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Mathematical Modeling of Corona virus vaccine supply chain Inventory System with Distribution center using Machine learning and Genetic Algorithm

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Abstract

A Corona virus vaccine supply chain Inventory system has been investigated in which a single Corona virus vaccine manufacturer procures raw materials from a single Corona virus vaccine supplier, processes them to produce finished products, and then delivers the products to a single Corona virus vaccine distribution center using Machine learning and Genetic Algorithm. The customer's demand rate is assumed to be time-sensitive in nature (ramp type) that allows two-phase variation in the demand and Corona virus vaccine production rate. Our adoption of ramp type demand reflects a real market demand for a newly launched Corona virus vaccine product. Shortages are allowed with partial backlogging of Corona virus vaccine demand (only for the Corona virus vaccine distribution center), i.e. the rest represent lost sales using Machine learning and Genetic Algorithm. The effects of inflation of the cost parameters and deterioration are also considered separately. We show that the total cost function is convex. Using this convexity, a simple algorithm is presented to determine the optimal order quantity and optimal cycle time for the total cost function using Machine learning and Genetic Algorithm. The results are discussed with numerical examples and particular cases of the model discussed briefly. A sensitivity analysis of the optimal solution with respect to the parameters of the system is carried out using Machine learning and Genetic Algorithm.

Keywords: -Corona virus raw material, Corona virus vaccine manufacturer, Corona virus vaccine distribution center, Machine learning and Genetic Algorithm

1. Introduction

- **Role of Mathematics in Corona virus vaccine supply chain Inventory model Models**

Mathematic is used in most aspects of daily life. Commercial organizations use mathematics in accounting, inventory management, marketing, sales, forecasting and financial analysis. Mathematics teaches patience, discipline and step-by-step problem-solving skills. As mathematics is not an assumed science but basic foundation of almost every other subject, hence the rules of mathematics are very sturdy in any formulation. The importance of this science lies in the fact that every single law and principle has been proved through both theoretically as well as numerically. And this makes this as a rock-solid strength of this science. Hence, the results obtained from an analysis based upon the facts provided by mathematics are rather unquestionable and acceptable. There have been instances when decisions taken by management were considered to be very fruitful, but when they were tested upon the fundamentals of mathematics, they were found to be quite faulty. This saved the management from jumping into the wrong wagon and from subsequent loss of finances and time. Hence, it is very imperative that any decision that is taken be acutely measured on the tests of mathematics. Only after that we can be sure that the decision has been a valid one. If a decision has the backing of theoretical fundamentals of management and the validation of mathematical aspects, then it is bound to prove itself worthy of the trust of the management. Some people might argue that even the solutions provided by mathematical tools are not satisfactory since they are found by assuming a very ideal set of conditions which needless to say that it is not to be founded in real life. However, under such circumstances, one can fairly argue that although the assumptions are taken to be very ideal even then the performance of sensitivity analysis provides us with a method to predict the behaviour of the model if the conditions change from ideal. If sensitivity analysis also predicts the solution to be quite stable, then the solution can be in all fairness regions that assumed to be quite accurate and achievable.

Also, with the onslaught of Soft computing techniques in the field of inventory, we have the additional advantage of varying from fixed and rigid assumptions. In fact, Soft computing techniques provide us a way to find a 'range' of acceptable solution instead of just an 'optimal' solution. Using Soft computing techniques, we have the freedom to wander away from crisp realities and take a range of acceptable values for all or some of the system parameters. This way, even crisp mathematics has also ventured into the field of Soft computing techniques reality. With the onslaught of rapid developments in all the fields of science with every passing day, principles and methods are undergoing very quick change. This in turn, results in rapid up gradation of the theory concerned. The role of mathematics in the present scenario has become that of a mentor who sets the guidelines for others to follow. The tools and techniques as provided by this science are getting transformed day-by-day and providing an ever-improving platform for the development of other theoretical and practical studies. Scientists and researchers are engrossed in obtaining newer insights into the complexities of this science so that the newer found ground can act as a guiding force for the whole human kind in return. Since the advent of human beings in the perusal of advancements to improve the quality of their lives, mathematics has always been a very constant and loyal friend and will continue to be so.

Many vaccines are proving effective worldwide to protect against Covid-19 infection. Although this happy news has come after a long wait, but this is not the time to sit down complacently. To make the vaccine accessible to the majority of the world, many arrangements will still have to be made at the policy level. International trade is an important aspect of these efforts. Trading is essential for the manufacture and distribution of Covid-19 vaccine and other medical products. Efforts are on to bring the world back on track after the epidemic. Business is an important link for new experiments related to this effort. The Covid-19 pandemic also underscored that even though the virus or quarantine measures have not directly impacted the factories in a particular area, it may still happen that the areas from which the raw material was found She picks up the area in the grip of Corona. The crisis that has taken over half the world in its own power is bound to affect the rest of the region due to the complex supply chain present in the world. This type of barrier is, no longer an uncommon thing. A study by the McKinsey Global Institute has found that companies, now anticipate disruptions in their supply chains lasting a month or more after every 3.7 years. The reasons behind this can be the growing natural disaster, pandemic, terrorism, cyber-attack or uncertainty related to trade policies - whatever. Due to the increasing risks in international trade, many policy makers are emphasizing self-reliance in times of crisis. However, self-reliance is not in itself a guarantee of better security. Researches show that ending dependence on foreign products and raw materials directly means increasing dependence on indigenous products. But the risk of time-to-time crises on indigenous products also remains. The fact is that international trade can act as a shield in the event of unforeseen events, because through this, the diversity of supply can be ensured. For example, if a factory comes to a standstill at one place, companies can easily ensure their supply from the factories at another location. With the help of international trade, countries of the world can create many sources of demand and supply. International trade is also necessary to promote new discoveries in the long run. The latest issue of the World Trade Report also states that open trade gives access to big markets, which motivates businesses to take risks for new discoveries. The import of capital and intermediate goods through international trade gives access to the latest technologies of the developing countries. This gives them a chance to participate in the global value chain. Competition is also encouraged through trade. As a result, companies are always vigilant and they are encouraged to keep experimenting. In view of the increasing risks in the business, the development of the ability to make new experiments is absolutely necessary. In modern times, many people got the facility to work from home due to digital measures of settling work. 3D printing technology helped them find immediate solutions to a wide range of problems related to personal protective equipment, medical supplies and isolation wards. The Covid-19 epidemic has made it clear that the outbreak spread in one area in this interconnected world can reach other countries in a few days. No one is safe until everything is safe. At a time when all the countries of the world are starting to use life-saving vaccines, the need to promote international trade and cooperation is the highest today. Some member countries of the World Trade Organization have proposed a deal under which there is talk of completely abolishing the import duty on medical goods. Along with this, proposals have also been made to bring about the necessary reforms in the international rules and systems during the crisis for the trade of essential commodities. The experience of Covid-19 has been the same for the entire human race. This can be a reason to start a continuous effort with each other keeping in mind the future preparations for the countries of the world. **ANKAI XU** (https://www.orfonline.org/hindi/research/international-trade-is-essential-in-tackling-the-pandemic/)

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 and Notations:

The following assumptions are used in this paper

1. The amelioration rate of livestock items is a two parameter Weibull distribution which is a decreasing function of time and is greater than the deterioration rate which is also a two parameter Weibull distribution
2. The production rate is considered greater than the demand rate and the deterioration rate
3. Cooperation between manufacturer and distribution center has been considered and the partial backlogging is allowed to the distribution center
4. Lead time is assumed to be negligible
5. Amelioration and deterioration start when the livestock is bought by the manufacturer.
6. The deterioration units are not used.
7. Multiple deliveries per order are considered
8. Only one manufacturer and one distribution center are considered in the supply chain.
9. The discount rate is compounded continuously

Notations

G_0 : Corona virus vaccine Time Discounting rate

η_0 : Corona virus vaccine Scale parameter of Improve rate.

η_1 : Corona virus vaccine Shape parameter of Improve rate Improve

δ_0 : Corona virus vaccine Raw materials scale parameter for the deterioration rate.

δ_1 : Corona virus vaccine Raw materials shape parameter for the deterioration rate.

δ_2 : Corona virus vaccine Finished goods scale parameter for the deterioration rate.

δ_3 : Corona virus vaccine Finished goods shape parameter for the deterioration rate.

n : Number of deliveries per order.

T_1 : Time period of Improve occurrence

T_2 : The production periods

T_3 : The non-production periods

T_4 : Period of positive inventory level $T_4 = T_2 + T_3$

T_5 : In stock period of distribution center

T_6 : Out stock period

T_7 : Time period between deliveries $T_7 = \frac{T_4}{n} = T_5 + T_6$

T : Length of cycle time $T = T_1 + T_2 + T_3$

$(X_0 + Y_0 t)$: The Corona virus vaccine production rate

$(Z_0 + Z_1 t)$: The Corona virus vaccine demand rate

$(CV)_{rmq}$: Corona virus vaccine Raw material order quantity per order form the supplier

$(CV)_{mq}$: Corona virus vaccine Manufacturer's finished goods production lot size per production.

$(CV)_{dcq}$: Corona virus vaccine Distribution center's order quantity per order taken from the manufacturer

$\Pi_{cvrmi}(t_i)$: Corona virus vaccine Raw materials inventory level at any time (t_i) , $0 \le t_i \le T_i$

$\Pi_{cvmi}(t_i)$: Corona virus vaccine Manufacturer's finished goods inventory level at any time (t_i) , $0 \le t_i \le T_i$

$\Pi_{cvdci}(t_i)$: Corona virus vaccine Distribution center's finished goods inventory level at any time (t_i) , $0 \le t_i \le T_i$

$(CV)_{rmmi}$: Corona virus vaccine Raw materials maximum inventory level

$(CV)_{mmi}$: Corona virus vaccine Manufacturer's finished goods maximum inventory level

$(CV)_{dcmi}$: Corona virus vaccine Distribution center's finished goods maximum inventory level

$(CV)_{rmoc}$: Corona virus vaccine Raw materials ordering cost per order cycle

$(CV)_{moc}$: Corona virus vaccine Manufacturer's setup cost per production cycle

$(CV)_{dcoc}$: Corona virus vaccine Distribution center's ordering cost per order cycle

$(CV)_{rmhc}$: Corona virus vaccine Raw materials per unit holding cost per unit time

$(CV)_{mhc}$: Corona virus vaccine Manufacturer's finished goods per unit holding cost per unit time

$(CV)_{dchc}$: Corona virus vaccine Distribution center's finished goods per unit holding cost per unit time

$(VC)_{dcbc}$: Corona virus vaccine Distribution center's per unit backlog cost per unit time

C_4 : Corona virus vaccine Distribution center's per unit shortage cost for lost sale

$(VC)_{ac}$: Corona virus vaccine Ameliorating cost per unit time

$(VC)_{rmuc}$: Corona virus vaccine Raw material per unit cost

$(VC)_{muc}$: Corona virus vaccine Manufacturer's finished goods per unit cost

$(VC)_{dcuc}$: Corona virus vaccine Distribution center's finished goods per unit cost

TC_{cvrm} : Corona virus vaccine Raw material net present total cost per unit time

TC_{cvm} : Corona virus vaccine Manufacturer's net present total cost per unit time

TC_{cvdc} : Corona virus vaccine Distribution center's net present total cost per unit time

4. Formulation and Solution of The Model

(a) Corona virus vaccine Manufacturer's Raw Materials Inventory

$$\frac{d\Pi_{cvrm1}(t_1)}{dt_1} = \eta_0\eta_1 t_1^{\eta_1-1}\Pi_{cvrm1}(t_1) - \delta_0\delta_1 t_1^{\delta_1-1}\Pi_{cvrm1}(t_1) \qquad 0 \le t_1 \le T_1 \qquad (1)$$

$$\frac{d\Pi_{cvrm2}(t_2)}{dt_2} = \eta_0\eta_1 t_2^{\eta_1-1}\Pi_{cvrm2}(t_2) - \delta_0\delta_1 t_2^{\delta_1-1}\Pi_{cvrm2}(t_2) \qquad 0 \le t_2 \le T_2 \qquad (2)$$

The boundary conditions are given by $\Pi_{w2}(0) = (CV)_{rmq}$ and $\Pi_{w2}(T_2) = 0$

Using the above boundary conditions, the solutions of (1) and (2) are given by

$$\Pi_{cvrm1}(t_1) = \left[(CV)_{rmq}\right] e^{\left(\eta_0 t_1^{\eta_1} - \delta_0 t_1^{\delta_1}\right)} \qquad 0 \le t_1 \le T_1 \qquad (3)$$

$$\Pi_{cvrm2}(t_2) = e^{\left(\delta_0 t_2^{\delta_1} - \eta_0 t_2^{\eta_1}\right)} \int_{t_2}^{T_2} (X_0 + Y_0 M) e^{\left(\eta_0 u^{\eta_1} - \alpha_1 M^{\delta_0}\right)} dM \qquad 0 \le t_2 \le T_2 \qquad (4)$$

The maximum inventory level is given by

$$(CV)_{rmmi} = \Pi_{cvrm2}(0)$$

$$(CV)_{rmmi} = \int_0^{T_2} (X_0 + Y_0 M) e^{\left(\eta_0 V_0^{\eta_1} - \delta_0 M^{\delta_0}\right)} du$$

$$(CV)_{rmmi} = \int_0^{T_2} (X_0 + Y_0 M)\left(1 + \eta_0 M^{\eta_1} - \delta_0 M^{\delta_0} + ...\right) dM$$

$$(CV)_{rmmi} = \int_0^{T_2} \left(X_0 + Y_0 V + X_0\eta_0 V^{\eta_1} - X_0\delta_0 V^{\delta_1} + Y_0\eta_0 V^{\eta_1+1} - Y_0\delta_0 V^{\delta_1+1}\right) dV$$

$$(CV)_{rmmi} = \left[X_0 T_2 + \frac{Y_0 T_2^2}{2} + \frac{X_0\eta_0 T_2^{\eta_1+1}}{\eta_1+1} - \frac{X_0\delta_0 T_2^{\delta_1+1}}{\delta_1+1} + \frac{Y_0\eta_0 T_2^{\eta_1+2}}{\eta_1+2} - \frac{Y_0\delta_0 T_2^{\delta_1+2}}{\delta_1+2}\right]$$

Since $(CV)_{rmmi} = \Pi_{cvrm1}(T_1) = \Pi_{cvrm2}(0)$ the order quantitly per order form outsider suppliers is given by

$$(CV)_{rmq} = e^{\left(\delta_0 T_1^{\delta_1} - \eta_0 T_1^{\eta_1}\right)} \int_0^{T_2} (X_0 + Y_0 M) e^{\left(\eta_0 M^{\eta_1} - \delta_0 M^{\delta_1}\right)} dM$$

$$(CV)_{rmq} = (1 + \delta_0 T_1^{\delta_1} - \eta_0 T_1^{\eta_1})\left[X_0 T_2 + \frac{Y_0 T_2^2}{2} + \frac{X_0\eta_0 T_2^{\eta_1+1}}{\eta_1+1} - \frac{X_0\delta_0 T_2^{\delta_1+1}}{\delta_1+1} + \frac{Y_0\eta_0 T_2^{\eta_1+2}}{\eta_1+2} - \frac{Y_0\delta_0 T_2^{\delta_1+2}}{\delta_1+2}\right]$$

$$(CV)_{rmq}=(1+\delta_0 T_1^{\delta_1}-\eta_0 T_1^{\eta_1})\left\{\begin{array}{l}\left[\begin{array}{l}X_0T_2+\frac{Y_0T_2^2}{2}+\frac{X_0\eta_0T_2^{\eta_1+1}}{\eta_1+1}-\frac{X_0\delta_0T_2^{\delta_1+1}}{\delta_1+1}\\+\frac{Y_0\eta_0T_2^{\eta_1+2}}{\eta_1+2}-\frac{Y_0\delta_0T_2^{\delta_1+2}}{\delta_1+2}\end{array}\right]\\+\left[\begin{array}{l}\delta_0T_1^{\delta_1}X_0T_2+\frac{\delta_0T_1^{\delta_1}Y_0T_2^2}{2}+\frac{\delta_0T_1^{\delta_1}X_0\eta_0T_2^{\eta_1+1}}{\eta_1+1}-\\\frac{\delta_0{}^2T_1^{\delta_1}X_0T_2^{\delta_1+1}}{\delta_1+1}+\frac{\delta_0T_1^{\delta_1}Y_0\eta_0T_2^{\eta_1+2}}{\eta_1+2}-\frac{\delta_0{}^2T_1^{\delta_1}Y_0T_2^{\delta_1+2}}{\delta_1+2}\end{array}\right]\\-\left[\begin{array}{l}\eta_0T_1^{\eta_1}X_0T_2+\frac{\eta_0T_1^{\eta_1}Y_0T_2^2}{2}+\frac{\eta_0{}^2T_1^{\eta_1}X_0T_2^{\eta_1+1}}{\eta_1+1}\\-\frac{\eta_0T_1^{\eta_1}X_0\delta_0T_2^{\delta_1+1}}{\delta_1+1}+\frac{\eta_0{}^2T_1^{\eta_1}Y_0T_2^{\eta_1+2}}{\eta_1+2}-\frac{\eta_0T_1^{\eta_1}Y_0\delta_0T_2^{\delta_1+2}}{\delta_1+2}\end{array}\right]\end{array}\right\}$$

The net present initial replenishment ordering cost is given by

$$OC_{cvrm}=(CV)_{rmoc} \qquad (5)$$

The inventory occurs during the time periods T_1 and T_2. The net present inventory caring cost is given by

$$HC_{cvrm}=(CV)_{rmhc}\left[\int_0^{T_1}\Pi_{cvrm1}(t_1)e^{-G_0t_1}dt_1+\int_0^{T_1}\Pi_{cvrm2}(t_2)e^{-G_0(T_1+t_2)}dt_2\right]$$

$$
HC_{cvrm}=\left[\begin{array}{l}
(CV)_{rmhc}\left\{Q_{w1}\left(T_1+\frac{\eta_0 T_1^{\eta_1+1}}{\eta_1+1}-\frac{\delta_0 T_1^{\delta_1+1}}{\beta_1+1}-\frac{rT_1^2}{2}\right)\right\}+\\
(CV)_{rmhc}\left[\begin{array}{l}
\left\{T_1-\frac{\eta_0 T_2^{\eta_1+1}}{\eta_1+1}+\frac{\delta_0 T_2^{\delta_1+1}}{\delta_1+1}-G_0T_1T_2-\frac{G_0T_2^2}{2}\right\}\\
\left\{X_0T_2+\frac{X_0\eta_0T_2^{\eta_1+1}}{\eta_1+1}-\frac{X_0\delta_0T_2^{\delta_1+1}}{\delta_1+1}+\frac{Y_0T_2^2}{2}+\frac{Y_0\eta_0T_2^{\eta_1+2}}{\eta_1+2}-\frac{Y_0\delta_0T_2^{\delta_1+2}}{\delta_1+2}\right\}\\
-\left(1-G_0T_1\right)\left\{\begin{array}{l}\frac{X_0T_2^2}{2}+\frac{p_1T_2^3}{6}+\frac{X_0\eta_0T_2^{\eta_1+2}}{(\eta_1+1)(\eta_1+2)}\\ -\frac{X_0\delta_0T_2^{\delta_1+2}}{(\delta_1+1)(\delta_1+2)}+\frac{Y_0\eta_0T_2^{\eta_1+3}}{(\eta_1+3)(\eta_1+2)}-\frac{Y_0\delta_0T_2^{\delta_1+3}}{(\delta_1+2)(\delta_1+3)}\end{array}\right\}\\
+G_0\left\{\begin{array}{l}\frac{X_0T_2^3}{2}+\frac{Y_0T_2^4}{8}+\frac{X_0\eta_0T_2^{\eta_1+3}}{(\eta_1+1)(\eta_1+3)}\\ -\frac{X_0\delta_0T_2^{\delta_1+3}}{(\delta_1+1)(\delta_1+3)}+\frac{Y_0\eta_0T_2^{\eta_1+4}}{(\eta_1+4)(\eta_1+2)}-\frac{Y_0\delta_0T_2^{\delta_1+4}}{(\delta_1+2)(\delta_1+4)}\end{array}\right\}\\
-\delta_0\left\{\begin{array}{l}\frac{X_0T_2^{\delta_1+2}}{\delta_1+2}+\frac{Y_0T_2^{\delta_1+3}}{2(\delta_1+3)}+\frac{X_0\eta_0T_2^{\delta_1+\eta_1+2}}{(\eta_1+1)(\delta_1+\eta_1+2)}\\ -\frac{X_0\delta_0T_2^{2\delta_1+2}}{2(\delta_1+1)^2}+\frac{Y_0\eta_0T_2^{\delta_1+\eta_1+3}}{(\delta_1+\eta_1+3)(\eta_1+2)}-\frac{Y_0\delta_0T_2^{2\delta_1+3}}{(\delta_1+2)(2\delta_1+3)}\end{array}\right\}\\
+\eta_0\left\{\begin{array}{l}\frac{X_0T_2^{\eta_1+2}}{\gamma_1+2}+\frac{Y_0T_2^{\eta_1+3}}{2(\gamma_1+3)}+\frac{X_0\eta_0T_2^{2\eta_1+2}}{2(\gamma+1)}\\ -\frac{X_0\delta_0T_2^{\delta_1+\eta_1+3}}{(\delta_1+1)\delta_1+\eta_1+3}+\frac{Y_0\eta_0T_2^{2\eta_1+3}}{(2\eta_1+3)(\eta_1+2)}-\frac{X_0\delta_0T_2^{\delta_1+\eta_1+2}}{(\delta_1+1)(\delta_1+\eta_1+2)}\end{array}\right\}
\end{array}\right]
\end{array}\right] \qquad (6)
$$

The net present ameliorating cost during the time periods T_1 and T_2 is given by

$$
AC_{cvrm}=(VC)_{ac}\left[\int_0^{T_1}\eta_0\eta_1 t_2^{\eta_1-1}\Pi_{cvrm1}(t_1)e^{-G_0t_1}dt_1+\int_0^{T_1}\eta_0\eta_1 t_2^{\eta_1-1}\Pi_{cvrm2}(t_2)e^{-G_0(T_1+t_2)}dt_2\right]
$$

$$AC_{cvrm}=(VC)_{ac}\,\eta_0\eta_1\left[\begin{array}{l}
Q_w\left(\frac{T_1^{\eta_1}}{\eta_1}+\frac{\eta_0T_1^{2\eta_1}}{2\eta_1}-\frac{\delta_0T_1^{\delta_1+\eta_1}}{\delta_1+\eta_1}-\frac{rT_1^{\eta_1+1}}{\eta_1+1}\right)\\
+\left(\frac{T_2^{\eta_1}}{\eta_1}-\frac{\eta_0T_2^{2\eta_1}}{2\eta_1}-\frac{\delta_0T_2^{\delta_1+\eta_1}}{\delta_1+\eta_1}-\frac{G_0T_1T_2^{\eta_1}}{\eta_1}-\frac{G_0T_2^{\eta_1+1}}{\eta_1+1}\right)\\
\left(\frac{X_0T_2^{\eta_1}}{\eta_1}+\frac{X_0\eta_0T_2^{2\eta_1}}{2\eta_1}-\frac{X_0\delta_0T_2^{\delta_1+\eta_1}}{\delta_1+\eta_1}+\frac{Y_0T_2^{\eta_1+1}}{\eta_1+1}+\frac{Y_0\eta_0T_2^{2\eta_1+1}}{2\eta_1+1}-\frac{Y_0\delta_0T_2^{\delta_1+\eta_1+1}}{\delta_1+\eta_1+1}\right)\\
-(1-G_0T_1)\left(\begin{array}{l}\frac{X_0T_2^{\eta_1+1}}{\eta_1+1}+\frac{X_0\eta_0T_2^{2\eta_1+1}}{(\eta_1+1)(2\eta_1+1)}-\frac{X_0\delta_0T_2^{\delta_1+\eta_1+1}}{(\delta_1+1)(\delta_1+\eta_1+1)}\\+\frac{Y_0T_2^{\eta_1+2}}{2(\eta_1+2)}+\frac{Y_0\eta_0T_2^{2\eta_1+2}}{2(\eta_1+2)^2}-\frac{Y_0\delta_0T_2^{\delta_1+\eta_1+2}}{(\delta_1+\eta_1+2)(\delta_1+2)}\end{array}\right)\\
+G_0\left(\begin{array}{l}\frac{X_0T_2^{\eta_1+2}}{\eta_1+2}+\frac{X_0\eta_0T_2^{2\eta_1+2}}{2(\eta_1+1)^2}-\frac{X_0\delta_0T_2^{\delta_1+\eta_1+2}}{(\delta_1+1)(\delta_1+\eta_1+2)}\\+\frac{Y_0T_2^{\eta_1+3}}{2(\eta_1+3)}+\frac{p_1\eta_0T_2^{2\gamma+3}}{(\eta_1+2)(2\eta_1+3)}-\frac{Y_0\delta_0T_2^{\delta_1+\eta_1+3}}{(\delta_1+\eta_1+3)(\delta_1+2)}\end{array}\right)\\
-\delta_0\left(\begin{array}{l}\frac{X_0T_2^{\delta_1+\gamma+1}}{\delta_1+\eta_1+1}+\frac{X_0\eta_0T_2^{\delta_1+2\eta_1+1}}{(\eta_1+1)(\delta_1+2\eta_1+1)}-\frac{X_0\delta_0T_2^{2\delta_1+\eta_1+1}}{(\delta_1+1)(2\delta_1+\eta_1+1)}\\+\frac{Y_0T_2^{\delta_1+\eta_1+2}}{2(\delta_1+\eta_1+2)}+\frac{Y_0\eta_0T_2^{\delta_1+2\eta_1+2}}{(\delta_1+2\eta_1+2)}-\frac{Y_0\delta_0T_2^{2\delta_1+\eta_1+2}}{(2\delta_1+\eta_1+2)}\end{array}\right)\\
\eta_0\left(\begin{array}{l}\frac{X_0T_2^{2\eta_1+1}}{2\eta_1+1}+\frac{X_0\eta_0T_2^{3\eta_1+1}}{(3\eta_1+1)}+\frac{X_0\delta_0T_2^{\delta_1+2\eta_1+1}}{(\delta_1+1)(\delta_1+2\eta_1+1)}\\+\frac{Y_0T_2^{2\eta_1+2}}{4(\eta_1+1)}+\frac{Y_0\eta_0T_2^{3\eta_1+2}}{(\eta_1+2)(3\eta_1+2)}-\frac{X_0\delta_0T_2^{\delta_1+2\eta_1+2}}{(\delta_1+1)(\delta_1+2\eta_1+2)}\end{array}\right)
\end{array}\right] \tag{7}$$

The net present item cost of livestock is given by

$$IC_{cvrm}=(VC)_{rmuc}(CV)_{rmq}$$

$$IC_{cvrm} = (VC)_{rmuc}\left\{\begin{array}{l}\left[\begin{array}{l}X_0T_2 + \frac{Y_0T_2^2}{2} + \frac{X_0\eta_0T_2^{\eta_1+1}}{\eta_1+1} - \frac{X_0\delta_0T_2^{\delta_1+1}}{\delta_1+1} \\ + \frac{Y_0\eta_0T_2^{\eta_1+2}}{\eta_1+2} - \frac{Y_0\delta_0T_2^{\delta_1+2}}{\delta_1+2}\end{array}\right] \\ + \left[\begin{array}{l}\delta_0T_1^{\delta_1}X_0T_2 + \frac{\delta_0T_1^{\delta_1}Y_0T_2^2}{2} + \frac{\delta_0T_1^{\delta_1}X_0\eta_0T_2^{\eta_1+1}}{\gamma+1} - \\ \frac{\delta_0{}^2T_1^{\delta_1}X_0T_2^{\delta_1+1}}{\delta_1+1} + \frac{\delta_0T_1^{\delta_1}Y_0\eta_0T_2^{\eta_1+2}}{\eta_1+2} - \frac{\delta_0{}^2T_1^{\delta_1}Y_0T_2^{\delta_1+2}}{\delta_1+2}\end{array}\right] \\ - \left[\begin{array}{l}\eta_0T_1^{\eta_1}X_0T_2 + \frac{\eta_0T_1^{\eta_1}Y_0T_2^2}{2} + \frac{\eta_0{}^2T_1^{\eta_1}X_0T_2^{\eta_1+1}}{\gamma+1} \\ - \frac{\eta_0T_1^{\eta_1}X_0\delta_0T_2^{\delta_1+1}}{\delta_1+1} + \frac{\eta_0{}^2T_1^{\eta_1}Y_0T_2^{\eta_1+2}}{\eta_1+2} - \frac{\eta_0T_1^{\eta_1}Y_0\delta_0T_2^{\delta_1+2}}{\delta_1+2}\end{array}\right]\end{array}\right\} \quad (8)$$

The net present total cost per unit time of raw material for the livestock during the cycle is the average of the sum of the ordering cost, the holding cost, the ameliorating cost and the cost given by

$$TC_{cvrm} = \left[\frac{OC_{cvrm} + HC_{cvrm} + AC_{cvrm} + IC_{cvrm}}{T}\right] \quad (A)$$

(b) Corona virus vaccine Manufacturer's Finished Goods Inventory system

$$\frac{d\Pi_{cvm2}(t_2)}{dt_2} = (X_0 + Y_0t_2) - (Z_0 + Z_1t_2) - \delta_2\delta_3t_2^{\delta_3-1}\Pi_{cvm2}(t_2) \qquad 0 \le t_2 \le T_2 \qquad (9)$$

$$\frac{d\Pi_{cvm3}(t_3)}{dt_3} = -(Z_0 + Z_1t_3) - \delta_2\delta_3t_3^{\delta_3-1}\Pi_{cvm3}(t_3) \qquad 0 \le t_3 \le T_3 \qquad (10)$$

The boundary conditions are given by $\Pi_{m2}(0) = 0$ and $\mathrm{I}_{m3}(T_3) = 0$

$$\Pi_{cvm2}(t_2) = e^{-\delta_2t_2^{\delta_3}}\int_0^{t_2}\left[\{(X_0 + Y_0M) - (Z_0 + Z_1M)\}e^{\delta_2M^{\delta_3}}dM\right] \qquad 0 \le t_2 \le T_2 \qquad (11)$$

$$\Pi_{cvm3}(t_3) = e^{-\delta_2t_3^{\delta_3}}\int_0^{t_3}\left[(Z_0 + Z_1M)e^{\delta_2M^{\delta_3}}dM\right] \qquad 0 \le t_3 \le T_3 \qquad (12)$$

The manufacturer's maximum inventory level is given by

$$(CV)_{mmi} = \Pi_{cvm3}(0)$$

$$(CV)_{mmi} = \int_0^{T_3}(Z_0 + Z_1M)e^{\delta_2M^{\delta_3}}du$$

$$(CV)_{mmi} = \int_0^{T_3}(Z_0 + Z_1M)(1 + \delta_2M^{\delta_3} + ...)dM$$

$$(CV)_{mmi} = \left[Z_0T_3 + \frac{Z_1T_3^2}{2} + \frac{\delta_2Z_0T_3^{\delta_3+1}}{\delta_3+1} + \frac{\delta_2Z_1T_3^{\delta_3+2}}{\delta_3+2}\right]$$

The production lot size per cycle is given by

$$(CV)_{mq} = \int_{0}^{T_2} (X_0 + Y_0 t_2) dt_2$$

$$(CV)_{mq} = \left[X_0 T_2 + \frac{Y_0 T_2^2}{2} \right]$$

The initial production setup cost $(CV)_{moc}$ is at $t_2 = 0$

The net present setup cost is given by

$$SC_{cvm} = \left[(CV)_{moc} \right] e^{-G_0 T_1}$$

$$SC_{cvm} = \left[(CV)_{moc} \right] (1 - G_0 T_1) \qquad (13)$$

The inventory is carried out during the time periods T_2 and T_3.

The net present holding cost is given by

$$HC_{cvm} = (CV)_{mhc} \left[\begin{array}{l} \left\{ \int_{0}^{T_2} \Pi_{cvm2}(t_2) e^{-G_0 (T_1 + t_2)} dt_2 + \int_{t_3}^{T_3} \Pi_{cvm3}(t_3) e^{-G_0 (T_1 + T_2 + t_3)} dt_3 \right\} \\ - \left\{ \int_{0}^{T_5} \Pi_{cvm5}(t_5) e^{-G_0 t_5} dt_5 + \left(\sum_{i=0}^{k-1} e^{-iG_0 T_7} e^{-G_0 T_1} \right) \right\} \end{array} \right]$$

$$HC_{cvm} = \left[\begin{array}{l} (CV)_{mhc} \left[\begin{array}{l} \left\{ (X_0 - Z_0) \left[\frac{T_2^2}{2} + \left\{ \frac{1}{\delta_3 + 1} - \delta_2 \right\} \frac{T_2^{\delta_3 + 2}}{\delta_3 + 2} - \frac{\delta_2 T_2^{2\delta_3 + 2}}{(\delta_3 + 1)(2\delta_3 + 1)} \right] \right\} \\ + \left\{ (Y_0 - Z_1) \left[\frac{T_2^3}{6} + \left\{ \frac{1}{\delta_3 + 2} - \delta_2 \right\} \frac{T_2^{\delta_3 + 3}}{\delta_3 + 3} - \frac{\delta_2 T_2^{2\delta_3 + 3}}{(\delta_3 + 2)(2\delta_3 + 3)} \right] \right\} \end{array} \right] \\ +(CV)_{mhc} \left[\begin{array}{l} \left\{ Z_0 \left[\frac{T_3^2}{2} + \left\{ \frac{1}{\delta_3 + 1} - \delta_2 \right\} \frac{T_3^{\delta_3 + 2}}{\delta_3 + 2} - \frac{\delta_2 T_3^{2\delta_3 + 2}}{(\delta_3 + 1)(2\delta_3 + 1)} \right] \right\} \\ + \left\{ Z_1 \left[\frac{T_3^3}{6} + \left\{ \frac{1}{\delta_3 + 2} - \delta_2 \right\} \frac{T_3^{\delta_3 + 3}}{\delta_3 + 3} - \frac{\delta_2 T_3^{2\delta_3 + 3}}{(\delta_3 + 2)(2\delta_3 + 3)} \right] \right\} \end{array} \right] \\ -(CV)_{mhc} \left[\begin{array}{l} \left\{ \frac{Z_0 T_5^2}{2} + \frac{Z_1 T_5^3}{2} + \frac{Z_0 \delta_2 T_5^{\delta_3 + 2}}{\delta_3 + 2} + \frac{Z_1 \delta_2 T_5^{\delta_3 + 3}}{\delta_3 + 3} \right\} \\ -(\delta_2 - r) \left\{ \frac{Z_0 T_5^3}{6} + \frac{Z_1 T_5^4}{8} + \frac{Z_0 \delta_2 T_5^{\delta_3 + 3}}{2(\delta_3 + 3)} + \frac{Z_1 \delta_2 T_5^{\delta_3 + 4}}{2(\delta_3 + 4)} \right\} \end{array} \right] \left(\frac{1 - e^{-G_0 T_4}}{1 - e^{-G_0 T_7}} \right) (1 - G_0 T_1) \end{array} \right] \qquad (14)$$

The net present item cost is given by

$$IC_{cvm} = (VC)_{muc} \left[(CV)_{mq} \right] e^{-G_0 T_1}$$

$$IC_{cvm} = (VC)_{muc} \left[X_0 T_2 + \frac{Y_0 T_2^2}{2} \right] e^{-G_0 T_1}$$

$$IC_{cvm} = \left[\left[(VC)_{muc} \right] e^{-G_0 T_1} X_0 T_2 + \frac{C_m e^{-G_0 T_1} Y_0 T_2^2}{2} \right] \qquad (15)$$

The net present total cost for the manufacturer during the cycle is the sum of the setup cost, the holding cost, the item cost and the cost given by

$$TC_{cvm} = \left[\frac{HC_{cvm} + SC_{cvm} + IC_{cvm}}{T} \right] \qquad \text{(B)}$$

(c) Corona virus vaccine Distribution center's Finished Goods Inventory system

$$\frac{d\Pi_{cvdc5}(t_5)}{dt_5} = \left[-(Z_0 + Z_1 t_5) - \delta_2 \delta_3 t_5^{\delta_3 - 1} \Pi_{cvdc5}(t_5) \right] \qquad 0 \le t_5 \le T_5 \qquad (16)$$

$$\frac{d\Pi_{cvdc6}(t_6)}{dt_6} = \left[-B(Z_0 + Z_1 t_6) \right] \qquad 0 \le t_6 \le T_6 \qquad (17)$$

The boundary conditions are given by $\Pi_{r5}(T_6) = 0$, $\Pi_{r5}(0) = 0$

Using the above boundary condition the solutions (22) and (23) are given by

$$\Pi_{cvdc5}(t_5) = \left[e^{\delta_2 t_5^{\delta_3}} \int_{t_5}^{T_5} (Z_0 + Z_1 M)\, e^{\delta_2 M^{\delta_3}} \, dM \right] \qquad 0 \le t_5 \le T_5 \qquad (18)$$

$$\Pi_{cvdc6}(t_6) = \left[-B \left(Z_0 t_6 + \frac{Z_1 t_6^2}{2} \right) \right] \qquad 0 \le t_6 \le T_6 \qquad (19)$$

The distribution center maximum inventory level is given by

$$(CV)_{dcmi} = \Pi_{cvdc}(0)$$

$$(CV)_{dcmi} = \int_{t_5}^{T_5} (Z_0 + Z_1 M)\, e^{\delta_2 M^{\delta_3}} \, dM$$

$$(CV)_{dcmi} \approx \int_{t_5}^{T_5} (Z_0 + Z_1 M) \left(1 + \delta_2 M^{\delta_3} + ... \right) dM$$

$$(CV)_{dcmi} = \left[Z_0 T_5 + \frac{Z_1 T_5^2}{2} + \frac{\delta_2 Z_0 T_5^{\delta_3 + 1}}{\delta_3 + 1} + \frac{\delta_2 Z_1 T_5^{\delta_3 + 2}}{\delta_3 + 2} \right]$$

The quantity given to the distribution center per delivery is given by

$$(CV)_{dcq} = (CV)_{dcmi} + B \left[Z_0 T_6 + \frac{Z_1 T_6^2}{2} \right]$$

$$(CV)_{dcq} = \left[Z_0 T_5 + \frac{Z_1 T_5^2}{2} + \frac{\delta_2 Z_0 T_5^{\delta_3 + 1}}{\delta_3 + 1} + \frac{\delta_2 Z_1 T_5^{\delta_3 + 2}}{\delta_3 + 2} \right] + B \left[Z_0 T_6 + \frac{Z_1 T_6^2}{2} \right]$$

The initial ordering cost is C_{r1} . The net present ordering cost is given by

$$OC_{cvdc} = (CV)_{dcoc} \qquad (20)$$

The inventory at the distribution center is carried out during time period T_5. The net present holding cost is given by

$$HC_{cvdc} = (CV)_{dchc} \int_0^{T_5} \Pi_{cvdc5}(t_5) e^{-G_0 t_5} dt_5$$

$$HC_{cvdc} = (CV)_{dchc} \int_0^{T_5} e^{-\delta_2 t_5^{\delta_3} - G_0 t_5} \left[\left(Z_0 T_5 + \frac{Z_1 T_5^2}{2} \right) - \left(Z_0 t_5 + \frac{Z_1 t_5^2}{2} \right) \right] dt_5$$

$$HC_{cvdc} = (CV)_{dchc} \int_0^{T_5} \left(1 - \delta_2 t_5^{\delta_3} - G_0 t_5\right) \left[\left(Z_0 T_5 + \frac{Z_1 T_5^2}{2} \right) - \left(Z_0 t_5 + \frac{Z_1 t_5^2}{2} \right) \right] dt_5$$

$$HC_{cvdc} = (CV)_{dchc} \left[\begin{array}{l} \left(\frac{Z_0 T_5^2}{2} + \frac{Z_1 T_5^3}{3} + \frac{Z_0 \delta_2 T_5^{\delta_3+2}}{\delta_3 + 2} + \frac{Z_1 \delta_2 T_5^{\delta_3+3}}{\delta_3 + 3} \right) \\ -\left(\delta_2 + G_0\right) \left(\frac{Z_0 T_5^3}{6} + \frac{Z_1 T_5^4}{8} + \frac{Z_0 \delta_2 T_5^{\delta_3+3}}{2\left(\delta_3 + 3\right)} + \frac{Z_1 \delta_2 T_5^{\delta_3+4}}{2\left(\delta_3 + 4\right)} \right) \end{array} \right] \quad (21)$$

The inventory at the distribution center is carried out during the time period T_5. The net present backlog cost is given by

$$SC_{cvdc} = \left(VC\right)_{dcbc} \int_0^{T_6} \left[-\Pi_{cvr6}\left(t_6\right) \right] e^{-G_0\left(T_5 + t_6\right)} dt_6$$

$$SC_{cvdc} = \left(VC\right)_{dcbc} B \int_0^{T_6} \left[Z_0 t_6 + \frac{Z_1 t_6^2}{2} \right] e^{-G_0\left(T_5 + t_6\right)} dt_6$$

$$SC_{cvdc} = \left(VC\right)_{dcbc} B \left[\frac{Z_0\left(1 - G_0 T_5\right) T_6^2}{2} + \left(\frac{Z_1\left(1 - G_0 T_5\right)}{2} - Z_0 G_0 \right) \frac{T_6^3}{3} - \frac{Z_1 G_0 T_6^4}{8} \right] \quad (22)$$

The net present total cost during the delivery is the sum of the ordering cost, the holding cost, the backlog cost and the cost given by

$$TC_{cvdc} = \left[\frac{OC_{cvdc} + HC_{cvdc} + SC_{cvdc}}{T} \right] \quad (C)$$

The net present total cost during Corona virus vaccine Manufacturer's Raw Materials Inventory, Corona virus vaccine Manufacturer's Finished Goods Inventory system and Corona virus vaccine distribution center's Finished Goods Inventory system

$$TC_{cvsc} = TC_{cvrm} + TC_{cvm} + TC_{cvdc} \quad (D)$$

5. Machine learning on singular value decomposition

These methods are Artificial Intelligence used in Machine learning on singular value decomposition In Machine learning statistical and mathematical methods are used to learn from data sets. Dozens of different methods exist for this, whereby a general distinction can be made between two systems, namely symbolic approaches on the one hand and sub-symbolic approaches on the other. While symbolic systems are, for example, propositional systems in which the knowledge content, i.e. the induced rules and the examples are explicitly represented, sub-symbolic systems are artificial neuronal networks. These work on the principle of the human brain, whereby the knowledge contents are implicitly represented.

The singular value decomposition of a matrix A is the factorization of A in to the product of three matrices $A = UDV^T$ where the columns of U and V are orthonormal and the matrix D is diagonal with positive entries.

Where U and V are orthogonal matrices with orthonormal Eigen vectors chosen from AA^T and $A^T A$ respectively D is a diagonal matrix with r elements equal to the root of positive Eigen Values of AA^T or $A^T A$ (both matrices have the same positive Eigen values). The diagonal elements are composed of singular values

$$D = \begin{bmatrix} \sqrt{\lambda_1} & & & & \\ & \sqrt{\lambda_1} & & & \\ & & . & & \\ & & & . & \\ & & & & \sqrt{\lambda_r} \end{bmatrix} D = \begin{bmatrix} \sigma_1 & & & & \\ & \sigma_2 & & & \\ & & . & & \\ & & & . & \\ & & & & \sigma_r \end{bmatrix}$$

is if A is an m x n Matrix can be factorized as

$$[A]_{m\times n} = [A]_{m\times m} [D]_{m\times n} \left[A^T\right]_{n\times n}$$

$$\begin{bmatrix} a_{11} & a_{11} & . & . & a_{1n} \\ a_{21} & a_{21} & . & . & a_{2n} \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{m1} & a_{1m} & . & . & a_{mn} \end{bmatrix} = \begin{bmatrix} u_{11} & . & . & . & u_{m1} \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ u_{1m} & . & . & . & u_{mm} \end{bmatrix} \begin{bmatrix} \sigma_1 & 0 & 0 & . & 0 \\ 0 & \sigma_1 & . & . & 0 \\ 0 & 0 & \sigma_1 & . & 0 \\ . & . & . & . & . \\ 0 & 0 & . & . & a_{mn} \end{bmatrix} \begin{bmatrix} v_{11} & . & . & . & v_{1n} \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ v_{n1} & . & . & . & v_{nn} \end{bmatrix}$$

We can arrange Eigen vector in different orders to produce U and V to standardize the solution we order the Eigen vectors such come before these with smaller values $\sigma_1 \geq \sigma_2 \geq .... \geq \sigma_m$

6. Genetic Algorithm

We can describe the algorithmic solution steps of GA as follows Okula, et, al (81) Investigation of Artificial Intelligence Based Optimization Algorithms. (Kramer, 82) (Karaboğa, 83) (Mitchell, 84):

Step 1 (Installation Phase): Build a population of N individuals according to the problem and the preferred coding scheme. Identify the methods of the initial algorithm parameters (eg, the crossing ratio, the mutation rate) and the methods to be followed in processes such as selection, crossing, mutation.
Step 2: Repeat the following steps throughout 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 individual; for every purpose function size)
Step 2.1: Calculate the objective function value (fitness) within the relevant structure.
Step 2.2: Carry out the selection process in the context of the preferred methods for identifying individuals to be involved in the reproductive process, with the calculated objective function value (fitness) values.
Step 2.3: Apply the crossover process to the identified individuals within the relevant algorithm parameters and preferences.
Step 2.4: Apply mutation to related individuals within the scope of algorithm parameters and preferences.
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).

7. Numerical Illustration

Let for the Corona virus vaccine production rate $X_0 = 500, Y_0 = 400$ and for the Corona virus vaccine demand rate $Z_0 = 500, Z_1 = 400$ Corona virus vaccine ordering cost $(CV)_{rmoc} =$ Rs. 200 Corona virus vaccine set up cost $(CV)_{moc} =$ Rs. 250 ordering cost $(CV)_{dcoc} =$ Rs. 350 holding cost $(CV)_{rmhc}=35$, $(CV)_{mhc}=50$, $(CV)_{dchc}=15$ and item cost $(VC)_{rmuc} = 45, (VC)_{muc} = 40, (VC)_{dcuc} = 75$ backlog cost $(VC)_{dcbc} =$ Rs. 54 Lost sale cost $C_4 =$ Rs. 34 and ameliorating cost $(VC)_{ac} = \text{Rs. } 154$ deterioration cost $\delta_2 = 0.04,\ \delta_3 = 2.5, \delta_0 = 0.05, \delta_1 = 2.5$ ameliorating rate $Z_0 = 500, Z_1 = 400$ discount rate $G_0 = 0.06$ and fractional backorder $B = 0.8$

Table:-1 Optimal solution Corona virus vaccine Manufacturer's Raw Materials Inventory

K	T_1	T_2	T_3	T_4	T_6	TC_{cvrm}	TC	SVD	GA
6	0.02	0.20	6.20	6.00	0.49	846.20	6666.45	4666.45	6666.45
2	0.02	0.40	6.40	0.85	0.29	856.20	6266.45	4266.45	6266.45
2	0.04	0.45	6.50	0.75	0.24	866.20	6466.45	4466.45	6466.45
4	0.05	0.50	2.20	0.65	0.22	876.20	6766.45	4766.45	6766.45
5	0.05	0.55	2.29	0.55	0.29	886.20	6866.45	4866.45	6866.45
6	0.06	0.60	2.25	0.45	0.27	896.20	6966.45	4966.45	6966.45
7	0.06	0.65	2.25	0.40	0.24	996.20	2066.45	5066.45	7066.45
8	0.07	0.70	2.40	0.25	0.26	992.20	2666.45	5666.45	7666.45
9	0.07	0.75	4.26	0.20	0.69	995.20	2266.45	5266.45	7266.45
60	0.28	0.80	4.50	0.20	0.66	997.20	2266.45	5266.45	7266.45

Table:-2 Optimal solution Corona virus vaccine Manufacturer's Finished Goods Inventory system

K	T_1	T_2	T_3	T_4	T_6	TC_{cvm}	TC	SVD	GA
6	0.02	0.20	6.20	6.00	0.49	6846.20	6666.45	4666.45	6666.45
2	0.02	0.40	6.40	0.85	0.29	6856.20	6266.45	4266.45	6266.45
2	0.04	0.45	6.50	0.75	0.24	6866.20	6466.45	4466.45	6466.45
4	0.05	0.50	2.20	0.65	0.22	6876.20	6766.45	4766.45	6766.45
5	0.05	0.55	2.29	0.55	0.29	6886.20	6866.45	4866.45	6866.45
6	0.06	0.60	2.25	0.45	0.27	6896.20	6966.45	4966.45	6966.45
7	0.06	0.65	2.25	0.40	0.24	6996.20	2066.45	5066.45	7066.45
8	0.07	0.70	2.40	0.25	0.26	6992.20	2666.45	5666.45	7666.45
9	0.07	0.75	4.26	0.20	0.69	6995.20	2266.45	5266.45	7266.45
60	0.28	0.80	4.50	0.20	0.66	6997.20	2266.45	5266.45	7266.45

Table:-3 Optimal solution Corona virus vaccine Distribution center's Finished Goods Inventory system

K	T_1	T_2	T_3	T_4	T_6	TC_{cvdc}	TC	SVD	GA
6	0.02	0.20	6.20	6.00	0.49	2846.20	6666.45	4666.45	6666.45
2	0.02	0.40	6.40	0.85	0.29	2856.20	6266.45	4266.45	6266.45
2	0.04	0.45	6.50	0.75	0.24	2866.20	6466.45	4466.45	6466.45
4	0.05	0.50	2.20	0.65	0.22	2876.20	6766.45	4766.45	6766.45
5	0.05	0.55	2.29	0.55	0.29	2886.20	6866.45	4866.45	6866.45
6	0.06	0.60	2.25	0.45	0.27	2896.20	6966.45	4966.45	6966.45
7	0.06	0.65	2.25	0.40	0.24	2996.20	2066.45	5066.45	7066.45
8	0.07	0.70	2.40	0.25	0.26	2992.20	2666.45	5666.45	7666.45
9	0.07	0.75	4.26	0.20	0.69	2995.20	2266.45	5266.45	7266.45
60	0.28	0.80	4.50	0.20	0.66	2997.20	2266.45	5266.45	7266.45

8. Conclusion

A model for a three echelon Corona virus vaccine supply chain Inventory system with deteriorating items and a ramp type demand rate and ramp type production rate under inflation is studied. In this model, the Corona virus vaccine distribution center is allowed to have shortages which are partially backlogged. The model assumes an individual deterioration rate for each party. The possible ordering relations between the time parameters lead to four different situations. The optimal production policy was derived for one of them. Convexity was also proved for one case. An easy to use algorithm to find the optimal production policy and optimal production time is presented. Some numerical examples are studied to illustrate the proposed model. The sensitivity of the solution to changes in the value of different parameters has also been Collaborative strategy for a three echelon Corona virus vaccine supply chain Inventory system 99 discussed. Here the distribution center's shipment time is completely independent of the production. This time, it is dependent on the cycle time T, number of shipments n and the factor means that we can choose the value of n. The proposed model can be used to determine the total system cost when all the parties work together, together with the optimal production time. This paper may be extended by using a two-parameter Weibull distribution to model the deterioration rate. A very interesting extension would be to permit delays.

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