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# Pharmaceutical Drug Two-Warehouse Inventory Model Under FIFO Dispatching Policy Using Ant Colony Optimization for Travelling Salesman Problem

**Ajay Singh Yadav**
SRM Institute of Science and Technology, Uttar Pradesh, India

**Veenita Sharma**
Chaudhary Charan Singh University, Uttar Pradesh, India

**Priyanka Agarwal**
SRM Institute of Science and Technology, Uttar Pradesh, India

**Anupam Swami**
Government Women (P.G.) College Kandhla (Shamli), Uttar Pradesh, India

**Piyush Kumar Yadav**
Veer Bahadur Singh Purvanchal University Jaunpur 222003, India

***Abstract*---**In this paper a deterministic Pharmaceutical drug inventory model for deteriorating items with two level of storage system and time dependent demand with partial backlogged shortages is developed. Stock is transferred RW to OW under bulk release pattern and the transportation cost is taken to be negligible Under FIFO dispatching policy Using Ant Colony Optimization for travelling salesman problem. The deterioration rates in both the warehouses are constant but different due to the different preservation procedures Under FIFO dispatching policy Using Ant Colony Optimization for travelling salesman problem. Holding cost is considered to be constant up to a definite time and is increases. Ant Colony Optimization for travelling salesman problem with varying population size is used to solve the model. In this Ant Colony Optimization for travelling salesman problem a subset of better children is included with the parent population for next generation and size of this subset is a percentage of the size of its parent set. The numerical example is presented to demonstrate the development of mode land to validate it.


***Corresponding author***: *Yadav, P. K.; Email: piyushpk0507@gmail.com*
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Sensitivity analysis is performed separately for each parameter and Ant Colony Optimization for travelling salesman problem.

***Keywords*---**instantaneous deterioration, shortages, time-dependent demand, two warehouses, variable holding cost.

## Introduction

Other drug companies do the same thing during the COVID-19 outbreak, and use their own abilities to ease the burden of the coronavirus on their patients. Eli Lilly has supported the diabetic population with full-page ads in various US newspapers, detailing how they can get support at such a financially volatile time. For many patients with insulin-dependent diabetes, unprecedented financial forecasts may make them unable to access life-saving medications, something Eli Lilly knows (Yadav et al., 2020; Yadav et al., 2021). Therefore, it offered more support to those who lost their business or insurance plans due to the virus. Patients are encouraged to call the Lilly Diabetes Solutions Center, where they can speak to a variety of options, such as switching to the appropriate generics or limiting monthly prescription costs, to ensure there are no interruptions in supply. Global Data expects each pharmaceutical company to find its own unique patient support strategy, as failure to do so can have detrimental effects on reputation (Maiti & Maiti, 2006; Pakkala & Achary, 1992).

The classical Pharmaceuticaldrug inventories models are basically developed with the single warehouse system .In the past, researchers have established a lot of research in the field of Pharmaceutical drug inventory management and Pharmaceutical drug inventory control system. Pharmaceutical drug inventory management and control system basically deals with demand and supply chain problems and for this, production units (Producer of finished goods), vender's, suppliers and retailers need to store the raw materials, finished goods for future demand and supply in the market and to the customers (Rana, 2020; Yadav et al., 2019). In the traditional models it is assumed that the demand and holding cost are constant and goods are supplied instantly underinfinite replenishment policy, when demanded but as time passed away many researchers considered that demand may vary with time, due to price and on the basis of other factors and holding cost also may vary with time and depending on other factors. Many models have been developed considering various time dependent demand with shortages and without shortage. All those models that consider demand variation in response to Pharmaceutical drug inventory level, assume that the holding cost is constant for the entire Pharmaceutical drug inventory cycle. In studies of Pharmaceutical drug inventory models, unlimited warehouse capacity is often assumed (Mishra et al., 2020; Zhang et al., 2015).

However, in busy marketplaces, such as super markets, corporation markets etc the storage area for items may be limited. Another case, of inadequate storage area, can occur when a procurement of a large amount of items is decided (Yadav et al., 2018; Yadav et al., 2017). That could be due to, an attractive price discount for bulk purchase which is available or, when the cost of procuring goods is higher than the other Pharmaceutical drug inventory related costs or, when demand for items is very high or, when the item under consideration is a seasonal product such as the yield of a harvest or, when there are some problems in frequent procurement. In this case these items cannot be accommodated in the existing store house (the own warehouse, abbreviated as OW). Hence, in order to store the excess items, an additional warehouse (the rented warehouse, abbreviated as RW),which may be located at a short distance from the OW or a little away from it, due to non-availability of warehouse nearby, is hired on a rental basis (Yadav et al., 2016; Yadav et al., 2012; Yadav et al., 2015). However, all of the above models have been developed for a single warehouse. It implies that the available storage has unlimited capacity in these models. But, in practice, the capacity of any warehouse is limited. Therefore, the above models are unsuitable for a situation where you need to have a large stock. In fact, there are many practical cases that force the inventory manager to hold more items than can be stored in the OW. For example, one case is that the cost of the surcharge may be higher than the other related costs or the demand for the item may be very high; the second is that managers can get an attractive discount on bulk purchase prices; and so on. In recent years, various researchers have discussed an inventory system with two warehouses (Niu & Zhou, 2013; Datta & Pal, 1991).

Supply chain management can be defined as: "Supply chain management is the coordination of production, stock, location and transportation between actors in supply chain to achieve the best combination of responsiveness and efficiency to a given market. Many researchers in the inventory system have focused on products that do not exceed deterioration (Yadav & Swami, 2014; Yadav & Swami, 2013; Swami et al., 2015). However, there are a number of things whose significance does not remain the same over time. The deterioration of these substances plays an important role and cannot be stored for long. Deterioration of an object can be described as deterioration, evaporation, obsolescence and loss of use or limit of an object, resulting in lower stock consumption compared to natural conditions. When commodities are placed in stock as inventory to meet future needs, there may be deterioration of items in the system of arithmetic that may occur for one or more reasons, etc. Storage conditions, weather or humidity. Inach it is generally claimed that management owns a warehouse to store purchased inventory. However, management can, for a variety of reasons, buy or give more than it can store in its warehouse and name it OW, with an additional number in a rented warehouse called RW located near OW or slightly away from. Inventory costs (including holding costs and depreciation costs) in RW are usually higher than OW costs due to additional costs of handling, equipment maintenance, etc. To reduce the cost of inventory will economically use RW products as soon as possible. Actual customer service is provided only by OW, and in order to reduce costs, RW stocks are first cleaned (Alfares, 2007; Muhlemann & Valtis-Spanopoulos, 1980).

Such arithmetic examples are called two arithmetic examples in the warehouse. Management of supply of electronic storage devices and integration of environment and nervous networks. Analysis of seven supply chain management measures in improving the inventory of electronic devices for storage by sending an economic load using GA and PSO and analysis of supply chain management in improving the inventory of storage and equipment using genetic calculation and model design and analysis of chain inventory from bi warehouse and economic difficulty of freight transport using genetic calculation. Inventory policies of inventory and inventory requirements and different storage costs under allowable payments and inventory delays An example of depreciation of goods and services of various types and costs of holding down a Business-Loan and an inventory model with sensitive needs of prices, holding costs in contrast to loans of business expenses under inflation (Gupta et al., 2015; Kumar et al., 2019). The objectives of the Multiple Objective Genetic Algorithm and PSO, which include the improvement of supply and deficit inventory, inflation, and a calculation model based on a genetic calculation of scarcity and low inflation by PSO. An example with two warehouses depreciation of items and storage costs under particle upgrade and an example with two warehouses of material damage and storage costs in inflation and soft computer techniques. Delayed alcohol supply management and refinement of particles and green cement supply system and inflation using particle enhancement and electronic inventory calculation system and distribution center using genetic calculations. Example of depreciation inventory with two warehouses and stock-based stocks using a genetic inventory and vehicle inventory system for demand and inflation of stocks with two distribution centers using genetic inventory. Marble Analysis Improvement of industrial reserves based on genetic engineering and multi-particle improvement. White wine industry in supply chain management using nervous networks. Best policy for importing damaged items immediately and payment of conditional delays under the supervision of two warehouses (Chauhan & Yadav, 2020; Pandey et al., 2019; Sharma et al., 2016).

**Assumption and notations**

The mathematical model of two warehouse Pharmaceutical drug inventory model for deteriorating items is based on the following notation and assumptions.

Notations:

- $C_A$ = "Cost of ordering under FIFO dispatching policy".
- $\Re^{ow}$ = "The ability of OW under FIFO dispatching policy".
- $\Re^{rw}$ = "The ability of RW under FIFO dispatching policy".
- $T_{F_n}$ = "The length of replenishment cycle under FIFO dispatching policy".
- $Q_{\max}$ = "Maximum Pharmaceutical drug Inventory level per cycle to be ordered".
- $t_{F_1}$: "The time up to which Pharmaceutical drug inventory vanishes in RW".
- $t_{F_2}$ = "The time at which Pharmaceutical drug inventory level reaches to zero in OW and shortages begins".
- $\phi_F$ = "Definite time up to which holding cost is constant under FIFO dispatching policy".
  $\delta_{ow}$ = "The holding cost of time per unit in OW under FIFO dispatching policy".
- $\delta_{rw}$ = "The holding cost of time per unit in RW under FIFO dispatching policy".
- d ="Data collection from RW to OW under FIFO dispatching policy".

- $\left(\prod_{RW}^{FIFO}\right)$ = "Pharmaceutical drug inventory in RW of the level".
- $\left(\prod_{OW_i}^{FIFO}\right)$ = "Pharmaceutical drug inventory in OW of the level *where* $i = 1, 2$".
- $\left(\prod_{S}^{FIFO}\right)$ = "Pharmaceutical drug inventory level at time t in which the product has shortages".
- $(\alpha - 1)$ = "Cost of Deterioration in RW under FIFO dispatching policy".
- $(\beta - 1)$ = "Cost of Deterioration in OW under FIFO dispatching policy".
- $\delta_{P_c}$ = "Cost of Purchase per unit of items under FIFO dispatching policy".
- $\delta_{L_c}$ = "Cost of opportunity of time per unit under FIFO dispatching policy".
- $\delta_{S_c}$ = "Cost of shortages of time per unit under FIFO dispatching policy".
- IB = "Maximum amount of Pharmaceutical drug inventory backlogged under FIFO dispatching policy".
- IL = "Amount of inventory lost under FIFO dispatching policy".
- $D_c(\text{FIFO})$ = "Data collection cost given by µd where $\mu > 0$."
- $P_c(\text{FIFO})$ = Cost of purchas.
- $L_c(FIFO)$ = Current value cost of shortage.
- $S_c(FIFO)$ = Current value cost of lost sale.
- $H_c(FIFO)$ =Current value cost of holding inventory.
- $T^{C}{}_{F}\left[\{t_{F1}, T_{F_n}\}(FIFO)\right]$ =The total relevant Pharmaceutical drug inventory cost per unit time of inventory system under FIFO dispatching policy.

**Assumption**

- “Replenishment rate is infinite and lead time is negligible i.e. zero”.
- “The time horizon of the Pharmaceutical drug inventory system is infinite”.
- “Goods of OW are consumed only after the consumption of goods kept in RW due to the more holding cost in RW than in OW under FIFO dispatching policy”.
- “The OW has the limited capacity of storage and RW has unlimited capacity”.
- “Demand vary with time and is linear function of time and given by”
  $D(t) = \left[(vu)\text{t} \quad \text{if} \quad \text{t} > 0\right]$ where $v > 0$, and u>0
- “For deteriorating items a fraction of on hand Pharmaceutical drug inventory deteriorates per unit time in both the warehouse with different rate of deterioration”.

- "Shortages are allowed and demand ispartially backlogged at the beginning of next replenishment".
- "The unit Pharmaceutical drug inventory cost (Holding cost) in RW>OW".
- "We assume that the holding cost will be fixed till a definite time in RW and the will increased according to a fraction of ordering cycle length. So for holding cost ($h_r$), we have k a time moment before which holding cost is constant". $\delta_{rw} = \begin{bmatrix} \delta_{rw} & \text{if } t<\phi_F \\ \delta_{rw} t & \text{if } t>\phi_F \end{bmatrix}$

**Mathematical formulation of model and analysis**

"During the time interval $\left(0, t_{F_1}\right)$ the Pharmaceutical drug inventory in RW decrease due to the demand and deterioration and is governed by the following differential equation":

$$\frac{d\left(\prod_{RW}^{FIFO}\right)(t)}{dt} = \left[-(vu)t - \left((\alpha-1)\left(\prod_{RW}^{FIFO}\right)(t)\right)\right] \; 0 \le t \le t_{F_1} \quad (1)$$

"In the time interval $\left(0, t_{F_2}\right)$ the Pharmaceutical drug inventory level decreases in OWdecreases due to deterioration only and is governed by differential equation".

$$\frac{d\left(\prod_{OW_1}^{FIFO}\right)(t)}{dt} = \left[-(\beta-1)\left(\prod_{OW_1}^{FIFO}\right)(t)\right] \; 0 \le t \le t_{F_1} \quad (2)$$

"During time interval $\left(t_{F_1}, t_{F_2}\right)$ the Pharmaceutical drug inventory level in OW is decreases due to demand and deterioration both and is governed by the following differential equation".

$$\frac{d\left(\prod_{OW_2}^{FIFO}\right)(t)}{dt} = \left[-(vu)t - \left((\beta-1)\left(\prod_{OW_2}^{FIFO}\right)(t)\right)\right] \; t_{F1} \le t \le t_{F_2} \quad (3)$$

"Now at $t = t_{F_2}$ the Pharmaceutical drug inventory level vanishes and the shortages occur in the time interval $t = t_{F_n}$ a fraction f of the total shortage is backlogged and the shortages quantity supplied to the customers at the beginning of the next replenishment cycle. The shortages is governed by the differential equation".

$$\frac{d\left(\prod_{S}^{FIFO}\right)(t)}{dt} = -f\left((vu)t\right)\; t_{F_3} \le t \le T_{F_n} \tag{4}$$

"At the time t=T replenishment cycle restarts. The objective of the model is to minimize thetotal Pharmaceutical drug inventory cost by the relevant cost as low as possible". "Now Pharmaceutical drug inventory level at different time intervals is given by solving the above differential equations (1) to (4) under boundary conditions".

$$\left(\prod_{RW}^{FIFO}\right)\left(t_{F_1}\right)=0;\left(\prod_{OW_1}^{FIFO}\right)(0)=\Re^{ow};\;\left(\prod_{OW_2}^{FIFO}\right)\left(t_{F_2}\right)=0;\;\left(\prod_{S}^{FIFO}\right)\left(t_{F_2}\right)=0$$

Therefore Differential eq. (1) gives

$$\left(\prod_{RW}^{FIFO}\right)(t)=\left\{\begin{array}{l}\left[\left[\frac{1}{(\alpha-1)}+\frac{(vu)}{(\alpha-1)^2}\left((\alpha-1)t_{F_1}-1\right)e^{(\alpha-1)\left(t_{F_1}-t\right)}\right]\right]\\ -\left[\frac{1}{(\alpha-1)}+\frac{(vu)}{(\alpha-1)^2}\left\{(\alpha-1)t\;-\;1\right\}\right]\end{array}\right\} \tag{5}$$

$$\left(\prod_{OW_1}^{FIFO}\right)(t)=\Re^{ow}e^{-(\beta-1)t_{F_1}} \tag{6}$$

$$\left(\prod_{OW_2}^{FIFO}\right)(t)=\left\{\begin{array}{l}\left[\left[\frac{1}{(\beta-1)}+\frac{(vu)}{(\beta-1)^2}((\beta-1)t_{F_2}-1)e^{(\beta-1)\left(t_{F_2}-t\right)}\right]\right]\\ -\left[\frac{1}{(\beta-1)}+\frac{(vu)}{(\beta-1)^2}\left\{(\beta-1)t-1\right\}\right]\end{array}\right\} \tag{7}$$

$$\left(\prod_{S}^{FIFO}\right)(t)=f\left\{\left(t_{F_2}-t\right)+\frac{(vu)}{2}(t_{F_2}^2-t^2)\right\} \tag{8}$$

Now at $t = 0$, $\left(\prod_{RW}^{FIFO}\right)(0) = \Re^{rw}$ therefore equation (5) yield

$$\Re^{rw} = \begin{bmatrix} \left(\dfrac{(vu)}{(\alpha-1)^2} - \dfrac{1}{(\alpha-1)}\right) \\ +\left(\dfrac{1}{(\alpha-1)} + \dfrac{(vu)}{(\alpha-1)^2}\left((\alpha-1)t_{F_1} - 1\right)e^{-(\alpha-1)t_{F_1}}\right) \end{bmatrix} \tag{9}$$

Maximum amount of Pharmaceutical drug inventory backlogged during shortages period (at t=T) is given by:

$$IB = -\left(\prod_{S}^{FIFO}\right)(T_{Fn})$$

$$= f\left\{\left(T_{F_n} - t\right) + \frac{(vu)}{2}(T_{F_n}{}^2 - t^2)\right\} \tag{10}$$

Amount of Pharmaceutical drug inventory lost during shortages period:

$$LI = (1 - IB)$$

$$= \left[1 - f\left\{\left(T_{F_n} - t\right) + \frac{(vu)}{2}(T_{F_n}{}^2 - t^2)\right\}\right] \tag{11}$$

The maximum Pharmaceutical drug inventory to be ordered is given as :

$$= \begin{bmatrix} \Re^{ow} + \left\{\left(\dfrac{(vu)}{(\alpha-1)^2} - \dfrac{1}{(\alpha-1)}\right) + \left[\dfrac{1}{(\alpha-1)} + \dfrac{(vu)}{(\alpha-1)^2}\right]\left((\alpha-1)t_{F_1} - 1\right)e^{(\alpha-1)t_{F_1}}\right\} \\ + f\left\{\left(T_{F_n} - t_2\right) + \dfrac{(vu)}{2}(T_{F_n} - t_{F_2}^2)\right\} \end{bmatrix} \tag{12}$$

Now continuity at $t = t_{F_1}$ shows that $\left(\prod_{OW_1}^{FIFO}\right)\left(t_{F_1}\right) = \left(\prod_{OW_2}^{FIFO}\right)\left(t_{F_1}\right)$ therefore from eq. (6) & (7) we have:

$$\begin{bmatrix} (vu)(\beta-1)^2 t_{F_2}^2 - (\beta-1)^2 t_{F_2} \\ -\left((\beta-1)^2\left(\Re^{ow}+Z\right)+(vu)-(\beta-1)\right) \end{bmatrix} = 0 \qquad (13)$$

$$\text{Where } Z = \left\{ \frac{1}{(\beta-1)} + \frac{(vu)}{(\beta-1)^2}\left((\beta-1)t_{F_1}-1\right) \right\} e^{-(\beta-1)t_{F_1}}$$

Which is quadratic in$t_2$ and further can be solved for $t_2$ in terms of $t_1$ i.e.

$$t_{F_2} = \varphi\left(t_{F_1}\right) \qquad (14)$$

$$\text{Where } \varphi\left(t_{F_1}\right) = \frac{-(\beta-1)^4 \pm \sqrt{D}}{2(vu)(\beta-1)^2}$$

And

$$D = \begin{bmatrix} (\beta-1)^4 \\ +4(vu)(\beta-1)^2 \left\{ \begin{matrix} (vu)-(\beta-1) \\ +(\beta-1)^2 \left[ \Re^{ow} + \left\{ \begin{matrix} \dfrac{1}{(\beta-1)} \\ +\dfrac{(vu)}{(\beta-1)^2}\left\{(\beta-1)t_{F_1}-1\right\} \end{matrix} \right\} e^{-(\beta-1)t_{F_1}} \right] \end{matrix} \right\} \end{bmatrix}$$

Next the total relevant Pharmaceutical drug inventory cost per cycle includes following parameters.

**Ordering cost under FIFO dispatching policy**

$$C_A(FIFO) = \delta_{C_A}$$

- *Purchase cost per cycle* $= P * Q_{max}$
- *The present worth holding cost* $= H_C$

Case-1 When $(\phi_F) < \mathbf{T}_{F_n}$ and $0 \le (\phi_F) < t_{F_1}$ in RW

$$H_c(FIFO) = \begin{bmatrix} \int_0^k \delta_{rw} \left( \prod_{RW}^{FIFO} \right)(t)\,dt + \int_k^{t_{F_1}} \delta_{rw} t \left( \prod_{RW}^{FIFO} \right)(t)\,dt \\ + \int_0^{t_{F_1}} \delta_{ow} \left( \prod_{OW_1}^{FIFO} \right)(t)\,dt + \int_{t_{F_1}}^{t_{F_2}} \delta_{ow} \left( \prod_{OW_2}^{FIFO} \right)(t)\,dt \end{bmatrix}$$

**Holding cost for Case -1 under FIFO dispatching policy**

$$H_c(FIFO) = \begin{bmatrix} \delta_{rw} \begin{pmatrix} t_{1F}(\phi_F) + (vu)t_{F_1}^2(\phi_F) - \frac{(vu)(\phi_F)^2}{2(\alpha-1)} - \frac{(vu)t_{F_1}^2}{3(\alpha-1)} \\ + t_{F_1}^3 + (vu)t_{F_1}^4 - \frac{(\phi_F)}{(\alpha-1)} - (vu)t_{F_1}(\phi_F)^2 - t_{F_1}(\phi_F)^2 \\ -(vu)t_{F_1}^2(\phi_F)^2 + \frac{(vu)t_{F_1}(\phi_F)^2}{(\alpha-1)} + \frac{(\phi_F)^2}{(\alpha-1)} + \frac{(vu)(\phi_F)^3}{3(\alpha-1)} \end{pmatrix} \\ + \delta_{ow} \left( \Re^{ow} t_{F_1} + \frac{(vu)t_{F_2}^2}{(\beta-1)} - \frac{(vu)t_{F_1}t_{F_2}}{(\beta-1)} + \frac{(vu)t_{F_1}^2}{2(\beta-1)} - \frac{(vu)t_{F_2}^2}{2(\beta-1)} \right) \end{bmatrix} \tag{15}$$

Case-2: When $(\phi_F) > \mathbf{T}_{F_n}$

$$H_c(FIFO) = \int_0^{t_{F_1}} \delta_{rw} \left( \prod_{RW}^{FIFO} \right)(t)\,dt + \int_0^{t_{F_1}} \delta_{ow} \left( \prod_{OW_1}^{FIFO} \right)(t)\,dt + \int_{t_{F_1}}^{t_{F_2}} \delta_{ow} \left( \prod_{OW_2}^{FIFO} \right)(t)\,dt$$

**Holding cost for Case -2 under FIFO dispatching policy**

$$H_c(FIFO) = \begin{bmatrix} \delta_{rw} \left( t_{F_1}^2 + (vu)t_{F_1}^3 + \frac{(vu)t_{F_1}^2}{(\alpha-1)} - \frac{(vu)t_{F_1}^2}{2(\alpha-1)} \right) \\ + \delta_{ow} \left( \Re^{ow} t_{F_1} + \frac{(vu)t_{F_2}^2}{(\beta-1)} - \frac{(vu)t_{F_1}t_{F_2}}{(\beta-1)} + \frac{(vu)t_{F_1}^2}{2(\beta-1)} - \frac{(vu)t_{F_2}^2}{2(\beta-1)} \right) \end{bmatrix} \tag{16}$$

**Shortages cost under FIFO dispatching policy**

$$S_c\left(FIFO\right)=\delta_{S_c}\ f\begin{pmatrix}\dfrac{T_{F_n}{}^2}{2}-\dfrac{t_{F_2}^2}{2}+\dfrac{(vu)T_{F_n}{}^3}{6}-\dfrac{(vu)t_{F_2}^3}{6}\\ -t_{F_1}T_{F_n}+t_{F_2}^2-\dfrac{(vu)t_{F_2}^2T_{F_n}}{2}+\dfrac{(vu)t_{F_2}^3}{2}\end{pmatrix} \tag{17}$$

**Lost sale cost under FIFO dispatching policy**

$$L_c\left(FIFO\right)=\delta_{L_c}\left(1-\begin{pmatrix}\dfrac{T_{F_n}{}^2}{2}-\dfrac{t_{F_2}^2}{2}+\dfrac{(vu)T_{F_n}{}^3}{6}-\dfrac{(vu)t_{F_2}^3}{6}\\ -t_{F_1}T_{F_n}+t_{F_2}^2-\dfrac{(vu)t_{F_2}^2T_{F_n}}{2}+\dfrac{(vu)t_{F_2}^3}{2}\end{pmatrix}\right) \tag{18}$$

**Purchase cost under FIFO dispatching policy**

$$P_c\left(FIFO\right)=\delta_{P_c}\begin{pmatrix}\Re^{ow}+\left(\dfrac{(vu)}{(\alpha-1)^2}-\dfrac{1}{(\alpha-1)}\right)\\ +\left\{\dfrac{1}{(\alpha-1)}+\dfrac{(vu)}{(\alpha-1)^2}\left(t_{F_1}-1\right)e^{-(\alpha-1)t_{F_1}}\right\}\\ +f\left\{\left(T_{F_n}-t_{F_2}\right)+\dfrac{(vu)}{2}\left(T_{F_n}{}^2-t_{F_2}^2\right)\right\}\end{pmatrix} \tag{19}$$

**The data collection cost is given asunder FIFO dispatching policy**

$$D_c\left(\mathrm{FIFO}\right)=\ \mu\mathrm{d} \tag{20}$$

Therefore Total relevant Pharmaceutical drug inventory cost per unit per unit of time is denoted and given by:

Case-1

$$T^C{}_F\left[\left\{t_{F1},T_{F_n}\right\}\left(FIFO\right)\right]=\begin{bmatrix}C_A\left(FIFO\right)+H_c\left(FIFO\right)+S_c\left(FIFO\right)+\\ L_c\left(FIFO\right)+P_c\left(FIFO\right)+D_c\left(\mathrm{FIFO}\right)\end{bmatrix} \tag{21}$$

Case-2

$$T^{C}{}_{F}\left[\left\{t_{F1},T_{F_n}\right\}(FIFO)\right]=\begin{bmatrix}C_A(FIFO)+H_c(FIFO)+S_c(FIFO)+\\ L_c(FIFO)+P_c(FIFO)+D_c(\mathrm{FIFO})\end{bmatrix} \tag{22}$$

**Travelling salesman problem**

The Travelling Salesman Problem (TSP) is a widespread computer problem that involves finding a way to Hamilton at minimal cost. The TSP has represented the interests of computer scientists and mathematicians, as the problem is not yet fully resolved, even after about half a decade of research. TSP can be applied to solve many practical problems such as logistics, transportation, semiconductor industry, etc. An effective TSP solution would thus ensure efficient execution of tasks and thus increase productivity (Eroglu & Ozdemir, 2007; Chung & Hou, 2003). Due to its importance in many industries, TSP is still studied by researchers from various disciplines. TSP is known to be hard NP. This means that no known algorithm is guaranteed to resolve the optimality of all TSP instances within a reasonable execution time. In order to find exact solutions, various ant colony optimization heuristics and algorithms have been developed to approximate the problems (Wang et al., 2003; Tiwari et al., 2014; Yang & Deb, 2009; Yang & Deb, 2010). They allow high quality solutions to be found with reasonable turnaround times. Optimization of ant colonies is generally improvement algorithms; H. You start with one or more possible solutions to the problem in question and suggest ways to improve those solutions. To solve the problem of TSP, researchers have proposed various meta-heuristic approaches such as the optimization of ant colonies to solve TSP.

$$A_{ij}=\begin{cases}1 & \text{the path goes form city i to city j}\\ 0 & \text{otherwise}\end{cases} \tag{5}$$

$$\min \sum_{i=1}^{N}\sum_{j\neq i,\, j=1}^{N} D_{ij}A_{ij} \tag{6}$$

$$A_{ij}\in\{0,1\} \qquad \text{i, j-1,..........,N;} \tag{7}$$

$$B_i\in Z \qquad \text{i, =2,..........,n;} \tag{8}$$

$$\sum_{j\neq i, i=1}^{n} A_{ij}\in\{0,1\} \qquad \text{j=1,..........,N;} \tag{9}$$

$$\sum_{j\neq i, j=1}^{n} x_{ij}\in\{0,1\} \qquad \text{i=1,..........,N;} \tag{10}$$

$$B_i-B_j+NA_{ij}\le N-1 \qquad 2\le i\neq j\le N \tag{11}$$

$$1\le B_i\le N-1 \qquad 2\le i\le N \tag{12}$$

**Ant colony optimization**

Ant Colony Optimization (ACO) was introduced by Marco Dorigo in 1991 and applied to TSP. The ACO algorithm models the behavior of real ant colonies when determining the shortest path from food sources to nests. Ants can communicate with each other in their immediate environment using chemicals called pheromones. Ants release pheromones to the ground when they leave their nest to feed, then return to the nest. Ants move according to the amount of pheromones. The richer the pheromone trail on a path, the more likely it is that other ants will follow it. So a shorter route has a greater amount of pheromones, ants tend to choose a shorter route. It is thanks to this mechanism that the ants find the shortest way (Zong & Zhen, 2021; Suryasa, 2019).

**Working of ACO for TSP**

Initially, each ant is placed at random on a city. When developing a viable solution, the ants select the next city to visit using a probabilistic decision rule. When an ant k declares in city i and constructs the partial solution, the probability of moving to the next neighboring city j i is given by (Tiwari et al., 2014).

$$[p_0]_{ij}^{k}(k)=\begin{bmatrix} \dfrac{\left\{[B_0]_{ij}(t_0)\right\}^{\alpha_3}\left\{[C_0]_{ij}\right\}^{\beta_3}}{\sum\limits_{[u_0]\in J_k(t_0)}\left\{[B_0]_{ij}(t_0)\right\}^{\alpha_3}\left\{[C_0]_{ij}\right\}^{\beta_3}} & \text{if } \ \mathrm{j}\in J_k(i) \\ 0 & \text{otherwise} \end{bmatrix} \quad (12)$$

Where $[B_0]_{ij}$ is the intensity of trails between edge (i,j) and $[C_0]_{ij}$ is the heuristic visibility of the edge (i, j), and $[C_0]_{ij}=\dfrac{1}{d_{ij}}$ $\alpha_3$ Is the influencing factor of pheromones, $\beta_3$ is the influence of the local node, and $J_k(i)$ is a set of cities that remain to be visited when the ant is in city i. Once each ant has completed their turn, the amount of pheromones on each path will be adjusted with the following equation.

$$[B_0]_{ij}(t_0+1)=(1-\rho_0)[B_0]_{ij}(t_0)+\Delta[B_0]_{ij}(t_0) \quad (13)$$

Is pheromone evaporation coefficient and$\rho$where

$$\Delta[B_0]_{ij}(t_0)=\sum_{k=1}^{m}\Delta[B_0]_{ij}^{k}(t_0) \quad (14)$$

$$\Delta[B_0]_{ij}^{k}(t_0)=\begin{bmatrix} \dfrac{Q_0}{[L_0]_k} & \text{if} \quad (i,j)\in \text{tour done by ant k} \\ 0 & \text{otherwise} \end{bmatrix} \quad (15)$$

(1-ρ ) is the decay parameter of pheromones (0<ρ<1) where it represents the evaporation of the track when the ant chooses a city and decides to move. Lk is the length of the turn for each formed per ant k and m is the number of ants. Q is the pheromone deposition factor (Irwanti & Ratnadi, 2021; Pratama et al., 2020).

**Numerical analysis**

The following randomly chosen data in appropriate units has been used to find the optimal solution and validate the model of the three players the producer, the distributor and the retailer. The data are given as $v=501,\ \delta_{C_A}=1501$, $\Re^{rw}=2001,\ \Re^{ow}=2011,\ u=5.01,\ \delta_{ow}=61,\ \delta_{rw}=71,\ \delta_{P_C}=1501,\ (\alpha-1)=0.113$, $(\beta-1)=0.114,\ \delta_{S_C}=251,\ \phi_F=1.67$, f=0.06, μ=1.25, d=1.56 and $\delta_{L_C}=101$. The values of decision variables are computed for the model for two cases separately. The computational optimal solutions of the models are shown in Table-1. The actual values are to be tuned to the specific ACOA through experience and trial-and-error. However some standard settings are reported in literature.
Population Size = 150, Number of generations = 3000, Crossover type = two Point, Crossover rate = 1.8. Mutation types = Bit flip, Mutation rate = 0.003 per bit. If single cut-point crossover instead of two cut-point crossover is employed the crossover rate can be lowered to a maximum of 1.50.

**Numerical comparison between two cases of the model**

Using the same value of parameters as given in numerical example we obtain the total relevant Pharmaceutical drug inventory costs of the model for two cases as given in table-1. From the table we observe that model with instantaneous deterioration and partially backlogged in case-1. Where holding cost vary in RW after a certain time is most expensive state of affairs. So for the case-2 where the holding cost does not vary with the cycle length, the model is the most flexible model and it corresponds to the least expensive circumstances (Kaharuddin, 2021; Zharovska et al., 2021).

Table 1
Total relevant pharmaceutical drug inventory costs

| Case | Cost function | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | Total relevant cost | Ant Colony Optimization for travelling salesman problem |
|---|---|---|---|---|---|---|
| 1 | $T^C{}_F\left[\left\{t_{F1},T_{F_n}\right\}(FIFO)\right]$ | 2.47477 | 62.7053 | 74.2487 | 135249 | 3.5249 |
| 2 | $T^C{}_F\left[\left\{t_{F1},T_{F_n}\right\}(FIFO)\right]$ | 7.31247 | 35.7460 | 37.9896 | 61042.2 | 4.6528 |

**Sensitivity analysis**

Table 2
Sensitivity analysis in relation to constant demand rate

| $(v)$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1},T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 551 | 3.49618 | 74.1910 | 84.6198 | 240800 |
| 601 | 3.51352 | 75.5790 | 85.0507 | 243858 |
| 751 | 3.55002 | 79.3147 | 86.5811 | 251940 |
| 451 | 3.44771 | 71.0971 | 83.4559 | 234125 |
| 401 | 3.41251 | 69.3314 | 83.7677 | 230524 |
| 251 | 3.1942 | 62.4114 | 84.3116 | 216654 |

Table 3
Sensitivity analysis in relation to variable demand rate

| $(u)$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1},T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 1.55 | 3.46488 | 69.4764 | 81.6827 | 243436 |
| 1.60 | 3.45425 | 66.6482 | 79.4710 | 248950 |
| 1.75 | 3.41861 | 59.8863 | 74.3341 | 263695 |
| 1.45 | 3.48385 | 76.4413 | 87.2679 | 231372 |
| 1.40 | 3.49201 | 80.8351 | 90.8821 | 224634 |
| 1.25 | 3.50921 | 91.9246 | 99.1062 | 200468 |

Table 4
Sensitivity analysis in relation to ordering cost

| $\delta_{C_A}$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1},T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 2651 | 3.47477 | 72.7062 | 84.2498 | 237624 |
| 2801 | 3.47478 | 72.7071 | 84.2709 | 237626 |

| | | | | |
|---|---|---|---|---|
| 3251 | 3.47479 | 72.7098 | 84.2542 | 237632 |
| 2351 | 3.47477 | 72.7045 | 84.2475 | 237620 |
| 2201 | 3.47475 | 72.7045 | 84.2475 | 237620 |
| 851 | 3.47475 | 72.7009 | 84.2431 | 237612 |

Table 5
Sensitivity analysis in relation to shortages cost

| $\delta_{S_c}$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1}, T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 271 | 3.47605 | 53.0333 | 63.6067 | 238282 |
| 301 | 3.47715 | 53.3126 | 63.0670 | 238844 |
| 371 | 3.47963 | 53.9473 | 61.8635 | 240123 |
| 221 | 3.47324 | 52.3148 | 65.0249 | 236835 |
| 201 | 3.47138 | 51.8417 | 65.9826 | 235.883 |
| 121 | 3.46235 | 49.5406 | 70.9334 | 231257 |

Table 6
Sensitivity analysis in relation to opportunity cost

| $\delta_{L_c}$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1}, T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 211 | 3.47468 | 52.6829 | 44.2602 | 237572 |
| 221 | 3.47459 | 52.6604 | 44.2717 | 237522 |
| 151 | 3.47433 | 52.5924 | 44.3056 | 237371 |
| 92 | 3.47486 | 52.7278 | 44.2371 | 237671 |
| 82 | 3.47494 | 52.7501 | 44.2254 | 237721 |
| 52 | 3.47521 | 52.8169 | 44.1899 | 237868 |

Table 7
Sensitivity analysis in relation to time up to which holding cost remain constant

| $\phi_F$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1}, T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 1.771 | 3.52073 | 78.6183 | 91.7013 | 251730 |
| 1.931 | 3.56961 | 84.4808 | 99.3418 | 266340 |
| 2.411 | 3.73079 | 91.8567 | 212.8710 | 312288 |
| 1.441 | 3.43217 | 67.1093 | 77.0702 | 224162 |
| 1.281 | 3.39351 | 61.8280 | 70.2908 | 211562 |
| 0.801 | 3.31021 | 49.5857 | 54.5368 | 72565.8 |

Table 8
Sensitivity analysis in relation to purchase cost

| $\delta_{P_c}$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1}, T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 1651 | 3.59282 | 53.9583 | 55.2051 | 240218 |
| 1801 | 3.70547 | 55.1431 | 56.0761 | 242667 |

| | | | | |
|---|---|---|---|---|
| 2251 | 3.01070 | 58.3322 | 58.2298 | 249574 |
| 1351 | 3.35049 | 51.3789 | 53.1999 | 234868 |
| 1201 | 3.2189 | 59.9723 | 52.0506 | 231945 |
| 751 | 2.76310 | 45.1799 | 57.8856 | 221981 |

Table 9
Sensitivity analysis in relation to holding cost in OW

| $\delta_{ow}$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1}, T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 61 | 3.46324 | 69.6488 | 81.9610 | 243077 |
| 71 | 3.45096 | 66.9546 | 79.9022 | 248202 |
| 91 | 3.41038 | 60.4533 | 75.2274 | 261955 |
| 51 | 3.48546 | 76.2148 | 86.9845 | 231789 |
| 41 | 3.49519 | 80.3033 | 90.2418 | 225519 |
| 31 | 3.51653 | 98.4028 | 91.3834 | 203172 |

Table 10
Sensitivity analysis in relation to holding cost in RW

| $\delta_{rw}$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1}, T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 82.1 | 3.37132 | 34.3002 | 46.3952 | 242302 |
| 90.1 | 3.28116 | 35.8104 | 48.4338 | 246798 |
| 112.1 | 3.06749 | 39.9336 | 54.0350 | 259432 |
| 67.1 | 3.5951 | 31.0109 | 41.9746 | 232718 |
| 60.1 | 3.73743 | 29.1963 | 39.5458 | 227538 |
| 37.1 | 4.39647 | 22.6439 | 30.8134 | 209302 |

Table 11
Sensitivity analysis in relation to Deterioration rate in RW

| $(\alpha-1)$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1}, T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 0.0141 | 3.48562 | 71.0270 | 42.1171 | 233742 |
| 0.0151 | 3.49444 | 69.5881 | 40.2887 | 230418 |
| 0.0191 | 3.51304 | 66.2776 | 36.0783 | 222777 |
| 0.0111 | 3.46111 | 74.6911 | 46.7690 | 242216 |
| 0.0101 | 3.44345 | 77.0818 | 49.8010 | 247752 |
| 0.0061 | 3.33759 | 88.6239 | 54.4048 | 274561 |

Table 12
Sensitivity analysis in relation to deterioration rate in OW

| $(\beta-1)$ | $t_{F_1}$ | $t_{F_2}$ | $T_{F_n}$ | $T^C{}_F\left[\left\{t_{F1}, T_{F_n}\right\}(FIFO)\right]$ |
|---|---|---|---|---|
| 0.0151 | 3.46512 | 86.0232 | 36.9065 | 232683 |
| 0.0161 | 3.45643 | 89.1559 | 39.4509 | 128287 |

| | | | | |
|---|---|---|---|---|
| 0.0211 | 3.43479 | 97.6484 | 46.5026 | 217490 |
| 0.0121 | 3.48558 | 69.1742 | 31.4646 | 243201 |
| 0.0111 | 3.49781 | 65.3941 | 28.5391 | 249575 |
| 0.001 | 3.54720 | 52.0103 | 18.7006 | 275946 |

## Conclusion

In this paper, we proposed a deterministic two-warehouse Pharmaceutical drug inventory model for deteriorating items with linear time-dependent demand and varying holding cost with respect to ordering cycle length with the objective of minimizing the total Pharmaceutical drug inventory costUnder FIFO dispatching policy Using Ant Colony Optimization for travelling salesman problem. Shortages are allowed and partially backlogged. Two different cases has been discussed one with variable holding cost during the cycle period and other with constant holding cost during total cycle length and it is observed that during variable holding cost the total Pharmaceutical drug inventory cost is much more than the other caseUnder FIFO dispatching policy Using Ant Colony Optimization for travelling salesman problem. Furthermore the proposed model is very useful for the items which are highly deteriorating, since as the deterioration rate increases in both ware-houses the total Pharmaceutical drug inventory cost decreasesUnder FIFO dispatching policy Using Ant Colony Optimization for travelling salesman problem. This model can be further extended by incorporation with other deterioration rate, probabilistic demand pattern and other realistic combinationsUnder FIFO dispatching policy Using Ant Colony Optimization for travelling salesman problem.

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