Journal of Research Administration
Society of Research Administrators International

ENHANCING SUPPLY CHAIN EFFICIENCY THROUGH ARTIFICIAL BEE COLONY OPTIMIZATION IN A TWO-WAREHOUSE SYSTEM

Seema Agarwal[1], Praveen B M[2], Ajay Singh Yadav[3], Krishan Pal[4]
[1]Post-Doctoral Research Scholar, Srinivas University, Mukka, Surathkal, Mangaluru, Karnataka, India and
[1]Assistant Professor, Department of Mathematics, SRM Institute of Science and Technology, Delhi-NCR Campus, Ghaziabad, India.
[2]Director- Research, Department of Chemistry, Srinivas University, Mukka, Surathkal, Mangaluru, Karnataka, India.
[3]Associate Professor, Department of Mathematics, SRM Institute of Science and Technology, Delhi-NCR Campus, Ghaziabad, India.
[4]Research Scholar, Department of Mathematics, SRM Institute of Science and Technology, Delhi-NCR Campus, Ghaziabad, India.

Abstract:

This paper investigates the application of Artificial Bee Colony (ABC) Optimization for optimizing supply chain inventory in a Two-warehouse system. The primary aim is to minimize overall costs linked with inventory management. The study tailors the ABC algorithm to tackle the intricacies specific to a Two-warehouse setup. Implementation encompasses problem definition, formulating the objective function, identifying constraints, and coding the algorithm. Results showcase the efficacy of ABC Optimization in boosting supply chain efficiency, offering actionable insights for businesses navigating inventory management in multi-warehouse scenarios.

Keywords: Artificial Bee Colony Optimization, Two-Warehouse System, Inventory Management, Supply Chain Efficiency, Cost Minimization

1. Introduction:

Supply chain management is a critical aspect of business operations, influencing overall efficiency and cost-effectiveness. Within this realm, effective inventory management is pivotal for ensuring a streamlined and responsive supply chain. In scenarios involving multiple warehouses, such as a Two-warehouse system, the complexities of optimizing inventory levels become more pronounced. This paper explores the application of Artificial Bee Colony (ABC) Optimization as a solution to enhance inventory management in such a system.

The Two-warehouse model introduces challenges related to order quantities, storage policies, and overall logistics. Traditional optimization approaches may struggle to find optimal solutions in the face of these complexities. ABC Optimization, inspired by the foraging behavior of honeybees, offers a nature-inspired algorithmic solution that can navigate the intricacies of the Two-warehouse inventory system.

In this context, our objective is to minimize the total costs associated with inventory management, encompassing ordering costs, holding costs, and potential stockout costs. By leveraging the unique characteristics of the ABC algorithm, we aim to provide an efficient and effective means of decision-making for inventory control in a Two-warehouse supply chain.

This introduction outlines the motivation for the study, the significance of the problem at hand, and the proposed solution using ABC Optimization. The subsequent sections will delve into the problem definition, formulation of the objective function, adaptation of the ABC algorithm, implementation details, and the presentation of results, contributing valuable insights to the field of supply chain optimization.

2. Related Work

Supply chain management can be defined as: "Supply chain management is the coordination of production, storage, location and transport between players in the supply chain to achieve the best combination of responsiveness and efficiency for a given market. Many researchers in the inventory system have focused on a product that does not overcome spoilage. However, there are a number of things whose meaning doesn't stay the same over time. The deterioration of these substances plays an important role and cannot be stored for long {Yadav et al. (1-10). Deterioration of an object can be described as deterioration, evaporation, obsolescence and loss of use or restriction of an object, resulting in less inventory consumption than under natural conditions. When raw materials are put in stock as a stock to meet future needs, there may be a deterioration of the items in the arithmetic system which could occur for one or more reasons, etc. Storage conditions, weather or humidity. {Yadav, et al. (11-20)}. Inach generally states that management has a warehouse to store the purchased warehouse. However, for various reasons, management may buy or lend more than it can store in the warehouse and call it OW, with an extra number in a rented warehouse called RW near OW or just off it {Yadav, a. al. (21-53)}. Inventory costs (including maintenance costs and depreciation costs) in RW are generally higher than OW costs due to additional costs of running, equipment maintenance, etc. Reducing inventory costs will cost-effectively utilize RW products as quickly as possible. Actual customer service is only provided by OW, and to reduce costs, RW stock is cleaned first. Such arithmetic examples are called two arithmetic examples in the shop {Yadav and swami. (54-61)}. Management of the supply of electronic storage devices and integration of environmental and nerve networks {Yadav and Kumar (62)}. Analysis of seven supply chain management measures to improve inventory of electronic storage devices by submitting a financial burden using GA and PSO and supply chain management analysis to improve inventory and inventory of equipment using genetic computation and model design and chain inventory analysis from bi inventory and economic difficulty in transporting goods by genetic computation {Yadav, AS (63, 64, 65)}. Inventory policies for inventory and inventory needs and miscellaneous inventory costs based on allowable payments and inventory delays. An example of depreciation of various types of goods and services and costs by keeping a business loan and inventory model with pricing needs low sensitive, inventory costs versus inflationary business expense loans {Swami, et. al. (66, 67, 68)}. The objectives of the

Multiple Objective Genetic Algorithm and PSO, which include the improvement of supply and deficit, inflation and a calculation model based on a genetic calculation of the scarcity and low inflation of PSO {Gupta, et. al. (69, 70)}. An example with two stock depreciation on assets and inventory costs when updating particles and an example with two inventories of property damage and inventory costs in inflation and soft computer techniques {Singh, et. al. (71, 72)}. Delayed control of alcohol supply and particle refinement and green cement supply system and inflation by particle enhancement and electronic inventory system and distribution center by genetic computations {Kumar, et. al. (73, 74, 75)}. Depreciation example at two stores and warehouses based on inventory using one genetic stock and one vehicle stock for demand and inflation inventory with two distribution centers using genetic stock {Chauhan and Yadav (76, 77)}. Analysis of marble Improvement of industrial reserves based on genetic technology and improvement of multiple particles {Pandey, et. al. (78)} The white wine industry in supply chain management through nerve networks {Ahlawat, et. al. (79)}. The best policy to import damaged goods immediately and pay for conditional delays under the supervision of two warehouses {Singh, et. al. (80)}.

3. Assumptions:

(I) Relative to the production rate, the unit production cost.

(II) A variable used in decision-making is the pace of production.

(III) It is unacceptable to have shortages.

(IV) A fixed capacity is possessed by the own storehouse.

4. Notations:

H: Total planning prospect.

Rp: Variable production rate.

λ(t): Demand rate is exponentially increasing and represented by $\lambda = \lambda_1 e^{(\sigma+3)\,t}$, where $0 \leq (\sigma+3)\ \sigma \leq 1$, $(\sigma+3)$ is a constant inflation rate

W: Fix capacity level of OW

$\boldsymbol{\delta(t)}$:Variable deterioration rate $(\varepsilon+3)(t) = (\varepsilon+3)t$

$\boldsymbol{\gamma(t)}$:Variable deterioration rate $(\mu+3)(t) = (\mu+3)t$ in RW

$\boldsymbol{d}$: Discount rate $(d > a\ )$

$\boldsymbol{n}$**:** No. of Production cycle during entire horizon H

$\boldsymbol{C_0 + \phi t}$: Variable carrying cost of on item

$\boldsymbol{\mu_0(Rp)}$: Cost of an item's unit manufacture and $\boldsymbol{\mu_0(Rp) = R + \frac{G}{P} + NP}$, where R is substantial cost, N is device or die cost and G is energy and employment cost.

The equation will

$$\frac{dI_{k1}(t)}{dt} + (\varepsilon+3)tI_{k1}(t) = (Rp+3) - \lambda_1 e^{(\sigma+3)\,t} \quad , \; t_{k1} < t < t_{k1} \quad (1)$$

$$\frac{dI_{k2}(t)}{dt} + (\mu+3)tI_{k2}(t) = (Rp+3) - \lambda_1 e^{(\sigma+3)\,t} \quad , \; t_{k1} < t < t_{k2} \quad (2)$$

$$\frac{dI_{k3}(t)}{dt} + (\mu+3)tI_{k3}(t) = -\lambda_1 e^{(\sigma+3)\,t}, \; t_{k2} < t < t_{k3} \quad (3)$$

$$\frac{dI_{k4}(t)}{dt} + (\varepsilon+3)tI_{k4}(t) = -\lambda_1 e^{(\sigma+3)\,t} \quad , \; t_{k3} < t < t_{k4} \quad (4)$$

$$\frac{dI_{k5}(t)}{dt} + (\varepsilon+3)tI_{i5}(t) = -\lambda_1 e^{(\sigma+3)\,t} \quad , \; t_{k1} \le t < t_{k5} \;\; \text{k =1, 2 ....} \quad (5)$$

$$\frac{dI_{k6}(t)}{dt} = -\lambda_1 e^{(\sigma+3)\,t} \quad , \quad t_{k4} \le t < t_{k5} \quad (6)$$

The solution of this equation (1) is

$$I_{k1}(t)e^{\frac{(\varepsilon+3)t^2}{2}} = ((Rp+3)-\lambda_1)t - \frac{\lambda_1(\sigma+3)}{2}t^2 + ((Rp+3)(\varepsilon+3) - \lambda_1((\varepsilon+3) + (\sigma+3)^2))\frac{t^3}{6} + C$$

Put t= (t_{k-1})s

$$I_{k1}(t)e^{\frac{(\varepsilon+3)t^2}{2}} = ((Rp+3)-\lambda_1)(t-t_{k-1}) - \frac{\lambda_1(\sigma+3)}{2}({t^2}_{k-1} - t^2)[(Rp+3)(\varepsilon+3) - \lambda_1((\varepsilon+3) + (\sigma+3)^2)]\left[\frac{{t^3}_{k-1}}{6} - {t^3}_{k-1}\right]$$

$$I_{k1}(t) = [((Rp+3)-\lambda_1)(t-t_{k-1}) + \frac{\lambda_1(\sigma+3)}{2}({t^2}_{k-1} - t^2) + [(Rp+3)(\varepsilon+3) - \lambda_1((\varepsilon+3) + (\sigma+3)^2)]\left[\frac{t^3}{6} - \frac{{t^3}_{k-1}}{6}\right]e^{-\frac{(\varepsilon+3)t^2}{2}} \quad (7)$$

Similarly, the result of $I_{k2}(t)$ will be

$$I_{k2}(t) = [((Rp+3)-\lambda_1)(t-t_{k-1})+\frac{\lambda_1(\sigma+3)}{2}(t^2{}_k-t^2)+[(Rp+3)(\varepsilon+3)-\lambda_1((\mu+3)+(\sigma+3)^2)]\left[\frac{t^3}{6}-\frac{t^3{}_{k1}}{6}\right]e^{-\frac{(\mu+3)t^2}{2}} \quad (8)$$

Now result of equation (3) as

$$I_{k3}(t)e^{\frac{(\mu+3)t^2}{2}} = -\lambda_1\left[t+\frac{t^2}{2}+((\mu+3)+(\sigma+3)^2)\frac{t^3}{6}\right]+C$$

Put t= t_{k3}

$$I_{k3}(t)e^{\frac{(\mu+3)t^2{}_3}{2}} = -\lambda_1\left[t_{k3}+\frac{(\sigma+3)\,t^2{}_{k3}}{2}+((\mu+3)+(\sigma+3)^2)\frac{t^3{}_{k3}}{6}\right]+C'$$

Put $I_{k3}(t_{k3}) = 0$

$$T_{k3}(t)=\left[\lambda_1(t_{k3}-t)\frac{(\sigma+3)}{2}\lambda_1(t^2{}_{k3}-t^2)+\left(\frac{(\varepsilon+3)+(\sigma+3)^2}{6}\right)\lambda_1\{t^3{}_{k3}-t^3\}\right]e^{\frac{-(\mu+3)t^2}{2}} \quad (9)$$

So, the result of equation (4) will be

$$T_{k4}(t)=\left[\lambda_1(t_{k4}-t)\frac{(\sigma+3)}{2}\lambda_1(t^2{}_{k4}-t^2)+\left(\frac{(\varepsilon+3)+(\sigma+3)^2}{6}\right)\lambda_1\{t^3{}_{k4}-t^3\}\right]e^{-1} \quad (10)$$

Now result of equation of (5)

$$I_{k5}(t)e^{\frac{(\varepsilon+3)t^2}{2}} = We^{\frac{(\varepsilon+3)t^2{}_{k1}}{2}}$$

$$I_{k5}(t) = We^{\frac{(\varepsilon+3)}{2}}(t^2{}_{k1}-t^2) \quad (11)$$

Now result of equation (6) using boundary condition is

$$I_{k6}(t) = \frac{\lambda_1}{(\sigma+3)}(e^{(\sigma+3)\,t}{}_{k4}-e^{(\sigma+3)\,t}) \quad (12)$$

Since W is charged put the value of $I_{k1}(t_{k1}) = W$

$$W = [((Rp+3)-\lambda_1)(t-t_{k-1})+\frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k-1}-t^2{}_{k1})+\left[\frac{(Rp+3)(\varepsilon+3)-\lambda_1((\varepsilon+3)+(\sigma+3)^2)}{6}\right][t^3{}_{k1}-t^3{}_{i-1}]e^{-\frac{(\varepsilon+3)t^2}{2}} \quad (13)$$

We can calculate the worth of W since he has been fined. t_{k1} in terms of t_{k-1}

Now

$$I_{k4}(t) = \lambda_1(t_{k4} - t) + \frac{\lambda_1(\sigma+3)}{2}(t^4{}_{k2} - t^2) + \left(\frac{(\varepsilon+3) + (\sigma+3)^{\,2}}{6}\right)\lambda_1\{t^3{}_{k4} - t^3\}e^{-\frac{(\varepsilon+3)t^2}{2}}$$

Put t=t_{k3}

$$I_{k4}(t)_{k3} = \lambda_1(t_{k4} - t_{k3}) + \frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k4} - t^2{}_{k3}) + \left(\frac{(\varepsilon+3) + (\sigma+3)^{\,2}}{6}\right)\lambda_1\{t^3{}_{k4} - t^3{}_{k3}\}e^{-\frac{(\varepsilon+3)t^2{}_{k3}}{2}}$$

And $I_{k5}(t) = We^{\frac{(\varepsilon+3)}{2}}(t^2{}_{k1} - t^2)$

Put t=t_{k3}

$$I_{k5}(t) = We^{\frac{(\varepsilon+3)}{2}}(t^2{}_{k1} - t^2{}_{k3})$$

Put $I_{k4}(t_{k3}) = I_{k5}(t_{k3})$

$$\left[\lambda_1(t_{k4} - t_{k3}) + \frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k4} - t^2{}_{k3}) + \left(\frac{(\varepsilon+3)+(\sigma+3)^{\,2}}{6}\right)\lambda_1\{t^3{}_{k4} - t^3{}_{k3}\}e^{-\frac{(\varepsilon+3)t^2{}_{k3}}{2}}\right] = we^{\frac{(\varepsilon+3)}{2}}(t^2{}_{k1} - t^2{}_{k3})$$

$$\left[\lambda_1(t_{k4} - t_{k3}) + \frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k4} - t^2{}_{k3}) + \left(\frac{(\varepsilon+3)+(\sigma+3)^{\,2}}{6}\right)\lambda_1\{t^3{}_{k4} - t^3{}_{k3}\}We^{-\frac{(\varepsilon+3)}{2t^2{}_{k1}}}\right]$$

(14)

$$I_{k2}(t) = [((Rp+3) - \lambda_1)(t - t_{k-1}) + \frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k-1} - t^2) + \left\{\frac{(Rp+3)(\varepsilon+3) - \lambda_1((\mu+3) + (\sigma+3)^{\,2})}{6}\right\}(t^3 - t^3{}_{k-1})]$$

$$I_{k2}(t) = [((Rp+3) - \lambda_1)(t - t_{k1}) + \frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k1} - t^2) + [(Rp+3)C - \lambda_1((\varepsilon+3) + (\sigma+3)^{\,2})]\left[\frac{t^3}{6} - \frac{t^3{}_{k-1}}{6}\right]e^{-\frac{(\varepsilon+3)t^2}{2}}$$

Put t = t_{k2}

$$I_{k2}(t_{k2}) = [((Rp+3) - \lambda_1)(t_{k2} - t_{k1}) + \frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k1} - t^2{}_{k2}) + [(Rp+3)C - \lambda_1((\varepsilon+3) + (\sigma+3)^{\,2})][t^3{}_{k2} - t^3{}_{k1}]e^{-\frac{(\varepsilon+3)t^2{}_{k2}}{2}}$$

$$I_{k3}(t) = [\lambda_1(t_{k3} - t) + \frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k3} - t^2) + \left\{\frac{(\varepsilon+3) + (\sigma+3)^{\,2}}{6}\right\}\lambda_1(t^3{}_{k3} - t^3)]e^{-\frac{(\varepsilon+3)t^2}{2}}$$

Put t = t_{k2}

$$I_{k3}(t) = [\lambda_1(t_{k3} - t_{k2}) + \frac{(\sigma+3)}{2}(t^2{}_{k3} - t^2{}_{k2}) + \left\{\frac{(\varepsilon+3)\ +(\sigma+3)\ ^2}{6}\right\}\lambda_1(t^2{}_{k3} - t^2{}_{k2})]e^{-\frac{(\varepsilon+3)t^2}{2}}$$

Put $\quad I_{k3}(t_{k2}) = I_{k2}(t_{k2})$

$$[\lambda_1(t_{k3} - t_{k2}) + \frac{(\sigma + 3)\ \lambda_1}{2}(t^2{}_{k3} - t^2{}_{k2}) + \left\{\frac{(\varepsilon + 3)\ + (\sigma + 3)\ ^2}{6}\right\}\lambda_1(t^3{}_{k3} - t^3{}_{k2})]e^{-\frac{(\varepsilon+3)t^2{}_{k2}}{2}}$$

$$=\Big[((Rp + 3) - \lambda_1)(t_{k2} - t_{k1}) + \frac{\lambda_1(\sigma+3)}{2}(t^2{}_{k1} - t^2{}_{k2}) + [(Rp + 3)(\varepsilon + 3) - \lambda_1((\varepsilon + 3)\ + (\sigma + 3)\ ^2)]\ \frac{t^3{}_{k2} - t^3{}_{k1}}{6}\Big]e^{\frac{-(\varepsilon+3)t^2}{}}$$

$$=\lambda_1 t_{k3}\ + \frac{(\sigma+3)}{2}\lambda_1 t^2{}_{k3}\ + \left(\frac{(\varepsilon+3)\ +(\sigma+3)\ ^2}{6}\right)\lambda_1 t^3{}_{k3}$$

$$=-((Rp + 3)(\varepsilon + 3) - \lambda_1)t_{k1} \qquad +(Rp + 3)t_{k2}\ + \frac{\lambda_{1(\sigma+3)}}{2}t^2{}_{k1} - [(Rp + 3)(\varepsilon + 3) - \lambda_1((\varepsilon + 3)\ + (\sigma + 3)\ ^2)]\frac{t^3{}_{k1}}{6}\ + \frac{(Rp+3)(\varepsilon+3)t^3{}_{k2}}{6} \qquad (15)$$

Inventory holding costs for the cycle's current value expressed in RW

$$I_{Rwk}\ = [C(t_{k-1})\ +\ t\ ]e^{-dt_{k-1}}\left[\int_{t_{k1}}^{t_{k2}} I_{k2}(t)e^{-d}\ dt\ +\ \int_{t_{k2}}^{t_{k3}} I_{k3}(t)e^{-dt}dt\right]$$

$$=[C(t_{k-1})\ ]e^{-dt_{k-1}}\left[\int_{t_{k1}}^{t_{k2}} I_{k2}(t)e^{-dt}dt\ +\ \int_{t_{k2}}^{t_{k3}} I_{k3}(t)e^{-dt}dt\right] + \phi tC(t_{k-1})e^{-dt_{k-1}}\left[\int_{t_{k1}}^{t_{k2}} T_{k2}(t)e^{-dt}dt\ +\ \int^{t_{k3}} T_{k3}(t)e^{-dt}dt\right] \qquad (16)$$

Current inventory holding costs for during the OW cycle

$$I_{owk}\ = [C(t_{k-1})\ +\phi\ t\ ]e^{-dt_{k-1}}\left[\int_{t_{k-1}}^{t_{k1}} I_{k1}(t)e^{-d}\ dt + \int_{t_{k1}}^{t_{k3}} I_{k5}(t)e^{-dt}dt\ +\int_{t_{k3}}^{t_{k-1}} I_{k4}(t)e^{-d}\ dt\right]$$

$$=C(t_{k-1})e^{-d(t_{k-1})}\left[\int_{t_{k-1}}^{t_{k1}} I_{k1}(t)e^{-dt}dt\ +\ \int_{t_{k1}}^{t_{k3}} I_{k5}(t)e^{-dt}dt\ +\int_{t_{k3}}^{t_{k4}} I_{k4}(t)e^{-dt}dt\right]$$

$$+\ \phi te^{-d(t_{k-1})}\left[\int_{t_{k-1}}^{t_{k1}} I_{k1}(t)e^{-dt}dt\ +\ \int_{t_{k1}}^{t_{k3}} I_{k5}(t)e^{-dt}dt\ +\int_{t_{k3}}^{t_{k4}} I_{k4}(t)e^{-dt}dt\right] \qquad (17)$$

Cost of the cycle's present worth setup

$$C_{s,k} = C_{so}e^{((\sigma+3)\,-d)t_{k-1}},\ k = 1,2,3\ldots\ldots k \tag{18}$$

The cycle's present-value production cost

$$\mathrm{P}C_k\ \ n_0((Rp+3))e^{((\sigma+3)\,-d)t_{k-1}}\left[\int_{t_{k-1}}^{k1}(Rp+3)e^{-d}\ dt\ +\int_{t_{k-2}}^{k1}(Rp+3)e^{-dt}dt\ +\right] \tag{19}$$

As a result, the cycle's total variable cost's present value

$$T_{Ck}\ =\ I_{RWk}\ +\ I_{OWk}\ +PC_k\ +C_{sk}\ ,\ \ \mathrm{k}=1,2,3\ldots\ldots\mathrm{n} \tag{20}$$

The current value of the system's total variable cost during the course of the planning horizon H is provided by

$$TC_H(n,(Rp+3)) = \sum_{k=1}^{n} TC_k\ = \sum_{k=1}^{n}\left[I_{RW,k}\ +\ I_{OW,k}\ +PC_k\ +C_{sk}\right]\ ,\ \mathrm{k}=1,2,3\ldots.\ \mathrm{n} \tag{21}$$

Our task is to ascertain the ideal value of Rp and n where Rp is decision variables and n discrete variable which minimizes $TC_n((Rp+3),n)$.For any given value of $n = n_0$ he necessary condition $TC_H((Rp+3),n)$ for to be minimum

$$\frac{dTC_H((Rp+3),n)}{dp}\ =\ 0 \tag{22}$$

Provided

$$\frac{d^2TC_H((Rp+3),n)}{d(Rp+3)^2}\ >\ 0 \tag{23}$$

5. Artificial Bee Colony

We can express the general structure of the algorithm as follows Okula, et, al (81) Investigation of Artificial Intelligence Based Optimization Algorithms. (Karaboğa, 82) (Karaboğa, 83):

Step 1 (Installation Phase): Build N food sources. Specify the corresponding bee particles as numbers in this context. Set the initial algorithm parameter values (eg resource incapacity counter, extinction limit). Make arrangements for the problem.
Step 2: Repeat the following steps during the iterative process (eg until you reach a certain number of iterations or until you reach a desired value in the objective function): (For each bee; for each purpose function size)
Step 2.1: (Worker Bee Phase): Ensure that worker bees select and send food source regions, taking.
Step 2.2: Calculate the objective function value (fitness) depending on the location of the food source and determine the nectar (quality) in the food sources with the objective function values

(fitness) found. Increase or decrease the counters of nonfood food sources according to nectar values.
Step 2.3 (Observer Bee Phase): According to the information from the worker bees to the beekeepers, the nectars in the food sources, perform the probabilistic selection process for the food sources (solutions) to be chosen by the beekeepers. To do this, determine the probability of selection of each source. After the beekeepers choose the food source zones and are sent to these areas as workers, Perform the processes described in step 2.2.
Step 2.4 (Exploring Bee Phase): Check the development counters in the food sources and turn the worker-in-source worker into an explorer bee (usually an explorer bee is formed in each cycle). Make the explorer call the food source.
Step 3: Iteration - At the end of the cycle the value (s) obtained according to the global best position is considered to be the optimum value (s).

6. Numerical Example

Here, they are now considering parameter values in the proper units so that

$(\sigma+3) \ = \ 20.003. d = 20.0065, n = 1/2, W = 2200, C_0 \ = 26, \lambda_1$ =1500, G=3250, R= 275, N=20.005, C_s =2500, H=1/2.

Then the optimal solution is P' =2517.1312, $\eta(P') = 2153.45, TC^* \ = 24493.49$

Table – 1

Demand Parameter λ_0 in Variation

N	λ_0	P'	η^*(P)	TC^* H
½	2500	2517.12	276.72	24493.49
	2550	2567.81	276.67	25175.1
	2600	2618.46	276.63	25880.85
	2650	2669.085	276.60	26608.95
	2700	2719.67	276.59	27358
	2750	2770.25	276.58	28126.5

We have implemented analysis based on Artificial Bee Colony optimization for optimal inventory management on the MATLAB platform. As mentioned, we have the detailed information on the excess and shortage stock levels in each member of the supply chain, the most important times of the product inventory levels to replenish each member of the supply chain, and the main time of the commodity. Sample data with this information is shown in Table 2.

Table 2: An example data set the length of with its stock level in each member of the Flower Pollination Optimization

Artificial Bee Colony optimization							
T-1	248.5	235.0	226.7	215.0	216.7	222.5	247.2
T-2	247.5	232.1	226.9	212.1	216.9	226.5	244.2
T-3	246.5	233.1	226.2	213.1	216.2	222.2	246.2
T-4	245.5	234.1	226.5	214.1	216.5	223.3	244.3
T-5	238.5	225.0	246.7	225.0	246.7	232.5	227.2
T-6	237.5	222.1	246.9	222.1	246.9	236.5	224.2
T-7	236.5	223.1	246.2	223.1	246.2	232.2	226.2
T-8	235.5	224.1	246.5	224.1	246.5	233.3	224.3

7. Conclusion:

conclusion, this study has delved into the application of Artificial Bee Colony (ABC) Optimization for optimizing supply chain inventory in a Two-warehouse system. The complexities inherent in managing inventory across multiple warehouses pose significant challenges, and the use of ABC Optimization has proven to be a promising approach to address these complexities.

Through a careful problem definition, formulation of an objective function, and adaptation of the ABC algorithm, we aimed to minimize overall costs associated with inventory management. The results obtained from the implementation of the ABC algorithm demonstrated its effectiveness in finding solutions that enhance supply chain efficiency in a Two-warehouse setting.

The insights gained from this study highlight the practical applicability of ABC Optimization in real-world supply chain scenarios. Decision-makers can leverage the findings to make informed choices regarding inventory control, leading to cost savings, improved logistics, and better overall supply chain performance.

As the field of optimization in supply chain management continues to evolve, the integration of nature-inspired algorithms like ABC Optimization offers a promising avenue for addressing the intricacies of modern supply chain challenges. Future research could explore further refinements to the algorithm, consider additional factors in the optimization model, and assess its performance in diverse supply chain contexts.

In summary, the application of ABC Optimization in a Two-warehouse system has proven to be a valuable strategy for optimizing inventory levels and improving the overall efficiency of the supply chain. This research contributes to the broader understanding of optimization techniques in supply chain management, providing practical insights for businesses striving to enhance their inventory control strategies.

References:

[1] Yadav, A.S., Bansal, K.K., Shivani, Agarwal, S. And Vanaja, R. (2020) FIFO in Green Supply Chain Inventory Model of Electrical Components Industry With Distribution Centres Using Particle Swarm Optimization. Advances in Mathematics: Scientific Journal. 9 (7), 5115–5120.

[2] Yadav, A.S., Kumar, A., Agarwal, P., Kumar, T. And Vanaja, R. (2020) LIFO in Green Supply Chain Inventory Model of Auto-Components Industry with Warehouses Using Differential Evolution. Advances in Mathematics: Scientific Journal, 9 no.7, 5121–5126.

[3] Yadav, A.S., Abid, M., Bansal, S., Tyagi, S.L. And Kumar, T. (2020) FIFO & LIFO in Green Supply Chain Inventory Model of Hazardous Substance Components Industry with Storage Using Simulated Annealing. Advances in Mathematics: Scientific Journal, 9 no.7, 5127–5132.

[4] Yadav, A.S., Tandon, A. and Selva, N.S. (2020) National Blood Bank Centre Supply Chain Management For Blockchain Application Using Genetic Algorithm. International Journal of Advanced Science and Technology Vol. 29, No. 8s, 1318-1324.

[5] Yadav, A.S., Selva, N.S. and Tandon, A. (2020) Medicine Manufacturing Industries supply chain management for Blockchain application using artificial neural networks, International Journal of Advanced Science and Technology Vol. 29, No. 8s, 1294-1301.

[6] Yadav, A.S., Ahlawat, N., Agarwal, S., Pandey, T. and Swami, A. (2020) Red Wine Industry of Supply Chain Management for Distribution Center Using Neural Networks, Test Engraining & Management, Volume 83 Issue: March – April, 11215 – 11222.

[7] Yadav, A.S., Pandey, T., Ahlawat, N., Agarwal, S. and Swami, A. (2020) Rose Wine industry of Supply Chain Management for Storage using Genetic Algorithm. Test Engraining & Management, Volume 83 Issue: March – April, 11223 – 11230.

[8] Yadav, A.S., Ahlawat, N., Sharma, N., Swami, A. And Navyata (2020) Healthcare Systems of Inventory Control For Blood Bank Storage With Reliability Applications Using Genetic Algorithm. Advances in Mathematics: Scientific Journal 9 no.7, 5133–5142.

[9] Yadav, A.S., Dubey, R., Pandey, G., Ahlawat, N. and Swami, A. (2020) Distillery Industry Inventory Control for Storage with Wastewater Treatment & Logistics Using Particle Swarm Optimization Test Engraining & Management Volume 83 Issue: May – June, 15362-15370.

[10] Yadav, A.S., Ahlawat, N., Dubey, R., Pandey, G. and Swami, A. (2020) Pulp and paper industry inventory control for Storage with wastewater treatment and Inorganic composition using genetic algorithm (ELD Problem). Test Engraining & Management, Volume 83 Issue: May – June, 15508-15517.

[11] Yadav, A.S., Pandey, G., Ahlawat, N., Dubey, R. and Swami, A. (2020) Wine Industry Inventory Control for Storage with Wastewater Treatment and Pollution Load Using Ant Colony Optimization Algorithm, Test Engraining & Management, Volume 83 Issue: May – June, 15528-15535.

[12] Yadav, A.S., Navyata, Sharma, N., Ahlawat, N. and Swami, A. (2020) Reliability Consideration costing method for LIFO Inventory model with chemical industry warehouse. International Journal of Advanced Trends in Computer Science and Engineering, Volume 9 No 1, 403-408.

[13] Yadav, A.S., Bansal, K.K., Kumar, J. and Kumar, S. (2019) Supply Chain Inventory Model For Deteriorating Item With Warehouse & Distribution Centres Under Inflation. International Journal of Engineering and Advanced Technology, Volume-8, Issue-2S2, 7-13.

[14] Yadav, A.S., Kumar, J., Malik, M. and Pandey, T. (2019) Supply Chain of Chemical Industry For Warehouse With Distribution Centres Using Artificial Bee Colony Algorithm. International Journal of Engineering and Advanced Technology, Volume-8, Issue-2S2, 14-19.

[15] Yadav, A.S., Navyata, Ahlawat, N. and Pandey, T. (2019) Soft computing techniques based Hazardous Substance Storage Inventory Model for decaying Items and Inflation using Genetic Algorithm. International Journal of Advance Research and Innovative Ideas in Education, Volume 5 Issue 9, 1102-1112.

[16] Yadav, A.S., Navyata, Ahlawat, N. and Pandey, T. (2019) Hazardous Substance Storage Inventory Model for decaying Items using Differential Evolution. International Journal of Advance Research and Innovative Ideas in Education, Volume 5 Issue 9, 1113-1122.

[17] Yadav, A.S., Navyata, Ahlawat, N. and Pandey, T. (2019) Probabilistic inventory model based Hazardous Substance Storage for decaying Items and Inflation using Particle Swarm Optimization. International Journal of Advance Research and Innovative Ideas in Education, Volume 5 Issue 9, 1123-1133.

[18] Yadav, A.S., Navyata, Ahlawat, N. and Pandey, T. (2019) Reliability Consideration based Hazardous Substance Storage Inventory Model for decaying Items using Simulated Annealing. International Journal of Advance Research and Innovative Ideas in Education, Volume 5 Issue 9, 1134-1143.

[19] Yadav, A.S., Swami, A. and Kher, G. (2019) Blood bank supply chain inventory model for blood collection sites and hospital using genetic algorithm. Selforganizology, Volume 6 No.(3-4), 13-23.

[20] Yadav, A.S., Swami, A. and Ahlawat, N. (2018) A Green supply chain management of Auto industry for inventory model with distribution centers using Particle Swarm Optimization. Selforganizology, Volume 5 No. (3-4)

[21] Yadav, A.S., Ahlawat, N., and Sharma, S. (2018) Hybrid Techniques of Genetic Algorithm for inventory of Auto industry model for deteriorating items with two warehouses. International Journal of Trend in Scientific Research and Development, Volume 2 Issue 5, 58-65.

[22] Yadav, A.S., Swami, A. and Gupta, C.B. (2018) A Supply Chain Management of Pharmaceutical For Deteriorating Items Using Genetic Algorithm. International Journal for Science and Advance Research In Technology, Volume 4 Issue 4, 2147-2153.

[23] Yadav, A.S., Maheshwari, P., Swami, A., and Pandey, G. (2018) A supply chain management of chemical industry for deteriorating items with warehouse using genetic algorithm. Selforganizology, Volume 5 No.1-2, 41-51.

[24] Yadav, A.S., Garg, A., Gupta, K. and Swami, A. (2017) Multi-objective Genetic algorithm optimization in Inventory model for deteriorating items with shortages using Supply Chain management. IPASJ International journal of computer science, Volume 5, Issue 6, 15-35.

[25] Yadav, A.S., Garg, A., Swami, A. and Kher, G. (2017) A Supply Chain management in Inventory Optimization for deteriorating items with Genetic algorithm. International Journal of Emerging Trends & Technology in Computer Science, Volume 6, Issue 3, 335-352.

[26] Yadav, A.S., Maheshwari, P., Garg, A., Swami, A. and Kher, G. (2017) Modeling& Analysis of Supply Chain management in Inventory Optimization for deteriorating items with Genetic algorithm and Particle Swarm optimization. International Journal of Application or Innovation in Engineering & Management, Volume 6, Issue 6, 86-107.

[27] Yadav, A.S., Garg, A., Gupta, K. and Swami, A. (2017) Multi-objective Particle Swarm optimization and Genetic algorithm in Inventory model for deteriorating items with shortages using Supply Chain management. International Journal of Application or Innovation in Engineering & Management, Volume 6, Issue 6, 130-144.

[28] Yadav, A.S., Swami, A. and Kher, G. (2017) Multi-Objective Genetic Algorithm Involving Green Supply Chain Management International Journal for Science and Advance Research In Technology, Volume 3 Issue 9, 132-138.

[29] Yadav, A.S., Swami, A., Kher, G. (2017) Multi-Objective Particle Swarm Optimization Algorithm Involving Green Supply Chain Inventory Management. International Journal for Science and Advance Research In Technology, Volume 3 Issue, 240-246.

[30] Yadav, A.S., Swami, A. and Pandey, G. (2017) Green Supply Chain Management for Warehouse with Particle Swarm Optimization Algorithm. International Journal for Science and Advance Research in Technology, Volume 3 Issue 10, 769-775.

[31] Yadav, A.S., Swami, A., Kher, G. and Garg, A. (2017) Analysis of seven stages supply chain management in electronic component inventory optimization for warehouse with economic load dispatch using genetic algorithm. Selforganizology, 4 No.2, 18-29 .

[32] Yadav, A.S., Maheshwari, P., Swami, A. and Garg, A. (2017) Analysis of Six Stages Supply Chain management in Inventory Optimization for warehouse with Artificial bee colony algorithm using Genetic Algorithm. Selforganizology, Volume 4 No.3, 41-51.

[33] Yadav, A.S., Swami, A., Gupta, C.B. and Garg, A. (2017) Analysis of Electronic component inventory Optimization in Six Stages Supply Chain management for warehouse with ABC using genetic algorithm and PSO. Selforganizology, Volume 4 No.4, 52-64.

[34] Yadav, A.S., Maheshwari, P. and Swami, A. (2016) Analysis of Genetic Algorithm and Particle Swarm Optimization for warehouse with Supply Chain management in Inventory control. International Journal of Computer Applications, Volume 145 –No.5, 10-17.

[35] Yadav, A.S., Swami, A. and Kumar, S. (2018) Inventory of Electronic components model for deteriorating items with warehousing using Genetic Algorithm. International Journal of Pure and Applied Mathematics, Volume 119 No. 16, 169-177.

[36] Yadav, A.S., Johri, M., Singh, J. and Uppal, S. (2018) Analysis of Green Supply Chain Inventory Management for Warehouse With Environmental Collaboration and Sustainability Performance Using Genetic Algorithm. International Journal of Pure and Applied Mathematics, Volume 118 No. 20, 155-161.

[37] Yadav, A.S., Ahlawat, N., Swami, A. and Kher, G. (2019) Auto Industry inventory model for deteriorating items with two warehouse and Transportation Cost using Simulated Annealing Algorithms. International Journal of Advance Research and Innovative Ideas in Education, Volume 5,Issue 1, 24-33.

[38] Yadav, A.S., Ahlawat, N., Swami, A. and Kher, G. (2019) A Particle Swarm Optimization based a two-storage model for deteriorating items with Transportation Cost and Advertising Cost: The Auto Industry. International Journal of Advance Research and Innovative Ideas in Education, Volume 5, Issue 1, 34-44.

[39] Yadav, A.S., Ahlawat, N., and Sharma, S. (2018) A Particle Swarm Optimization for inventory of Auto industry model for two warehouses with deteriorating items. International Journal of Trend in Scientific Research and Development, Volume 2 Issue 5, 66-74.

[40] Yadav, A.S., Swami, A. and Kher, G. (2018) Particle Swarm optimization of inventory model with two-warehouses. Asian Journal of Mathematics and Computer Research, Volume 23 No.1, 17-26.

[41] Yadav, A.S., Maheshwari, P.,, Swami, A. and Kher, G. (2017) Soft Computing Optimization of Two Warehouse Inventory Model With Genetic Algorithm. Asian Journal of Mathematics and Computer Research, Volume 19 No.4, 214-223.

[42] Yadav, A.S., Swami, A., Kumar, S. and Singh, R.K. (2016) Two-Warehouse Inventory Model for Deteriorating Items with Variable Holding Cost, Time-Dependent Demand and Shortages. IOSR Journal of Mathematics, Volume 12, Issue 2 Ver. IV, 47-53.

[43] Yadav, A.S., Sharam, S. and Swami, A. (2016) Two Warehouse Inventory Model with Ramp Type Demand and Partial Backordering for Weibull Distribution Deterioration. International Journal of Computer Applications, Volume 140 –No.4, 15-25.

[44] Yadav, A.S., Swami, A. and Singh, R.K. (2016) A two-storage model for deteriorating items with holding cost under inflation and Genetic Algorithms. International Journal of Advanced Engineering, Management and Science, Volume -2, Issue-4, 251-258.

[45] Yadav, A.S., Swami, A., Kher, G. and Kumar, S. (2017) Supply Chain Inventory Model for Two Warehouses with Soft Computing Optimization. International Journal of Applied Business and Economic Research, Volume 15 No 4, 41-55.

[46] Yadav, A.S., Rajesh Mishra, Kumar, S. and Yadav, S. (2016) Multi Objective Optimization for Electronic Component Inventory Model & Deteriorating Items with Two-warehouse using Genetic Algorithm. International Journal of Control Theory and applications, Volume 9 No.2, 881-892.

[47] Yadav, A.S., Gupta, K., Garg, A. and Swami, A. (2015) A Soft computing Optimization based Two Ware-House Inventory Model for Deteriorating Items with shortages using Genetic Algorithm. International Journal of Computer Applications, Volume 126 – No.13, 7-16.

[48] Yadav, A.S., Gupta, K., Garg, A. and Swami, A. (2015) A Two Warehouse Inventory Model for Deteriorating Items with Shortages under Genetic Algorithm and PSO. International Journal of Emerging Trends & Technology in Computer Science, Volume 4, Issue 5(2), 40-48.

[49] Yadav, A.S. Swami, A., and Kumar, S. (2018) A supply chain Inventory Model for decaying Items with Two Ware-House and Partial ordering under Inflation. International Journal of Pure and Applied Mathematics, Volume 120 No 6, 3053-3088.

[50] Yadav, A.S. Swami, A. and Kumar, S. (2018) An Inventory Model for Deteriorating Items with Two warehouses and variable holding Cost. International Journal of Pure and Applied Mathematics, Volume 120 No 6, 3069-3086.

[51] Yadav, A.S., Taygi, B., Sharma, S. and Swami, A. (2017) Effect of inflation on a two-warehouse inventory model for deteriorating items with time varying demand and shortages. International Journal Procurement Management, Volume 10, No. 6, 761-775.

[52] Yadav, A.S., R. P. Mahapatra, Sharma, S. and Swami, A. (2017) An Inflationary Inventory Model for Deteriorating items under Two Storage Systems. International Journal of Economic Research, Volume 14 No.9, 29-40.

[53] Yadav, A.S., Sharma, S. and Swami, A. (2017) A Fuzzy Based Two-Warehouse Inventory Model For Non instantaneous Deteriorating Items With Conditionally Permissible Delay In Payment. International Journal of Control Theory And Applications, Volume 10 No.11, 107-123.

[54] Yadav, A.S. and Swami, A. (2018) Integrated Supply Chain Model for Deteriorating Items With Linear Stock Dependent Demand Under Imprecise And Inflationary Environment. International Journal Procurement Management, Volume 11 No 6, 684-704.

[55] Yadav, A.S. and Swami, A. (2018) A partial backlogging production-inventory lot-size model with time-varying holding cost and weibull deterioration. International Journal Procurement Management, Volume 11, No. 5, 639-649.

[56] Yadav, A.S. and Swami, A. (2013) A Partial Backlogging Two-Warehouse Inventory Models For Decaying Items With Inflation. International Organization of Scientific Research Journal of Mathematics, Issue 6, 69-78.

[57] Yadav, A.S. and Swami, A. (2019) An inventory model for non-instantaneous deteriorating items with variable holding cost under two-storage. International Journal Procurement Management, Volume 12 No 6, 690-710.

[58] Yadav, A.S. and Swami, A. (2019) A Volume Flexible Two-Warehouse Model with Fluctuating Demand and Holding Cost under Inflation. International Journal Procurement Management, Volume 12 No 4, 441-456.

[59] Yadav, A.S. and Swami, A. (2014) Two-Warehouse Inventory Model for Deteriorating Items with Ramp-Type Demand Rate and Inflation. American Journal of Mathematics and Sciences Volume 3 No-1, 137-144.

[60] Yadav, A.S. and Swami, A. (2013) Effect of Permissible Delay on Two-Warehouse Inventory Model for Deteriorating items with Shortages. International Journal of Application or Innovation in Engineering & Management, Volume 2, Issue 3, 65-71.

[61] Yadav, A.S. and Swami, A. (2013) A Two-Warehouse Inventory Model for Decaying Items with Exponential Demand and Variable Holding Cost. International of Inventive Engineering and Sciences, Volume-1, Issue-5, 18-22.

[62] Yadav, A.S. and Kumar, S. (2017) Electronic Components Supply Chain Management for Warehouse with Environmental Collaboration & Neural Networks. International Journal of Pure and Applied Mathematics, Volume 117 No. 17, 169-177.

[63] Yadav, A.S. (2017) Analysis of Seven Stages Supply Chain Management in Electronic Component Inventory Optimization for Warehouse with Economic Load Dispatch Using GA and PSO. Asian Journal Of Mathematics And Computer Research, volume 16 No.4, 208-219.

[64] Yadav, A.S. (2017) Analysis Of Supply Chain Management In Inventory Optimization For Warehouse With Logistics Using Genetic Algorithm International Journal of Control Theory And Applications, Volume 10 No.10, 1-12 .

[65] Yadav, A.S. (2017) Modeling and Analysis of Supply Chain Inventory Model with two-warehouses and Economic Load Dispatch Problem Using Genetic Algorithm. International Journal of Engineering and Technology, Volume 9 No 1, 33-44.

[66] Swami, A., Singh, S.R., Pareek, S. and Yadav, A.S. (2015) Inventory policies for deteriorating item with stock dependent demand and variable holding costs under permissible delay in payment. International Journal of Application or Innovation in Engineering & Management, Volume 4, Issue 2, 89-99.

[67] Swami, A., Pareek, S., Singh S.R. and Yadav, A.S. (2015) Inventory Model for Decaying Items with Multivariate Demand and Variable Holding cost under the facility of Trade-Credit. International Journal of Computer Application, 18-28.

[68] Swami, A., Pareek, S., Singh, S.R. and Yadav, A.S. (2015) An Inventory Model With Price Sensitive Demand, Variable Holding Cost And Trade-Credit Under Inflation. International Journal of Current Research, Volume 7, Issue, 06, 17312-17321.

[69] Gupta, K., Yadav, A.S., Garg, A. and Swami, A. (2015) A Binary Multi-Objective Genetic Algorithm &PSO involving Supply Chain Inventory Optimization with Shortages, inflation. International Journal of Application or Innovation in Engineering & Management, Volume 4, Issue 8, 37-44.

[70] Gupta, K., Yadav, A.S., Garg, A., (2015) Fuzzy-Genetic Algorithm based inventory model for shortages and inflation under hybrid & PSO. IOSR Journal of Computer Engineering, Volume 17, Issue 5, Ver. I , 61-67.

[71] Singh, R.K., Yadav, A.S. and Swami, A. (2016) A Two-Warehouse Model for Deteriorating Items with Holding Cost under Particle Swarm Optimization. International Journal of Advanced Engineering, Management and Science, Volume -2, Issue-6, 858-864.

[72] Singh, R.K., Yadav, A.S. and Swami, A. (2016) A Two-Warehouse Model for Deteriorating Items with Holding Cost under Inflation and Soft Computing Techniques. International Journal of Advanced Engineering, Management and Science, Volume -2, Issue-6, 869-876.

[73] Kumar, S., Yadav, A.S., Ahlawat, N. and Swami, A. (2019) Supply Chain Management of Alcoholic Beverage Industry Warehouse with Permissible Delay in Payments using Particle Swarm Optimization. International Journal for Research in Applied Science and Engineering Technology, Volume 7 Issue VIII, 504-509.

[74] Kumar, S., Yadav, A.S., Ahlawat, N. and Swami, A. (2019) Green Supply Chain Inventory System of Cement Industry for Warehouse with Inflation using Particle Swarm Optimization. International Journal for Research in Applied Science and Engineering Technology, Volume 7 Issue VIII, 498-503.

[75] Kumar, S., Yadav, A.S., Ahlawat, N. and Swami, A. (2019) Electronic Components Inventory Model for Deterioration Items with Distribution Centre using Genetic Algorithm. International Journal for Research in Applied Science and Engineering Technology, Volume 7 Issue VIII, 433-443.

[76] Chauhan, N. and Yadav, A.S. (2020) An Inventory Model for Deteriorating Items with Two-Warehouse & Stock Dependent Demand using Genetic algorithm. International Journal of Advanced Science and Technology, Vol. 29, No. 5s, 1152-1162 .

[77] Chauhan, N. and Yadav, A.S. (2020) Inventory System of Automobile for Stock Dependent Demand & Inflation with Two-Distribution Center Using Genetic Algorithm. Test Engraining & Management, Volume 83, Issue: March – April, 6583 – 6591.

[78] Pandey, T., Yadav, A.S. and Medhavi Malik (2019) An Analysis Marble Industry Inventory Optimization Based on Genetic Algorithms and Particle swarm optimization. International Journal of Recent Technology and Engineering Volume-7, Issue-6S4, 369-373.

[79] Ahlawat, N., Agarwal, S., Pandey, T., Yadav, A.S., Swami, A. (2020) White Wine Industry of Supply Chain Management for Warehouse using Neural Networks Test Engraining & Management, Volume 83, Issue: March – April, 11259 – 11266.

[80] Singh, S. Yadav, A.S. and Swami, A. (2016) An Optimal Ordering Policy For Non-Instantaneous Deteriorating Items With Conditionally Permissible Delay In Payment

Under Two Storage Management International Journal of Computer Applications, Volume 147 –No.1, 16-25.