

Extensive Analysis and Prediction of Optimal Inventory levels in supply chain management based on Particle Swarm Optimization Algorithm

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Abstract

Efficient inventory management is a complex process which entails the management of the inventory in the whole supply chain. The dynamic nature of the excess stock level and shortage level from one period to another is a serious issue. In addition, consideration of multiple products and more supply chain members leads to very complex inventory management process. Moreover, the supply chain cost increases because of the influence of lead times for supplying the stocks as well as the raw materials. A better optimization methodology would consider all these factors in the prediction of the optimal stock levels to be maintained in order to minimize the total supply chain cost. Here, we are proposing an optimization methodology that utilizes the Particle Swarm Optimization algorithm, one of the best optimization algorithms, to overcome the impasse in maintaining the optimal stock levels at each member of the supply chain.

Keywords

Supply chain management, supply chain cost, Inventory, lead time, optimization, Particle swarm optimization (PSO)

1. Introduction

The manufacturing enterprises are under competitive pressure due to the remarkable changes in the market scenario effected by universal competition, shorter product life cycles, active variations in demand patterns and product varieties and environmental standards [1]. The competitiveness of a business enterprise in the modern market place is established by the traits such as decline in lead times and expenses, fortification of customer service levels and superior

product quality [2]. The company is forced to pay due attention to their supply chains due to the aforesaid features. A supply chain denotes a company or group that offers goods and services to the market. Otherwise, a group of several units that function in order to 1) acquire raw materials, (2) convert these unprocessed supplies into specific end products, and (3) distribute the end products to retailers or end users can be referred as a supply chain [7].

Purchase of raw resources/materials and converting them into usable outputs at a single or multiple plants, transporting them to diverse warehouses for storage and subsequent delivery of the same to the specific retailers or customers are the processes performed by a conventional supply chain management [2].

Supply chain management aims at integrating and coordinating the activities of the suppliers, manufacturers, warehouses and stores to ensure appropriate manufacture and delivery of the outputs to the exact place at the right time and to minimize the entire supply chain cost and also to ensure meeting service level requirements. The producer is deemed to be the manager of the supply chain as they are responsible for obtaining raw resources, changing it to end products, delivering the completed goods to the customers. The management of varying demands is a massive issue encountered by the common supply chains intending to cut the expenses of supply chains in addition to advancing customer service intensities [9]. There are serious issues in the management of the supply chain due to the rising supply chain intricacy owing to the shorter product lifecycles causing high uncertainty in demands, affecting global markets. From the operational point of view, Information sharing, coordination, monitoring; and use of operation tools are the four important topics that are dealt with by the researchers [8].

The high expectation in customer service levels of late has forced the organizations to manage their

supply chains efficiently [5]. The excess or lack of inventories has resulted in the high supply chain cost for the organizations. Hence, the inventory optimization in supply chain management has emerged as one of the most recent and important issue.

The stock of items/components accumulated by an organization for prospective exploitation is known as inventory. The inspection and management of the inventory is facilitated by a set of procedures called inventory systems. At various stages along the production and distribution supply chain, items/components/products can get accumulated resulting in stockpile of inventory [3]. The inventory system is expected to decide the quantity of each item to be stored depending upon the status of the stock level and as a result, item may have to be ordered or manufactured.

The improvement of inventory control and its management over an extended supply network is facilitated by the systematic application of inventory optimization techniques and technologies. The inventory optimization approach should dwell upon important aspects such as the enhancement in customer service, reduction of lead times and costs and managing the fluctuating market demand [3][10][11].

Even though the total supply chain cost is minimized, the chief concern for the inventory and supply chain managers is the assessment of the accurate amount of inventory to be kept at each point in the supply chain free of surpluses and scarcities. The accurate assessment of most desirable inventory is crucial, as lack of inventory leads to lost sales, while overload of inventory may well result in futile storage costs [14]. A factory may manufacture certain number of products, each supply chain member may consume a few or all the products and each product may be manufactured using certain number of raw materials sourced from different suppliers. All these considerations pose additional challenge in extracting the exact list of products and the stock levels that influence the supply chain cost heavily.

In our paper, we are proposing a methodology that considers some of the above factors such that the resulting analysis paves the way for minimizing the supply chain cost. The supply chain cost can be minimized by maintaining optimal stock levels at each one of the supply chain members. Such optimal stock levels can be predicted by analyzing the past records. The minimization of supply chain cost will be realistic only if the optimal level is predicted with the knowledge of the lead times of the stocks. Hence we are developing a methodology that analyzes the past records and projects the emerging excess/shortage stock levels that are to be considered to finally ascertain the optimal stock levels that have to be

maintained by each one of the supply chain members. We are using Particle Swarm Optimization algorithm, which is considered to be one of the best optimization algorithms in Evolutionary computation, for our analysis purposes. The stock levels that are obtained from the analysis are the stock levels that contribute more to the increase in total supply chain cost and is the essential information required for supply chain inventory optimization.

The organization of rest of the paper is as follows; a brief review of related researches on inventory optimization is provided in Section 2; Section 3 introduces the particle swarm optimization algorithm. The proposed prediction analysis by Particle Swarm optimization algorithm with required illustrations and mathematical formulations are covered in section 4 and Section 5 discusses the implementation of the results. Section 6 summarizes the discussions dealt with in the paper and section 7 is constituted by the referred articles.

2. Related Works

Lee et al. [6] introduced a supply chain model functioning under periodic review base-stock inventory system to assist the manufacturing managers at HP to administer material in their supply chains. A search routine facilitated the achievement of the inventory levels across supply chain members.

A study and evaluations of the performance measures employed in supply chain models as well as a framework for the beneficial selection of performance measurement systems for manufacturing supply chains was displayed by Beamon et al. [7].

A System Dynamics simulation model of a typical retail supply chain was developed by Barlas et al [13]. The creation of inventory policies that simultaneously enhance the retailer's revenue and reduce costs is the objective of their simulation. The study of the implications of different diversification strategies was also the aim of their research.

Buffett et al. [14] proposed a technique to utilize in supply-chain management that supports the decision-making process for purchases of direct goods. The projections for future prices and demand are the basis of the creation of Request for Quotations (RFQs) which accept the quotes that optimize the level of inventory each day, besides minimizing the cost.

The impacts of neighborhoods topologies on particle swarm optimization for complex functions were discussed by Wei Jian et.al [15]. They illustrated the convergence features affected by constant parameters on particle swarm optimization. To prevent premature phenomenon of the original algorithm, they

introduced the velocity and position disturbances. A valve was also introduced and the selection criteria were discussed.

An algorithm based on the particle swarm paradigm to address nonlinear constrained optimization problems was proposed by A.I. de Freitas Vaz et.al [16]. The relaxation of the dominance concept introduced in the multi-objective optimization is the basis of the algorithm. The selection of the best particle position and the best ever particle swarm position was performed using the concept.

Pardoe et al. [17] presented TacTex-06, a supply chain management agent comprising of predictive, optimizing, and adaptive components. TacTex-06 predicts the future of the economy, such as the prices that will be proffered by component suppliers and the degree of customer demand and subsequently ensures maximum profit by strategizing its future actions.

Caldeira et al. [18] proposed the accomplishment of Beam-ACO in supply-chain management. The supply and logistic agents of a supply chain are optimized using the Beam-ACO. The optimization of the distributed system is facilitated by a standard ACO algorithm. The local and global results of the supply chain are improved by the application of Beam-ACO.

The investigations on the application of particle swarm optimization (PSO) to solve shortest path (SP) routing problems were performed by Ammar W. Mohemmed et. al [12]. A heuristic operator that reduces the possibility of loop-formation in the path construction process for particle representation in PSO was incorporated in a modified priority-based encoding proposed by the authors.

A dominance variation which enables a finer neighborhood handling in criterion space was introduced by Gerard Dupont et. al [4]. Several enhancements to particle swarm optimizer dealing with multi-objective problems were proposed.

3. Particle Swarm Optimization

In 1995, Kennedy and Eberhartin, inspired by the choreography of a bird flock, first proposed the Particle Swarm Optimization (PSO). In comparison with the evolutionary algorithm, PSO, relatively recently devised population-based stochastic global optimization algorithm has many similarities and the robust performance of the proposed method over a variety of difficult optimization problems has been proved [24]. 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 [19].

Simulation of simplified social models has been employed to develop Particle Swarm Optimization

techniques. The following are the features of the method [20]:

The researches on swarms such as fish schooling and bird flocking are the basis of the method.

The computation time is short and it requires little memory as it is based on a simple concept.

Nonlinear optimization problems with continuous variables were the initial focus of this method. Nevertheless, problems with discrete variables can be treated by easy expansion of the method. Hence, the mixed integer nonlinear optimization problems with both continuous and discrete variables can be treated with this method.

In addition to PSO, we have several evolutionary paradigms which include Genetic algorithms (GA), Genetic programming (GP), Evolutionary strategies (ES) and Evolutionary programming (EP). Biological evolution is simulated by these approaches which are based on population [21]. Genetic algorithm and PSO are two widely used types of evolutionary computation among the various types of EC paradigms [22].

PSO and evolutionary computation techniques such as Genetic Algorithms (GA) have many similarities between them. A population of random solutions is used to initialize the system which updates generations to search for optima. Nevertheless, PSO does not have evolution operators such as crossover and mutation that are available in GA.

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 namely 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 [23].

When the neighborhood of a particle is the entire swarm, the global best particle refers to the best position in the neighborhood and gbest PSO refers the resulting algorithm. Generally, lbest PSO refers the algorithm in cases when smaller neighborhoods are used [22].

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 [23].

4. The Proposed Prediction Analysis Based On Particle Swarm Optimization Algorithm.

The methodology proposed here will minimize the total supply chain cost by predicting optimal stock levels not only by considering the past records of the stock levels but also considering the lead time of the products to reach each supply chain member from its previous stage as well as the lead time involved in supplying the raw materials to the factory. Usually, shortage for a particular stock at a particular member, excess stock levels at a particular member, time required to transport stock from one supply chain

member to another i.e. lead time of a stock in a member, time taken to supply raw materials to the factory to manufacture certain products i.e. lead time of raw materials used in factory are some of the key factors that play a vital role in deciding the supply chain cost. A better optimization methodology should consider all these factors. In our methodology we consider all the above mentioned key factors in predicting the optimal stock levels. Also, different priorities are assigned to those factors. As per the priority given, the corresponding factors will influence the prediction of optimal stock levels. Hence as per the desired requirement, the optimal stock level will be maintained by setting or changing the priority levels in the optimization procedure.

Supply chain model is broadly divided into four stages in which the optimization is going to be performed. The supply chain model is illustrated in the figure 1.

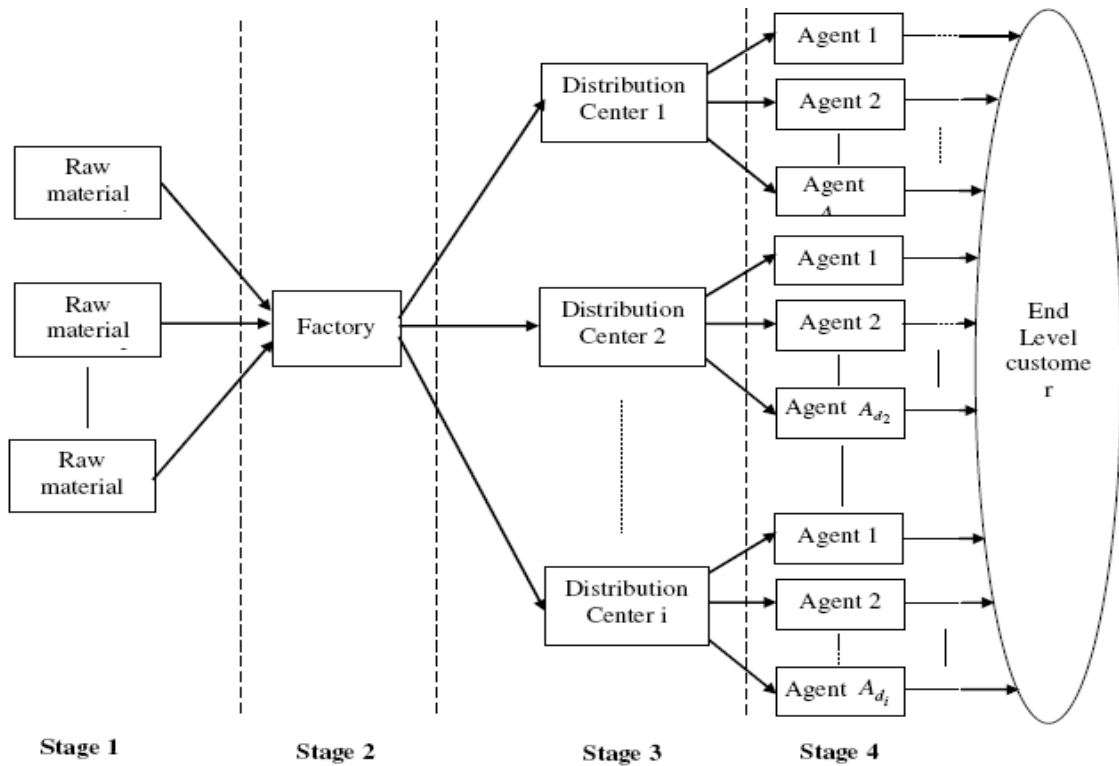


Figure 1: Four stage supply chain model

The members participating in the supply chain model are raw material sources $\{r_1, r_2, r_3, \dots, r_m\}$, a factory f , i distribution centers $D = \{d_1, d_2, d_3, \dots, d_i\}$ and the

agents $A = \{A_{d_1}, A_{d_2}, A_{d_3}, \dots, A_{d_i}\}$, A_{d_i} is the number of agents for the distribution center d_i . Hence, the total number of agents in the supply chain model can be arrived using formula

$$N_A = \sum_{m=1}^i A_{d_m} \quad (1)$$

where N_A is the total number of agents used in the supply chain model.

The factory is assumed to be manufacturing k number of products. The database holds the information about the stock levels of each product in each of the supply chain member, lead time of products in each supply chain member and lead time of raw material. For l members from factory to end-level-Agents, there are $l-1$ lead times for a particular product and these times are collected from the past records. Similarly, the lead time for raw materials from r_m to f is also taken from the earlier period and thus the database is constituted. Each and every dataset recorded in the database is indexed by a Transportation Identification (TID). For P periods, the TID will be $\{T_1, T_2, T_3, \dots, T_p\}$. This TID will be used as an index in mining the lead time information.

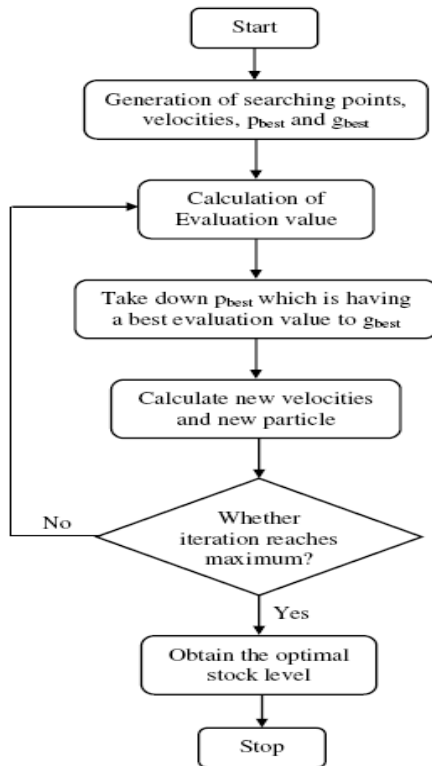


Figure 2: Particle swarm optimization in optimizing the stock levels

Now, the particle Swarm Optimization (PSO) is utilized to predict the optimal stock levels to be

maintained in the future to minimize the supply chain cost. The procedures involved in determining the optimal stock levels are illustrated in figure 2

As the particle swarm optimization is more suitable for finding the solution for the optimization problem with general characteristics such as shorter computation time, less memory requirements etc., we have utilized particle swarm optimization in finding the optimal stock levels to be maintained in each member of the supply chain. The flow of methodology is discussed below.

The individuals of the population including searching points, velocities, p_{best} and g_{best} are initialized randomly but within the lower and upper bounds of the stock levels for all supply chain members, which have to be specified initially.

Hence the generated searching point individual is

$$I_i = [P_k \ S_1 \ S_2 \ S_3 \ \dots \ S_l] \quad (2)$$

$i = 1, 2, 3, \dots, N_p$

$$\text{where, } P_{L.B} < P_k < P_{U.B}, \\ S_{L.B} < S_l < S_{U.B}$$

$P_{L.B}$, $P_{U.B}$ and $S_{L.B}$, $S_{U.B}$ are the lower and upper bound values of the number of products and stock levels respectively. The generated population is having the size of N_p i.e. N_p number of individuals. Since the total number of members that are maintaining the stock levels from f is l , the dimension d of each individual is given by

$$d = l + 1 \quad (3)$$

and hence the equation (3). Similarly, the initial velocity for the individual will be

$$[v_1 \ v_2 \ v_3 \ \dots \ v_{l+1}], \ v_{\min} < v_{l+1} < v_{\max} \quad (4)$$

where, v_{\min} and v_{\max} are the minimum and maximum limit for velocities respectively.

Then each individual is queried into the database for obtaining the details regarding the TID and frequency of the individual. This will bring T_q , $q \in p$ and $P(occ)$, number of periods of occurrence of that particular individual. Here, q need not to be consecutive integers. This obtained TID is queried into the database having the lead time of a particular product to a particular supply chain member. The product I.D. obtained from the individual is queried into the database having the lead time each raw material for the particular product. After all these

queries, we have obtained the lead time of stocks as follows

$$T_s = [t_{q,1} \ t_{q,2} \ \dots \ t_{q,l-1}] \quad (5)$$

And the lead time for raw materials is obtained as

$$T_r = [t_1 \ t_2 \ \dots \ t_r] \quad (6)$$

where, r is the number of raw materials required for a certain product.

Then, for each individual the evaluation function is calculated.

Determination of Evaluation function

The evaluation function is determined for each randomly generated individual. The function is given by

$$f(a) = w_1 \left(1 - \frac{P(occ)}{T(periods)} \right) + \log(w_2 \cdot t_{stock} + w_3 \cdot t_{raw})$$

$a = 1, 2, 3, \dots, N_p$ (7)

where

$T(periods)$ is the total number of periods of records in database.

In equation (7), w_1 , w_2 and w_3 are the weightings of the factors, stock levels, lead time of stocks and lead time of raw materials in optimization, respectively and they are determined as

$$w_1 = \frac{R_1}{R_1 + R_2 + R_3} \quad (8.1)$$

$$w_2 = \frac{R_2}{R_1 + R_2 + R_3} \quad (8.2)$$

$$w_3 = \frac{R_3}{R_1 + R_2 + R_3} \quad (8.3)$$

R_1 , R_2 and R_3 are the priority levels of influence of stock levels, lead time of stocks and lead time of raw materials in optimization respectively. Increasing the priority level of a factor increases the influence of the corresponding factor in the evaluation function.

Hence this R_1 , R_2 and R_3 decide the amount of influence of the factors. The lead time of the stocks

t_{stock} is determined as follows

$$t_{stock} = \sum_{i=1}^{l-1} \sum_q t_{q,i} \quad (9)$$

And the lead time required to fill the raw materials is given as

$$t_{raw} = \sum_{i=1}^r t_i \quad (10)$$

When equation (9) and (10) are also substituted in the equation (7), an evaluation value for each individual is obtained.

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 nothing but an index that points towards the best individual we have generated so far.

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

$$v_{new}(a,b) = w * v_{cnt}(a) + c_1 * r_1 * [P_{best}(a,b) - I_{cnt}(a,b)] + c_2 * r_2 * [G_{best}(b) - I_{cnt}(a,b)] \quad (11)$$

where,

$$a = 1, 2, \dots, N_p$$

$$b = 1, 2, \dots, d$$

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

$$w = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} \times iter \quad (12)$$

where,

w_{max} and w_{min} are the maximum and minimum inertia weight factors respectively that are chosen randomly in the interval $[0,1]$

In equation (12), $iter_{max}$ is the maximum number of iterations and

$iter$ is the current number of iteration

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

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

and 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

$$I_{new}(a,b) = I_{cnt}(a,b) + v_{new}(a,b) \quad (13)$$

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,

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

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

This is to be done for the other parameters also. This process will be repeated again and again until either the maximum number of iterations is reached or as long as minimization of the evaluation function value is still possible based on simulation run. Once

the stopping criteria is decided, then the latest g_{best} particle pointing towards the individual is the best individual having the information about the excess/shortage of stock levels and this inference is utilized for the purpose of taking necessary steps for maintaining the future optimal stock levels at each supply chain member.

5. Implementation Results

We have implemented the analysis based on PSO for optimal inventory control in the platform of MATLAB (version 7.4). As stated, we have the detailed information about the excess and the shortage stock levels in each supply chain member, the lead times of product stock levels to replenish each supply chain member as well as raw material lead time. The sample data having this information is given in the Table 1.

Table 1: Sample data from database of different stock levels

TI	PI	F1	F2	F3	F4	F5	F6	F7
1	3	632	424	247	-298	-115	365	961
2	5	-415	488	-912	979	-492	-922	205
3	2	369	-686	-468	-807	183	-386	-228
4	2	459	289	-522	-316	130	-854	468
5	3	-663	944	856	451	-763	657	484
6	4	-768	-937	-768	242	369	-890	289

The Table 1 is having the product ID, the Transportation ID, the stock levels which are in excess or in shortage at each supply chain member. Negative values represent shortage of stock levels and positive values represent the excess of stock levels. The transportation ID mentioned in table is working as an index in extracting the lead times for stocks and raw material lead times. Table 2 depicts the sample data which is having the transportation ID and the lead times for stocks. For seven member supply chain, six lead times can be obtained.

Similarly, Table 3 represents the lead time to fill the raw materials which are essential to manufacture each product. In the Table 3, product ID '1' needs three raw materials having the raw Material ID '1', '2' and '3' having the lead times '20', '3' and '8' respectively.

Table 2: Sample data from Database which is having lead times for stocks

TI	T1	T2	T3	T4	T5	T6
1	28	27	19	9	19	19
2	35	33	16	4	24	15
3	38	38	20	8	10	18
4	25	25	9	21	22	13
5	45	40	15	4	16	11
6	36	43	7	13	21	3

Table 3: Raw material lead time for different products

PI	RM	T
1	1	20
1	2	3
1	3	8
2	1	10
2	2	3
2	3	9

Table 4: Initial random individuals

PI	F1	F2	F3	F4	F5	F6	F7
3	855	61	215	863	24	75	-757
5	854	-154	145	-241	-215	415	845

Table 5: Initial Random velocities corresponding to each particle of the individual

PI	F1	F2	F3	F4	F5	F6	F7
-	0.0376	-	0.3567	0.0982	-	-	-
0.1298		0.3439			0.0560	0.1765	0.0409
-	0.0863	0.3573	-	0.0524	0.2177	0.6550	0.0342
0.4997			0.0113				

For PSO based analysis, we have to generate random individuals having eight numbers of particles representing product ID and seven supply chain members. Table 4 describes two random individuals.

Similarly, Table 5 represents random velocities which correspond to each particle of the individual.

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

The final individual obtained after a predefined maximum number of iterations is:

[3 -602 -280 -821

398 382 -764 -125]

The database format of this final individual is given in Table 6.

Table 6: database format of Final Individual

PI	F1	F2	F3	F4	F5	F6	F7
3	-602	-280	-821	398	382	-764	-125

The final individual thus obtained represents a product ID and excess or shortage stock levels at each of the seven members providing essential information for supply chain inventory optimization.

6. Conclusion

Inventory management is one among the several vital areas in supply chain management. The inventory levels in several production and distribution operations related with diverse chain phases should be controlled by the associates of the supply chain in order to curtail the overheads of a supply chain. As the lead time plays vital role in the increase of supply chain cost, the complexity in predicting the optimal stock levels increases. The novel and proficient approach based on

Particle Swarm optimization algorithm presented here reduced the total supply chain cost as it undoubtedly established the most probable surplus stock level and shortage level along with the consideration of lead time in supplying the stocks as well as raw materials that are required for inventory optimization. The MATLAB 7.4 is employed to implement the approach and to envision its performance. As anticipated, the proposed Particle Swarm optimization algorithm offers us a superior calculation of stock levels amidst diverse stock levels at diverse members of the supply chain by its excellent performance. Thus the attained stock level is a most advantageous value that is required to be maintained at the holding location for a minimized supply chain cost.

7. References

- [1] Sarmiento, A. Rabelo, L. Lakkoju, R. Moraga, R., "Stability analysis of the supply chain by using neural networks and genetic algorithms", in proceedings of the winter Simulation Conference, pp: 1968-1976, December 9-12, Washington, DC, 2007.
- [2] Joines, J.A. Gupta, D. Gokce, M.A. King, R.E. Kay, M.G., "Supply Chain Multi-Objective Simulation Optimization", in proceedings of the winter Simulation Conference, Vol. 2, pp: 1306- 1314, December 8-11, 2002.
- [3] "Optimization Engine for Inventory Control", White paper from Golden Embryo Technologies pvt. Ltd., Maharastra, India, 2004.
- [4] Gerard Dupont, Sebastien Adam, Yves Lecourtier and Bruno Grilheres, "Multi objective particle swarm optimization using enhanced dominance and guide selection", International Journal of Computational Intelligence Research, Vol. 4, No. 2, pp. 145-158, 2008.
- [5] Mileff, Peter, Nehez, Karoly, "A new inventory control method for supply chain management", 12th International

- Conference on Machine Design and Production, pp. 393-408, September, Istanbul, Turkey, 2006.
- [6] Lee HL, Billington C, "The evolution of supply-chain-management models and practice at Hewlett-Packard", *Interface*, vol. 25, no. 5, 1995.
- [7] Beamon BM, "Supply chain design and analysis: models and methods", *International Journal of Production Economics*, Vol: 55, No. 3, page: 281–294, 1998.
- [8] Ganeshan, R., Jack, E., Magazine, M.J., Stephens, P., "A taxonomic review of supply chain management research", *Quantitative Models for Supply Chain Management*. Kluwer Academic Publishers, Massachusetts, pp. 841–879, 1999.
- [9] Rajesh Gangadharan, "Supply Chain Strategies to Manage Volatile Demand", 2007. <http://www.celuro.com/resources/Supply+Chain+Strategies+to+Manage+Volatile+Demand.pdf>
- [10] Jinmei Liu, Hui Gao, Jun Wang, "Air material inventory optimization model based on genetic algorithm," in proceedings of the 3rd World Congress on Intelligent Control and Automation, vol.3, pp: 1903 - 1904, June 28-July 2, 2000.
- [11] C.M. Adams, "Inventory optimization techniques, system vs. item level inventory analysis," in proceedings of 2004 Annual Symposium RAMS - Reliability and Maintainability, pp: 55 - 60, January 26-29, TX, USA, 2004.
- [12] Ammar W. Mohemmed, Nirod Chandra Sahoo, Tan Kim Geok, "Solving shortest path problem using particle swarm optimization," *Applied Soft Computing*, Vol. 8, No. 4, pp. 1643-1653, 2008.
- [13] Y. Barlas, A. Aksogan, "Product Diversification and Quick Response Order Strategies in Supply Chain Management" in proceedings of International System Dynamics Conference, Cambridge, USA, 1996.
- [14] S. Buffett, N. Scott, "An Algorithm for Procurement in Supply Chain Management", in proceedings of AAMAS-04 Workshop on Trading Agent Design and Analysis, New York, 2004.
- [15] Wei Jian, Yun-Can Xue, Ji-Xin Qian, "An improved particle swarm optimization algorithm with neighborhoods topologies," in Proceedings of 2004 International Conference on Machine Learning and Cybernetics, Vol. 4, No. 26-29, pp. 2332 - 2337, August, 2004.
- [16] I. de Freitas Vaz and E. M. D. G. Pinto Fernandes, "Optimization of nonlinear constrained particle swarm," *Technological and Economic Development of Economy*, Vol. 12, No. 1, pp. 30-36, 2006
- [17] D. Pardoe and P. Stone, "An autonomous agent for supply chain management". In G. Adomavicius and A. Gupta, editors, *Handbooks in Information Systems Series: Business Computing*. Elsevier, pp. 1-32, 2007.
- [18] Joao Caldeira, Ricardo Azevedo, Carlos A. Silva, Joao M. C. Sousa, "Supply-Chain Management Using ACO and Beam-ACO Algorithms", in proceedings of IEEE International Fuzzy Systems Conference, pp: 1-6, July 23-26, London, 2007.
- [19] H. Lu, "Dynamic Population Strategy Assisted Particle Swarm Optimization in Multiobjective Evolutionary Algorithm design," *IEEE Neural Network Society, IEEE NNS Student Research Grants 2002, Final reports 2003*.
- [20] Hirotaka Yoshida Kenichi Kawata and Youshikazu Fukuyama Yosuke Nakanishi, "A Particle Swarm Optimization for Reactive Power and voltage control considering voltage stability", in proc. of IEEE International Conference on Intelligent System Applications to Power Systems, pp: 117- 121, April 4- 8, 1999.
- [21] Mahamed G.H. Omran, Andries P Engelbrecht, and Ayed Salman, "Dynamic Clustering using Particle Swarm Optimization with Application in Unsupervised Image Classification", in proceedings of World Academy of Science, Engineering and Technology, vol. 9, November 2005, ISSN: 1307- 6884.
- [22] S. A. Hamdan, "Hybrid Particle Swarm Optimiser using multi-neighborhood topologies", *INFOCOMP - Journal of Computer Science*, Vol.7, No.1, p.p.36-43, March, 2008.
- [23] Ling-Feng Hsieh, Chao-Jung Huang and Chien-Lin Huang, "Applying Particle Swarm Optimization to Schedule order picking Routes in a Distribution Center, in proceedings of Asian Journal on Management and Humanity Sciences, vol. 1, no. 4, pp: 558- 576, 2007.
- [24] Alberto Moraglio, Cecilia Di Chio, Julian Togelius and Riccardo Poli, "Geometric Particle Swarm Optimization", in proceedings of Journal on Artificial Evolution and Applications, vol. 2008, Article ID: 143624, 2008, Doi: 10.1155/2008/143624.