# An inventory model for deteriorating items under inflation and permissible delay in payments by Genetic Algorithm

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**Abstract.** Inventory models are crucial in analyzing a wide range of realistic situations that arise in places such as vegetable markets, food markets, oil industries, chemical factories and so on. In this paper, we build an inventory model for deteriorating items with changing prices due to inflation and delays in a given situation,

In the model, the demand rate is assumed to be stock-dependent, and the rate of deterioration is assumed to be zero and each item that comes under deterioration follows to the Weibull distribution. And the model is created under various circumstances which depends on the condition of credit period that if it is greater than the life cycle of that item or less than the life cycle of that item.

**Keywords:** EOQ, Inflation, Stock-dependent demand, genetic algorithm.

## 1 Introduction

Decaying of vegetables, fruits, electrical equipment's, chemicals and many other items is a natural phenomenon which can be occurred frequently. Then sometimes due to inflation or delay in payments leads to delay in shipment of items or we can simply say that the items take time to reach out to its destination and therefore deterioration occurs. And deterioration of items really creates a lot of problems the customer will face. But as deterioration is a frequent and natural phenomenon which cannot be ignored, So, here is an approach to prevent it.

## 2 Assumption

1. The inventory model involves only one item.
2. The rate of replenishment is uniform.
3. Costs are changing relatively to various factors like inflation or delays.

## 3 Optimizing Inventory

Importing all the required libraries first for our model such as numpy that is also known as numerical python

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

Importing sample dataset for our model and print head of our dataset or top 5 rows of our dataset

```
dataset= pd.read_csv("Datasets/sample.csv")
dataset.head()
```

| | Item | holding_cost | ordering_cost | purchase_cost | rate | demand | setup_cost |
|---|---|---|---|---|---|---|---|
| 0 | item1 | 2498 | 1474 | 5895 | 60 | 34 | 150 |
| 1 | item1 | 4082 | 2476 | 2079 | 68 | 35 | 151 |
| 2 | item1 | 1410 | 1735 | 5652 | 76 | 34 | 173 |
| 3 | item1 | 4760 | 3032 | 3923 | 46 | 20 | 191 |
| 4 | item1 | 4842 | 2491 | 2087 | 200 | 49 | 195 |

Show all the columns of our dataset describe or summarise our dataset along with pairplot from seaborn library that defines the relationship between various columns in our dataset basically to do the data analysis part to understand the dataset in a better way.

```
dataset.columns
dataset.describe()
sns.pairplot(dataset)
```

Now, as we have all the required data in our dataset that is holding cost, ordering cost, purchase cost, fixed rate per order, demand and setup cost. Therefore, we can calculate the Economic Order Quantity from these fields.
Add a new column in our dataset for calculating economic order quantity and print the head of our dataset

```
da-
ta-
set["eoq"]=np.sqrt((2*dataset["demand"]*dataset["setup_cost"])/dataset["holding_c
ost"])
dataset.head()
```

We can also add a new column for total cost that shows the total cost to organization for ordering and storing a item in its inventory.

```
da-
ta-
set["total_cost"]=dataset["holding_cost"]+dataset["ordering_cost"]+dataset["purch
ase_cost"]
dataset.head()
```

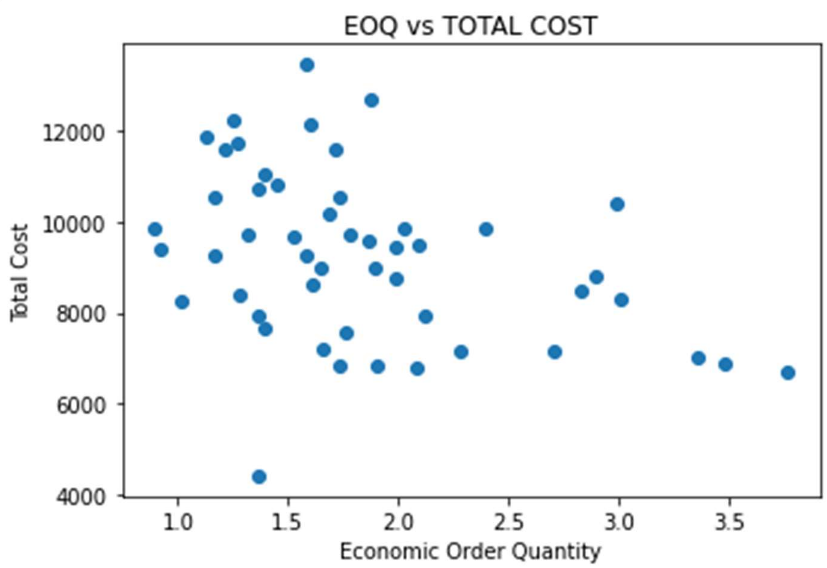
Now again describe our dataset after adding new fields for total cost and eoq.

*dataset.describe()*

| | holding_cost | ordering_cost | purchase_cost | rate | demand | setup_cost | eoq | total_cost |
|---|---|---|---|---|---|---|---|---|
| count | 50.00000 | 50.000000 | 50.000000 | 50.00000 | 50.000000 | 50.000000 | 50.000000 | 50.000000 |
| mean | 3155.80000 | 2379.720000 | 3711.580000 | 103.12000 | 31.380000 | 151.040000 | 1.841546 | 9247.100000 |
| std | 1214.33894 | 937.299857 | 1171.189123 | 53.65979 | 10.838122 | 31.490173 | 0.672142 | 1861.541782 |
| min | 1015.00000 | 1054.000000 | 2020.000000 | 20.00000 | 11.000000 | 103.000000 | 0.892015 | 4423.000000 |
| 25% | 2382.25000 | 1550.000000 | 2719.250000 | 61.25000 | 23.000000 | 122.250000 | 1.365468 | 7921.000000 |
| 50% | 3164.50000 | 2338.000000 | 3616.000000 | 96.50000 | 32.500000 | 153.000000 | 1.699489 | 9336.500000 |
| 75% | 4138.25000 | 3063.500000 | 4679.250000 | 148.75000 | 38.750000 | 182.250000 | 2.065030 | 10488.250000 |
| max | 4974.00000 | 3969.000000 | 5895.000000 | 200.00000 | 50.000000 | 199.000000 | 3.763388 | 13445.000000 |

Now, show the relationship between the eoq vs total cost fields that shows that how much it costs for a specific optimal order quantity with the help of scatterplot.

*plt.scatter(dataset["eoq"],dataset["total_cost"])*
*plt.title("EOQ vs TOTAL COST")*
*plt.xlabel("Economic Order Quantity")*
*plt.ylabel("Total Cost")*
*plt.show().*




Now, optimize our eoq with the help of genetic algorithm.
input to our model is population that is eoq column in 1d array

*population = dataset["eoq"].values.flatten()*

number of weights or items we are looking to optimise

*weights = len(population)*

number of solution per solution ,here we take 50 solution for our population that includes 50 individuals

*sol_per_pop = 50*

population size that holds our population 50 weights in 50 solution

*pop_size=(sol_per_pop,weights)*

now new population or actual population on which we are going to prepare our model

*new_population=np.random.uniform(low=np.min(population),high=np.max(population),size=pop_size)*

*print(new_population)*

Now we take a GA class or module that is imported from a reference [1]whose functions we are going to use for our model which helps us in using decimal representation for genes along with one point crossover and uniform mutation as we have various types of representations for genes, crossover and mutation like binary, integer gene representation, one point, 2-point, uniform crossover and bit flip, swap, inverse mutation.

Number of generations is 5 to present results of all generation easily

*num_generations=5*

*num_parents_mating=4*

*for generation in range(num_generations):*

Using the rate of total order items to determine the fitness of each chromosome in the population

*fitness=GA.cal_pop_fitness(dataset["rate"].values.flatten(),new_population)*

Selecting the most fit parents in the population for mating

*parents=GA.select_mating_pool(new_population,fitness,num_parents_mating)*

Creating the next generation using a crossover method that takes into account the parents' and offspring's sizes in a ring order

*offspring_crossover=GA.crossover(parents,offspring_size=(pop_size[0]-parents.shape[0], weights))*

Using single point cross-over mutation to add some changes to the offsrping

*offspring_mutation=GA.mutation(offspring_crossover)*

After iterating through all generations, the optimal solution is found.

*best_match_idx = np.where(fitness == np.max(fitness))*

*print("Optimised Solution :")*

*print(new_population[best_match_idx, :])*

```
Optimised Solution :
[[[1.59937053 3.2710669  3.6787968  1.94796638 2.12744461 3.34546057
   2.52889929 3.67067406 2.08417821 2.14183798 3.22895889 3.07350076
   2.06885618 1.16780854 2.77004969 3.56964652 3.58772349 3.05471443
   3.39937764 3.01130762 2.10641536 2.4579161  1.12377984 3.25639706
   3.4559998  3.70541731 1.12389646 2.61979971 3.5440339  3.69366858
   3.09075226 2.90404979 1.72307599 2.09908081 3.05715958 3.3582375
   3.03585373 1.95494318 2.78738817 2.38077189 3.5841475  1.58365496
   3.15150378 2.74287239 3.44286594 2.15801967 1.62595778 3.12088761
   1.29822318 6.95137726]]]
```

## 4 EOQ

The best order quantity for a corporation to purchase in order to reduce inventory costs such as holding charges, shortage costs, and order fees is the economic order quantity.

Variables in EOQ:

| | |
|---|---|
| T | total annual inventory cost |
| P | purchase unit price, unit production cost |
| Q | order quantity |
| D | demand quantity (Annual) |
| K | fixed cost, setup cost (per order) |
| H | holding cost (Annual per unit) |

The EOQ formula for a single item:

Total Cost = purchase cost (production cost) + ordering cost + holding cost

Where:

Purchase cost: This is the variable cost of goods: purchase unit price × annual demand quantity. This is

$P \times D$

Ordering cost: This is the cost of placing orders: each order has a fixed cost K, and we need to order D/Q times per year. This is

$K \times D/Q$

Holding cost: the average quantity in stock (between fully replenished and empty) is Q/2, so this cost is $h \times Q/2$.

$T = PD + K*D/Q + H*Q/2$

Calculate the derivative of the total cost with respect to Q (assuming all other variables are constant) and set it equal to 0 to find the total cost curve's minimal value:

$0 = -DK/Q^2 + H/2$

Solving for Q gives the optimal order quantity:
$Q^2 = 2DK/H$
Therefore:
$Q = \sqrt{(2DK/H)}$
Q is independent of P and it is only a function of K, D, H.
This simply means that the optimal order quantity that we have required is basically depends on setup cost that means shipping and handling costs only and annual demand quantity as well as annual holding cost per unit.

For example, The EOQ considers the time it takes to reorder, the cost of placing an order, and the cost of holding things. When a company makes small purchases on a regular basis to maintain a specific level of inventory, the ordering costs climb, as does the demand for more storage space.
Assume you own a retail apparel store that sells men's shirts. Every year, the business sells 1,000 shirts. A single shirt costs the corporation 500 Rs. per year to keep in inventory, while placing an order cost 200 Rs.
Now according to the EOQ formula:
$Q = (2*1000*200)/500$
$Q = 28$
the ideal order value to minimize costs and meet customer demand is 28 shirts.

## 5 Genetic Algorithm

Basic Steps to find optimized solution:

a. Selection rules: Here, we select individuals, called parents that contribute to the next generation's population.
b. Crossover rules: Here, we apply crossover operation between two parents to produce children.
c. Mutation rules: At last, we apply some random changes to individual parents.

Working Algorithm:

a. INITIALIZE
   Generate the initial population randomly
   Calculate fitness of population
b. REPEAT following steps
   Selection
   Crossover
   Mutation
   Compute fitness

c. UNTIL population has converged
d. FINISH

# 6 Literature Review

## 6.1 EOQ

It is an old classical production scheduling model developed by Ford W. Harris in 1913, and it has been refined over time as R.H. Wilson who was a consultant applied it extensively and then after him K. Andler performed in-depth analysis and give this model a new height. It is applied in any organization whenever the demand of any product is same over the year and new order that is delivered is in full when inventory emptied. Regardless of the number of units ordered each order has a fixed cost. There is per unit storage cost, known as holding. While the EOQ formulation is straightforward, some aspects, such as transportation prices and quantity discounts, must be considered in practical implementation [2]. We want to figure out how many pieces to get in order to save money on the product's purchase, shipping, and storage. The important parameters for the solution are the overall demand for the year, the purchase cost for each item, the fixed cost to place the order for a single item, and the storage cost for each item per year. It is vital to remember that the number of times an order is placed influences the total cost, which can also be computed using the other factors.
Advantages of EOQ

1. Minimize the storage and costs for every kind of business owner by providing the most ideal quantity they required for their business.
2. It provides specific data for the firm regarding how much inventory to hold and how much to replenish.

Disadvantages of EOQ

1. It requires a very good understanding of math algebra which became a hard task for especially small business owners
2. It assumes various actors like steady demand of a product, immediate availability of items to be re-stocked, fixed costs of units.

## 6.2 Weibull distribution

It is also noticed that consumer product demand often varies with time, meaning that the demand rate should be considered time-dependent. Furthermore, inventory shortages may occur for a variety of reasons from time to time. Our goal is to create a mathematical model for inventory management that takes into account all of these factors. As a result, we develop an economic order quantity model for a decaying item's inventory, employing a time-variable demand rate and accounting for inventory shortages [3]. The Weibull distribution was first summarized in the 1951 work [4] published in the Journal of Applied Mechanics. Then first identified by Frechet in 1927 and applied by Rosin & Rammler in 1933. Previously, statisticians knew the

Weibull distribution as one of three types of extreme value distributions. Fisher and Tippett proposed this original theory in 1928, and Gumbel [5] elaborated on it subsequently. It is now frequently used to evaluate product dependability, examine life statistics, and predict failure times. The Weibull model may also fit data from many other disciplines, including as biology, economics, engineering sciences.

**Shape Parameter: (β)** It is known as Weibull slope or we can say the threshold parameter for Weibull distribution that states the behavior of the distribution. Different values can have a different impact on the distribution's behavior. $\beta < 1$ means to have a failure rate that decreases with time, that is also known as infantile or early-life failures. β close to or equal to 1 means that the item has fairly constant failure rate, or random failures. $\beta > 1$ have a failure rate that increases with time, these are known as wear-out failures.

**Scale Parameter:(η)** Characteristics life parameter, the larger the scale parameter the more spread out the distribution. Increasing of η while taking β constant stretched out the pdf. As the area remains same under a pdf curve, therefore with the increase of η the peak of the pdf curve will decrease.

**Location Parameter:(γ)** It is known as waiting time parameter or shift parameter. It shows that where the graph is located as it tells us about the measures of central tendencies also. Mostly, it is not used much, and its value can be taken to zero but whenever this parameter taken into consideration equation is reduced to the two-parameter Weibull distribution equation [6].

### 6.3 Inflation

Inflation is the rate at which prices rise over a certain time period. Inflation is generally defined as a broad metric, such as the total increase in prices or the cost of living in a country. Inflation measures how much more expensive a particular set of products and services has become over time. The classical economic order quantity model is based on the premise that the product's demand is constant. However, once a season has passed, the need for seasonal commodities, weather-appropriate clothing, and so on drops. Another basic EOQ assumption is that the retailer settles the accounts for the items as soon as they arrive in his inventory system. In practice, if the overdue amount is paid within the authorized fixed settlement time and the order quantity is large, the supplier will grant the merchant a permissible credit period. The credit period is viewed as a promotional tool for attracting new consumers. It can be showed as a kind of price discount because paying later indirectly reduces the purchase cost which motivates retailers to increase their order quantity [7]. When the total price level rises, each unit of currency purchases fewer goods and services, resulting in inflation, which indicates a loss of purchasing power per unit of money - a loss of real value in the economy's medium of exchange and unit of account. The supplier will grant a specific fixed period (credit period) for settling the sum owed to the merchant for the items supplied. The retailer can sell the products and receive income and interest before the trade credit period expires. If the payment is not made by the end of the trade credit period, a higher interest rate is levied. In practice, the supplier frequently employs this policy to advertise his goods. A lot of research articles dealing with the EOQ problem under fixed credit period have published in this area. [8].

**Inflation Causes:**

A variety of factors can influence price or inflation in an economy. In most cases, inflation is caused by an increase in production costs or an increase in demand for goods and services.

But simply we have two main causes:

**Cost-Push Inflation:** It occurs when prices rise as a result of rising manufacturing expenses such as raw materials and wages. The demand for commodities remains unchanged, while the supply of goods decreases due to rising production costs. As a result, the increased production costs are passed on to customers in the form of higher finished goods pricing. Wages have an impact on production costs and are often the single largest expense for enterprises. When the economy is doing well and the unemployment rate is low, labor or worker shortages might emerge. Companies, in turn, raise wages to attract qualified candidates, leading the company's production costs to grow. Natural calamities can also raise prices. Such as, if a storm destroyed a crop such as wheat or rice, prices for that crop can rise across the economy since wheat and rice are used in many products.

**Demand-Pull Inflation:** Strong demand for a product or service might cause it. Prices tend to rise as demand for a wide range of commodities rises across an economy. While continual demand can affect the economy and raise costs for other commodities, resulting in demand-pull inflation. When unemployment is low and salaries are rising, consumers' confidence is high, which leads to increased spending. Economic prosperity has a direct impact on consumer spending, which can lead to a surge in product and service demand.

For example, In India, the XYZ Company can request a full trade credit period from his supplier while only giving his dealership a partial trade credit. That example, the XYZ Company can defer payment of the entire purchase price until his supplier's delay period expires. The XYZ Company, on the other hand, only permits his dealership to defer payment for a portion of the approved credit period, with the remaining due when the dealership submits a replenishment order.

## 6.4 Stock Dependent Demand

**Dependent Demand** is occurring when the demand for an item's inventory is dependent on another item, such as component parts, raw materials, or other items.

For example, when a company manufactures cars, dependent demand includes the manufacturing processes for the tires, motor, seats, steering wheel, controls, and chassis of however many cars are scheduled for production. As an example, if 100 cars are scheduled for production, the dependent demand includes 400 tires and 100 motors. The dependent demand for electric motors in this case is based on a known factor, which is the number of cars to be manufactured. [9]. Now, increasing demands will create high fluctuations of inventory. So, here Stock dependent demand will come in picture as the dependent demands are now depends on the on-display stocks that is what is the stocks of that item which leads to stability in results and maintain order in the process.

### 6.5 Permissible delays

Permissible delays are simply allowed delays because, in most shipbuilding contracts, the delivery date specified in the contract can be postponed if one of a number of listed events occurs. Such events are frequently referred to as force majeure (irresistible events) because they are beyond human control. For example: act of God like earthquakes, thunderstorms, lightning, etc. Force majeure notices: If the Supplier or Seller wishes to extend the delivery date due to an occurrence, he must normally notify the Buyer within a specified time period of the occurrence causing delay, such as 10 days in the SAJ document [10]. The notices issued in response to force majeure events are critical. The time limit allows the Buyer to challenge the Supplier's claim while also allowing the parties to keep track of the number and duration of claims for extension of the date in order to determine when the Buyer's right to cancel arises.

### 6.6 Genetic Algorithm

A genetic algorithm (GA) is a natural selection method that produces optimal tools that reduce total costs in supply chain management. It is a method of solving inventory problems that employs evolutionary computation. This is one of the most effective methods for locating the best answer. The genetic algorithm employs three types of rules at each phase to generate the next generation from the current population [11]. Developed by John Holland in the 1960-70s.

Five phases are considered in a genetic algorithm:
**Initial population:** Population (a group of individuals) is taken, where each individual is a potential solution and defined by a set of characteristics (variables).
**Fitness function:** Find out how fit an individual is or the ability to compete with others. A fitness score is calculated for every individual. Based on its fitness score the possibility to select that individual is calculated.
**Selection:** This phase selects the fittest individuals based on previous phase and let them pass their genes or characteristics to the next generation. Parents (pairs of individuals) are selected.
**Crossover:** A crossover point is picked at random from within the genes for each parent to be mated. Parents' genes are exchanged among themselves to make offspring until the crossover point is achieved. The population is increased by the new children.
**Mutation:** Some of the genes in particular new children can be submitted to mutation with a low random probability. This means that some of the bits in the bit string can be switched around. Mutation happens in order to sustain population variety. [12].

# 7 Conclusion

In the present article we designed a model to calculate optimal order quantity for a inventory model that deals with the inflation in payments as we designed a model based on a single item whose costs are changing again and again due to different factors. So, our model helps in finding out the best optimal number of items organization have to order to reduce the total cost.

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