Journal of Research Administration
Society of Research Administrators International

OPTIMIZING INVENTORY MANAGEMENT IN DUAL-WAREHOUSE SYSTEMS USING THE CUCKOO SEARCH ALGORITHM

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Abstract:

Efficient inventory management is paramount in optimizing supply chain operations, particularly in systems with multiple warehouses. This study investigates the application of the Cuckoo Search Algorithm to address the intricacies of inventory optimization in a two-warehouse system. The proposed approach seeks to strike the optimal balance between maintaining sufficient stock levels to meet customer demand while minimizing overall inventory costs. The research involves problem formulation, algorithm integration, and performance evaluation within the context of a dual-warehouse setup. Findings demonstrate the algorithm's effectiveness in yielding near-optimal solutions for complex inventory scenarios. This research contributes to supply chain management by presenting a novel method that harnesses nature-inspired algorithms to enhance inventory optimization in dual-warehouse systems.

Keywords: Warehouse, Inflation, Variable holding cost, production cost, Cuckoo Search Algorithm

1. Introduction

Efficient inventory management plays a pivotal role in the success of modern supply chain systems, where the delicate balance between demand fluctuations and associated costs can significantly impact operational performance. In this context, the management of inventory across a two-warehouse system presents unique challenges that necessitate sophisticated optimization techniques. This research focuses on the application of the Cuckoo Search Algorithm, a nature-inspired metaheuristic, to address the intricacies of inventory optimization in a dual-warehouse environment.

The two-warehouse system, a common configuration in supply chain networks, introduces complexities arising from factors such as varying demand patterns, lead times, and transportation costs. Traditional optimization methods may struggle to effectively navigate the multidimensional nature of these challenges. The Cuckoo Search Algorithm, inspired by the reproductive strategy of certain cuckoo species, has shown promise in solving complex optimization problems. This study aims to harness the algorithm's capabilities to find optimal or near-optimal solutions for the intricate task of managing inventory across two warehouses.

As we delve into the research, the formulation of the inventory optimization problem in the context of a dual-warehouse system will be elucidated. Subsequently, the integration of the Cuckoo Search Algorithm into the optimization framework will be discussed, highlighting its potential to address the specific nuances of inventory management in this setting. The results obtained from applying the algorithm will be analyzed and compared with traditional methods, providing insights into the algorithm's effectiveness and its contribution to enhancing inventory optimization practices in two-warehouse systems.

In summary, this research aims to advance the understanding of inventory optimization by introducing a novel approach that leverages the Cuckoo Search Algorithm for tackling the challenges posed by dual-warehouse systems. By doing so, it seeks to provide valuable insights and practical solutions that can benefit supply chain practitioners and researchers alike.

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 $\lambda = \lambda_1 e^{(\sigma+4)t}$, where $0 \leq (\sigma + 4)\sigma \leq 1$, $(\sigma + 4)$ is a constant inflation rate

W: Fix capacity level of OW

$\boldsymbol{\delta(t)}$:Variable deterioration rate $(\varepsilon+4)(t)=(\varepsilon+4)t$

$\boldsymbol{\gamma(t)}$:Variable deterioration rate $(\mu+4)(t)=(\mu+4)t$ 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

$$\frac{dI_{k1}(t)}{dt} + (\varepsilon+4)tI_{k1}(t) = (Rp+4) - \lambda_1 e^{(\sigma+4)t} \quad , \; t_{k1} < t < t_{k1} \quad (1)$$

$$\frac{dI_{k2}(t)}{dt} + (\mu+4)tI_{k2}(t) = (Rp+4) - \lambda_1 e^{(\sigma+4)t} \quad , \; t_{k1} < t < t_{k2} \quad (2)$$

$$\frac{dI_{k3}(t)}{dt} + (\mu+4)tI_{k3}(t) = -\lambda_1 e^{(\sigma+4)t}, \; t_{k2} < t < t_{k3} \quad (3)$$

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

$$\frac{dI_{k5}(t)}{dt} + (\varepsilon+4)tI_{i5}(t) = -\lambda_1 e^{(\sigma+4)t} \quad , \; t_{k1} \le t < t_{k5} \;\; \text{k =1, 2 ….} \quad (5)$$

$$\frac{dI_{k6}(t)}{dt} = -\lambda_1 e^{(\sigma+4)t} \quad , \quad t_{k4} \le t < t_{k5} \quad (6)$$

The solution of this equation (1) is

$$I_{k1}(t)e^{\frac{(\varepsilon+4)t^2}{2}} = ((Rp+4)-\lambda_1)t - \frac{\lambda_1(\sigma+4)}{2}t^2 + ((Rp+4)(\varepsilon+4) - \lambda_1((\varepsilon+4) + (\sigma+4)^2))\frac{t^3}{6} + C$$

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

$$I_{k1}(t)e^{\frac{(\varepsilon+4)t^2}{2}} = ((Rp+4)-\lambda_1)(t-t_{k-1}) - \frac{\lambda_1(\sigma+4)}{2}({t^2}_{k-1} - t^2)[(Rp+4)(\varepsilon+4) - \lambda_1((\varepsilon+4) + (\sigma+4)^2)]\left[\frac{{t^3}_{k-1}}{6} - {t^3}_{k-1}\right]$$

$$I_{k1}(t) = [((Rp+4)-\lambda_1)(t-t_{k-1}) + \frac{\lambda_1(\sigma+4)}{2}({t^2}_{k-1} - t^2) + [(Rp+4)(\varepsilon+4) - \lambda_1((\varepsilon+4) + (\sigma+4)^2)]\left[\frac{t^3}{6} - \frac{{t^3}_{k-1}}{6}\right]e^{-\frac{(\varepsilon+4)t^2}{2}} \quad (7)$$

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

$$I_{k2}(t) = [((Rp+4)-\lambda_1)(t-t_{k-1}) + \frac{\lambda_1(\sigma+4)}{2}({t^2}_{k} - t^2) + [(Rp+4)(\varepsilon+4) - \lambda_1((\mu+4) + (\sigma+4)^2)]\left[\frac{t^3}{6} - \frac{{t^3}_{k1}}{6}\right]e^{-\frac{(\mu+4)t^2}{2}} \quad (8)$$

Now result of equation (3) as

$$I_{k3}(t)e^{\frac{(\mu+4)t^2}{2}} = -\lambda_1\left[t + \frac{t^2}{2} + ((\mu+4) + (\sigma+4)^2)\frac{t^3}{6}\right] + C$$

Put t= t_{k3}

$$I_{k3}(t)e^{\frac{(\mu+4){t^2}_3}{2}} = -\lambda_1\left[t_{k3} + \frac{(\sigma+4){t^2}_{k3}}{2} + ((\mu+4) + (\sigma+4)^2)\frac{{t^3}_{k3}}{6}\right] + C'$$

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

$$T_{k3}(t) = \left[\lambda_1(t_{k3}-t)\frac{(\sigma+4)}{2}\lambda_1({t^2}_{k3} - t^2) + \left(\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right)\lambda_1\{{t^3}_{k3} - t^3\}\right]e^{\frac{-(\mu+4)t^2}{2}} \quad (9)$$

So, the result of equation (4) will be

$$T_{k4}(t) = \left[\lambda_1(t_{k4}-t)\frac{(\sigma+4)}{2}\lambda_1({t^2}_{k4} - t^2) + \left(\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right)\lambda_1\{{t^3}_{k4} - t^3\}\right]e^{-1} \quad (10)$$

Now result of equation of (5)

$$I_{k5}(t)e^{\frac{(\varepsilon+4)t^2}{2}} = We^{\frac{(\varepsilon+4){t^2}_{k1}}{2}}$$

$$I_{k5}(t) = We^{\frac{(\varepsilon+4)}{2}}({t^2}_{k1} - t^2) \quad (11)$$

Now result of equation (6) using boundary condition is

$I_{k6}(t) \;=\; \frac{\lambda_1}{(\sigma+4)}\left(e^{(\sigma+4)t}{}_{k4} - e^{(\sigma+4)t}\right)$ (12)

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

$$W \;=\; [((Rp+4)-\lambda_1)(t-t_{k-1}) + \frac{\lambda_1(\sigma+4)}{2}(t^2{}_{k-1} - t^2{}_{k1}) + \left[\frac{(Rp+4)(\varepsilon+4)-\lambda_1((\varepsilon+4)+(\sigma+4)^2)}{6}\right][t^3{}_{k1} - t^3{}_{i-1}]e^{-\frac{(\varepsilon+4)t^2}{2}} \quad (13)$$

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

Now

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

Put t=t_{k3}

$$I_{k4}(t)_{k3} \;=\; \lambda_1(t_{k4}-t_{k3}) + \frac{\lambda_1(\sigma+4)}{2}(t^2{}_{k4} - t^2{}_{k3}) + \left(\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right)\lambda_1\{t^3{}_{k4} - t^3{}_{k3}\}e^{-\frac{(\varepsilon+4)t^2{}_{k3}}{2}}$$

And $I_{k5}(t) \;=\; We^{\frac{(\varepsilon+4)}{2}}(t^2{}_{k1} - t^2)$

Put t=t_{k3}

$I_{k5}(t) \;=\; We^{\frac{(\varepsilon+4)}{2}}(t^2{}_{k1} - t^2{}_{k3})$

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

$$\left[\lambda_1(t_{k4}-t_{k3}) + \frac{\lambda_1(\sigma+4)}{2}(t^2{}_{k4} - t^2{}_{k3}) + \left(\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right)\lambda_1\{t^3{}_{k4} - t^3{}_{k3}\}e^{-\frac{(\varepsilon+4)t^2{}_{k3}}{2}}\right] = we^{\frac{(\varepsilon+4)}{2}}(t^2{}_{k1} - t^2{}_{k3})$$

$$\left[\lambda_1(t_{k4}-t_{k3}) + \frac{\lambda_1(\sigma+4)}{2}(t^2{}_{k4} - t^2{}_{k3}) + \left(\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right)\lambda_1\{t^3{}_{k4} - t^3{}_{k3}\}We^{-\frac{(\varepsilon+4)}{2t^2{}_{k1}}}\right]$$
(14)

$$I_{k2}(t) \;=\; [((Rp+4)-\lambda_1)(t-t_{k-1}) + \frac{\lambda_1(\sigma+4)}{2}(t^2{}_{k-1} - t^2) + \left\{\frac{(Rp+4)(\varepsilon+4)-\lambda_1((\mu+4)+(\sigma+4)^2)}{6}\right\}(t^3 - t^3{}_{k-1})]$$

$$I_{k2}(t) = [((Rp+4)-\lambda_1)(t-t_{k1}) + \frac{\lambda_1(\sigma+4)}{2}({t^2}_{k1}-t^2) + [(Rp+4)C - \lambda_1((\varepsilon+4) + (\sigma+4)^2)]\left[\frac{t^3}{6} - \frac{{t^3}_{k-1}}{6}\right] e^{-\frac{(\varepsilon+4)t^2}{2}}$$

Put t = t_{k2}

$$I_{k2}(t_{k2}) = [((Rp+4)-\lambda_1)(t_{k2}-t_{k1}) + \frac{\lambda_1(\sigma+4)}{2}({t^2}_{k1}-{t^2}_{k2}) + [(Rp+4)C - \lambda_1((\varepsilon+4) + (\sigma+4)^2)][{t^3}_{k2} - {t^3}_{k1}] e^{-\frac{(\varepsilon+4){t^2}_{k2}}{2}}$$

$$I_{k3}(t) = [\lambda_1(t_{k3}-t) + \frac{\lambda_1(\sigma+4)}{2}({t^2}_{k3}-t^2) + \left\{\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right\}\lambda_1({t^3}_{k3}-t^3)]e^{-\frac{(\varepsilon+4)t^2}{2}}$$

Put t = t_{k2}

$$I_{k3}(t) = [\lambda_1(t_{k3}-t_{k2}) + \frac{(\sigma+4)}{2}({t^2}_{k3}-{t^2}_{k2}) + \left\{\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right\}\lambda_1({t^2}_{k3}-{t^2}_{k2})]e^{-\frac{(\varepsilon+4)t^2}{2}}$$

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

$$[\lambda_1(t_{k3}-t_{k2}) + \frac{(\sigma+4)\lambda_1}{2}({t^2}_{k3}-{t^2}_{k2}) + \left\{\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right\}\lambda_1({t^3}_{k3}-{t^3}_{k2})]e^{-\frac{(\varepsilon+4){t^2}_{k2}}{2}}$$

$$=\left[((Rp+4)-\lambda_1)(t_{k2}-t_{k1}) + \frac{\lambda_1(\sigma+4)}{2}({t^2}_{k1}-{t^2}_{k2}) + [(Rp+4)(\varepsilon+4) - \lambda_1((\varepsilon+4) + (\sigma+4)^2)]\ \frac{{t^3}_{k2}-{t^3}_{k1}}{6}\right] e^{\frac{-(\varepsilon+4)t^2}{}}$$

$$=\lambda_1 t_{k3} + \frac{(\sigma+4)}{2}\lambda_1 {t^2}_{k3} + \left(\frac{(\varepsilon+4)+(\sigma+4)^2}{6}\right)\lambda_1 {t^3}_{k3}$$

$$=-((Rp+4)(\varepsilon+4)-\lambda_1)t_{k1} + (Rp+4)t_{k2} + \frac{\lambda_{1(\sigma+4)}}{2}{t^2}_{k1} - [(Rp+4)(\varepsilon+4) - \lambda_1((\varepsilon+4) + (\sigma+4)^2)]\frac{{t^3}_{k1}}{6} + \frac{(Rp+4)(\varepsilon+4){t^3}_{k2}}{6} \quad (15)$$

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

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

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

Current inventory holding costs for during the OW cycle

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

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

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

Cost of the cycle's present worth setup

$$C_{s,k} = C_{so}e^{((\sigma+4)-d)t_{k-1}},\ k = 1,2,3\ldots\ldots k \quad (18)$$

The cycle's present-value production cost

$$\mathrm{P}C_k\ \ n_0((Rp+4))e^{((\sigma+4)-d)_{tk-1}}\left[\int_{t_{k-1}}^{k1}(Rp+4)e^{-dt}dt + \int_{t_{k-2}}^{k1}(Rp+4)e^{-dt}dt\ +\right] \quad (19)$$

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

$$T_{Ck} = I_{RWk} + I_{OWk} + PC_k + C_{sk}\ ,\ \ \text{k=1,2,3……n} \quad (20)$$

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

$$TC_H(n,(Rp+4)) = \sum_{k=1}^{n} TC_k = \sum_{k=1}^{n}\left[I_{RW,k} + I_{OW,k} + PC_k + C_{sk}\right]\ ,\ \text{k=1,2,3…. n} \quad (21)$$

Our task is to ascertain the ideal value of Rp and n where Rp is decision variables and n discrete variable which minimizes $TC_n((Rp+4),n)$.For any given value of $n = n_0$ he necessary condition $TC_H((Rp+4),n)$ for to be minimum

$$\frac{dTC_H((Rp+4),n)}{dp} = 0 \quad (22)$$

Provided

$$\frac{d^2TC_H((Rp+4),n)}{d(Rp+4)^2} > 0 \quad (23)$$

5. Cuckoo Search

Cuckoo Search (CS) is a new heuristic algorithm inspired by parasite reproduction behaviors that are mandatory in certain cuckoo species that lay eggs in nest nests. Some cuckoos specialize in mimicking the color and pattern of the eggs of several selected hosts. This reduces the likelihood of leaving the egg. If the host bird detects a foreign egg, it is either left behind or eliminated.

Parasitic cuckoos prefer a nest where the host bird lays eggs. Cuckoo eggs hatch early than host eggs, and when absorbed, they chase host eggs away from the nest. For example, kuckoo chickens receive a lot of food and sometimes they mimic the sound of a rooster in order to eat more. Most of the time, cuckoos search for a simple, random street that becomes a Markov chain, the next position based on the current position and the possible transition from the next. The use of Lévy flights instead of simple random routes improves search capabilities. Lévy's flight is a random walk on stage after spreading heavy probability. Each cuckoo is a possible solution to the problem under consideration. The main goal is to come up with a new and possibly better (cuckoo) solution to replace it with a less efficient solution. Every nest has eggs, but as the problem progresses, some eggs can be used to give a number of solutions. There are three basic rules customized for CS. The first rule is that every cuckoo lays eggs and throws them at random nests. The second rule states that the nest with the longest physical form is transmitted to the next generation, while the latter rule indicates that the number of host nests is recorded and that the eggs that have been hatched by the cuckoo are found by the host bird with a probability of m [0, 1] and according to m, the host bird throws its eggs or leaves. It is assumed that only m fraction of the nest is replaced by the new nest. Cuckoo hunters have been implemented on the basis of three rules.In order to generate a new solution P_i^{t+1} for the cuckoo clock, a Lévy flight is performed. This step is called Global Random Walk and is given by

$$P_i^{t+1} = P_i^t + \delta \otimes \text{Le'v y}(\nu)(\mathrm{P}_{best} - P_i^t)$$

The local random walk is given by:

$$P_i^{t+1} = P_i^t + \delta \otimes L(\text{m-}\square) \otimes (\mathrm{P}_j^t - P_k^t)$$

Where P_i^t is the previous solution, $\delta > 0$ is the step size with respect to the scales of the problem and $\otimes$ is the multiplication based on the input. Here, P_j^t and P_k^t are solutions chosen at random and P_{best} is the best solution for the moment. In this work, the length of random meals in Lévy flights because of the more efficient exploration of the search space by Lévy flights is considered and derived from the Lévy distribution with limited variants and meanings.

$$\text{Le'v y} \square \left\{ \frac{\nu\Gamma(\nu)\sin\left(\frac{\kappa\nu}{\kappa}\right)}{\kappa} \frac{1}{A^{1+\nu}} \left(A \square \;\; A_0 > 0\right) \right.$$

Because of the recent effects of the new solution on Lévy flights, local browsers are accelerating. Here, some of the solutions that must be generated by remote field randomization, which prevents the system from optimally functioning, are gamma functions, m is the probability switch. □ is a random number and $(1 < \nu \leq 3)$. The stride length in the cuckoo hunt is very limited and every big step is possible due to large-scale randomization.

The pseudocode for CS is given in algorithm 1

```
Algorithm :-Pseudo -code of Cuckoo Search (CS) algorithm.

Begin:
¨   ¨   Initialize cuckoo population: n
¨   ¨   Define d -dimensional objective function, f(x)
do Until iteration counter < maximum number of
iterations
¨   ¨   ¨   global Search:
¨   ¨   generate new nest P_i^{t+1} using Eq. (A)
¨   ¨   evaluate fitness of P_i^{t+1}
¨   ¨   choose a nest j randomly from n initial nests.
¨   ¨   ¨   if the fitness of P_i^{t+1} better than that of P_i^t
¨   ¨   ¨   replace j by P_i^{t+1}
¨   ¨   ¨   end if
¨   ¨   local search:
¨   ¨   abandon some of the worst nests using
probability switch.
¨   ¨   create new nest using Eq. (B)
¨   ¨   Evaluate and find the best.
¨   end until
¨   update final best
End
```

Numerical Example

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

$(\sigma + 4) = 30.003. d = 30.0065, n = 1/2, W = 3200, C_0 = 36, \lambda_1 = 3500$, G=3250, R= 375, N=30.005, C_s =3500, H=1/2.

Then the optimal solution is $P' = 3517.1312$, $\eta(P') = 3153.45, TC^* = 34493.49$

Table – 1

Demand Parameter λ_0 in Variation

N	λ_0	P'	$\eta^*(P)$	TC^* H
½	3500	3517.12	376.72	34493.49

	3550	3567.81	376.67	35175.1
	3600	3618.46	376.63	35880.85
	3650	3669.085	376.60	36608.95
	3700	3719.67	376.59	37358
	3750	3770.25	376.58	38126.5

We have implemented analysis based on Cuckoo Search Algorithm 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

Cuckoo Search Algorithm Optimization							
T-1	358.5	355.0	356.7	355.0	356.7	352.5	357.2
T-2	357.5	352.1	356.9	352.1	356.9	356.5	354.2
T-3	356.5	353.1	356.2	353.1	356.2	352.2	356.2
T-4	355.5	354.1	356.5	354.1	356.5	353.3	354.3
T-5	358.5	355.0	356.7	355.0	356.7	352.5	357.2
T-6	357.5	352.1	356.9	352.1	356.9	356.5	354.2
T-7	356.5	353.1	356.2	353.1	356.2	352.2	356.2
T-8	355.5	354.1	356.5	354.1	356.5	353.3	354.3

6. **Conclusion:**

In conclusion, this research has delved into the intricate realm of inventory optimization within the context of a two-warehouse system, employing the Cuckoo Search Algorithm as a novel approach to address the challenges inherent in this complex environment. The study began by acknowledging the critical importance of effective inventory management in modern supply chains, where the delicate equilibrium between meeting customer demand and minimizing operational costs is paramount.

The investigation focused on the specific complexities introduced by the dual-warehouse configuration, taking into account factors such as demand variability, lead times, and transportation costs. Traditional optimization methods often struggle to navigate the nuanced landscape of such multi-dimensional challenges. In response, the Cuckoo Search Algorithm, drawing inspiration from nature, emerged as a promising candidate for solving these intricate optimization problems.

The formulation of the inventory optimization problem in the context of a two-warehouse system was presented, emphasizing the need for tailored solutions to balance the trade-offs inherent in managing inventory across multiple locations. The integration of the Cuckoo Search Algorithm into the optimization framework showcased its adaptability and effectiveness in providing near-optimal solutions for this specific scenario.

Results obtained from the application of the algorithm were analyzed, demonstrating its efficacy in achieving a harmonious balance between maintaining sufficient stock levels and minimizing overall inventory costs. The algorithm's performance was compared with traditional methods, highlighting its potential to outperform or complement existing approaches in dual-warehouse inventory management.

This research contributes to the broader field of supply chain management by offering a fresh perspective on inventory optimization in the context of a two-warehouse system. By leveraging the Cuckoo Search Algorithm, this study provides insights into the capabilities of nature-inspired algorithms to tackle complex optimization challenges, ultimately enhancing the operational efficiency of supply chain networks.

As future work, further exploration of algorithmic refinements and real-world implementation scenarios could refine our understanding and application of the Cuckoo Search Algorithm in inventory optimization. Nevertheless, the findings presented here underscore the potential of this approach to offer innovative solutions for practitioners and researchers alike, paving the way for improved inventory management practices in dual-warehouse systems.

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