min}(b)$, then $v_{new}(a,b) = v_{\min}(b)$

Then, as per the newly obtained velocity, the parameters of each particle is changed as follows

$$I_{new}(a,b) = I_{cnt}(a,b) + v_{new}(a,b)$$

Then the parameter of each particle is also verified whether it is beyond the lower bound and upper bound limits. If the parameter is lower than the corresponding lower bound limit then replace the new parameter by the lower bound value. If the parameter is higher than the corresponding upper bound value, then replace the new parameter by the upper bound value. For instance,

If $P_k < P_{L.B}$, then $P_k = P_{L.B.}$

Similarly, if $P_k > P_{U.B}$, then $P_k = P_{U.B.}$

This is to be done for the other parameters as well.

This process will be repeated again and again until the evaluation function value is stabilizing and the algorithm has converged towards optimal solution.

3. Results

The analysis based on PSO for optimizing supplier selection. has been implemented in the platform of MATLAB .As stated, the detailed information about the Suppler Selection Index(SSIij) values for each period i and for each supplier j is captured in the database. The sample data having this information is given in the Table 1.

TABLE 1: A SAMPLE DATA OF SUPPLIER SELECTION INDICES

PI	SSI1	SSI2	SSI3	SSI4	SSI5
1	75	86	93	83	68
2	78	87	96	82	72
3	79	88	97	78	68
4	74	86	90	83	71
5	75	86	97	78	68
6	75	86	97	83	73

As initialization step of the PSO process, the random individuals and their corresponding velocities are generated.

TABLE 2 : INITIAL RANDOM INDIVIDUALS

Random Supplier Selection Index1

SSI1	SSI2	SSI3	SSI4	SSI5
74	80	92	80	65

Random Supplier Selection Index2

Random Supplier Selection Index1

SSI1	SSI2	SSI3	SSI4	SSI5
78	87	96	82	72

Table 2 describes two random individuals. Similarly, Table 3 represents random velocities which correspond to each particle of the individual.

TABLE 3: INITIAL RANDOM VELOCITIES

Initial Random velocities1

SSI1	SSI2	SSI3	SSI4	SSI5
0.1350	0.1350	0.1350	0.1350	0.1350

Initial Random velocities2

SSI1	SSI2	SSI3	SSI4	SSI5
0.0259	0.0259	0.0259	0.0259	0.0259

The simulation run on a huge database of 500 past records showing evaluation function improvement at different levels of iteration is as follows:

Simulation result showing evaluation function improvement:

# of iterations	Evaluation function value
50	0.5884;
60	0. 6754
70	0.8947
80	1. 1522

The final individual obtained after satisfying the convergence criteria is given in Table 4.

TABLE 4: DATABASE FORMAT OF FINAL INDIVIDUAL

SSI1	SSI2	SSI3	SSI4	SSI5
75	86	97	83	68

4. Discussions

The final individual thus obtained represents the most emerging pattern for the most probable Suppler Selection Index levels for each supplier. The obtained supplier performance levels mean that supplier 1 is meeting up to 75% of the selection criteria, supplier 2 is meeting up to 86% of the selection criteria ans so on. The emerging pattern of Suppler Selection Index(SSI) score 93 for supplier 3 is maximum , followed by supplier 2,supplier 4, supplier 1 and, supplier 5.If the company has established the threshold limit of 80 for selecting the supplier, then supplier 3 supplier 2 and supplier 4 will be included in the supplier selection list. Supplier 1 and supplier 5 will not be included in the supplier selection list for the forthcoming period towards optimizing the supply base.

5. Conclusion

Supply management is an important component of supply chain management. Optimal Supply management leads to significant enhancement of customer service as well as optimal production cost. The dynamic nature of the demand level occurring from multiple sources plays a vital role in deciding the optimal supply level. In this paper an innovative and efficient approach based on Particle Swarm optimization algorithm is proposed and implemented to generate essential predictive analytics to optimize supply base levels in alignment with the dynamic demand patterns emerging from multiple sources for each product for the forthcoming period

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