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Research Article

Modelling An Inventory Model For Food Grains In Northern Telangana Using Meta Heuristic Techniques.

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ABSTRACT
To explore the inventory optimization of circulation businesses, a demand analysis was conducted first, with the supply-demand balance in mind. Cold storage facilities are one of India's most rapidlygrowing industries. Despite a high production of perishable food, India's cold storage business is stillin its infancy. Increasing urbanization and the rise of organized retail, food service, and food processing sectors, on the other hand, are leading to the growth of India's cold storage chain industry.This study used a multi-level Public Distribution System (PDS) of facilities such as godowns and distribution centers such as Mandal Level Stock Points (MLSPs). Traditional optimization approaches usually necessitate the formulation of an explicit mathematical model based on specific assumptions. The validity of such models and methodologies for real-world applications is primarilydetermined by how closely the beliefs reflect reality. In contrast to previous methods, meta-heuristicsdo not require such assumptions, allowing for more realistic modelling of the inventory control system and its solution. It is proposed in this work to provide a model to reduce overall overheads, including ordering and reordering expenses and inventory holding costs, enabling seamless productdistribution from warehouses to MLSPs and fair pricing shops (FPS). The ideal ending inventory atthe end of each time period and a total variable cost estimate for Food Corporation of India (FCI) using realistic data for the Binary Particle Swarm Optimization (BPSO) technique. When comparing the overall cost of the existing system to the total cost of the PDS problem under discussion using the BPSO method, roughly forty cores and 33.47% decrease the total cost.

Keywords: Inventory system, Ordering Cost, Holding Cost, Binary Particle Swarm Optimization, meta-heuristics

1. Introduction

For around 58% of India's overall population, agriculture is their primary source of income. India'sdemand for food goods is being driven by the country's vast population and migration from rural tourban areas [1, 2]. In the agriculture sector, the majority of Indians rely heavily on the monsoon. Many sections of India have recently been affected by climate change. As a result of these factors, food grain production varies yearly, with one year having an abundance of food produce followed by a year with a severe shortage. Like the pharmaceutical industry, the food industry requires cold storage facilities to retain perishable items for a length of time. The production of perishable items such as food grains, fruits, vegetables, and marine produce continues to rise in demand due to inflation, which causes a need in the food supply. As a result, we must maintain these commodities;a cold storage facility is required to keep these goods from deteriorating. Cold storage facilities, moreover, assist in extending the shelf life of fresh items. Furthermore, it helps minimize waste andextend the time range for marketing these perishable commodities [3, 4].
According to a recent survey, poor farmers are forced to sell their produce at the lowest price possible shortly after harvesting due to a lack of cold storage facilities and the associated supply chain ecology. Our country has seen significant price changes in horticultural output, mainly onions,tomatoes, and other vegetables, due to increased demand for food. These are the reasons why a coldstorage facility is critical and necessary for our farmers. In India, most cold storage facilities are usedto keep only 75% of the potatoes grown between January and March. There will be no price changes during the harvest season. Prices began to vary after April. Since then, fresh potatoes are only available for three months on the market throughout the harvesting season.

The majority of FSC operations are carried out by the Food Corporation of India (FCI), which works in partnership with other state agencies and authorities in India. The FSC network isparticularly complicated in underdeveloped countries like India, where procurement and distributiondecisions rarely use a scientific approach. Figure 1 depicts India's integrated food grain supply chainnetwork constructed by carefully researching existing food grain production, procurement, and distribution activities. Procurement, intra-state transportation (among different regions within the state), inter-state distribution (across other states—mostly from surplus to deficit states) and, finally,transportation of food grains from district level warehouses (DLW) to end delivery points known asFair Price Shops are the four critical nodes in the food grain supply chain network (FPS). The PublicDistribution System (PDS) is the final stage of transportation from a storage location (at the regionallevel) to an end customer (a population below the poverty line) via FPS.

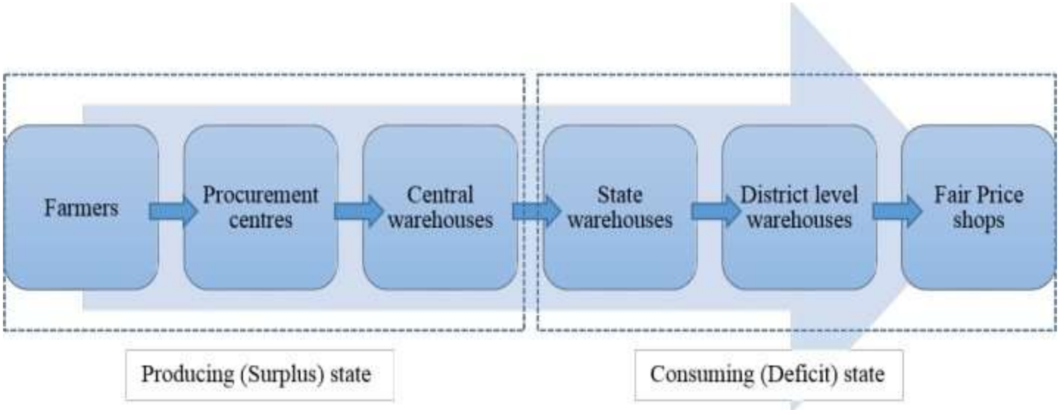

Fig 1 Operations involved in food grain supply chain in India

Increased production, procurement, and loss reduction are required to feed India's rising populationdue to escalating and post-harvest losses. Alternatively, ordering a more considerable amount minimizes the number of orders and hence the cost of ordering. However, the carrying cost has increased. In addition, extra storage space and store staff are necessary. Inventory products that havebeen stored for an extended period of time may develop defects. As a result, achieving a balance between carrying and ordering expenses is critical. As a result, an effective inventory model is created, which determines the lot size with the lowest total inventory cost. However, this research aims to reduce total expenditure on warehouses and MLSPs by minimizing procurement expenses, ordering/reordering costs, and inventory holding costs during a twelve-month planning horizon in the year 2020. The BPSO technique is used to solve the defined problem, then tested using the dataacquired. It has been recommended that the best method to address this issue is to establish district MLSPs, which allow for the decrease of rice wastage and storage costs. In this study, the current PDS uses many FCI MLSP-owned godowns, which incur costs for holding and ordering/reorderingfor the transportation demands of all points, all of which are required to meet the requisiterequirements demand.

2. Background works

The authors of [7] discussed the two total cost equations that were studied and optimized. One factorto consider is the cost of a shortage, while another is the cost of backlog. The holding cost is the most critical parameter in both equations. Data was gathered from a well-known firm. The L9 orthogonal array of Taguchi Analysis was applied to both equations to discover the optimum parameter of the total cost equation. After that, the optimum parameters were used to construct both equations, and it was found that the total cost, which includes the shortage cost, is significantly moreprofitable.

The authors of [8] looked at a robust inventory problem in which perishable products havea set shelf life, and demand is believed to be uncertain and can take any value in a given polytope. Interestingly, when unpredictable requests are considered, a portion of the production gets spoilt, a phenomenon that does not occur in the deterministic context. They suggested a resilient model basedon a deterministic model. Production decisions are first-stage variables, and inventory levels and ruined production are recourse variables that can be adjusted to the demand situation using the FIFO policy. To deal with the FIFO policy's non-anticipatively requirements, a non-linear reformulation of the vital issue was given, which was then linearized using classical techniques. Also, using a decomposition technique suggested a row-and-column generation approach to solve the reformulated model to optimality. The decomposition approach has been proved to solve a set of examples representing various practical circumstances in a reasonable time in computational tests. Furthermore, when worst-case scenarios occur, the robust solutions obtained assure minimal production losses.

The authors of [9] provided an inventory control model for perishable commodities that was reliant on the inventory rate and had a demand rate that changed over time. The model also tookinto account the possibility of backlogs and missed sales. Deterioration is represented as a time- dependent variable, and poor product quality is considered. The framework envisions the capacity to specify variables influenced by uncertainty as probability distribution functions, which are subsequently handled together using a Monte Carlo simulation. This research aims to provide an analytical framework for dealing with uncertainty and time-dependent inventory functions for a range of perishable goods. The formulation is intended to assist decision-making in determining thebest order quantity. A numerical example illustrates the paper's

findings and includes a cost-based sensitivity analysis to understand the effects of critical parameters better.
The authors of [10] look at the challenge of establishing the best pricing and inventory replenishment strategy for a deterministic perishable inventory system with time and price- dependent demand. The inventory is also expected to depreciate over time. During the sales season,the seller can adjust costs several times at a fixed cost to affect demand and increase revenues. Theydevised a mathematical model to determine the best times to modify pricing and the best prices andorder quantities. They presented analytical results for choosing the best pricing when price changesare known and heuristic algorithms for choosing the best times to alter prices. They compared the profits obtained by a single price case to the efficiency of numerous pricing strategies and the effectof other factors on the ideal solution through numerical tests.
The authors of [11] focused on a specific type of dynamic pricing and advertising model for perishable goods sales, incorporating marginal unit costs and inventory holding costs. They assume a finite time horizon and allow specific model parameters to be time-dependent. They provide closed-form expressions of the value function and the optimal pricing and advertising policyin feedback form for the stochastic version of the model. Furthermore, they show that the model converges to a deterministic version of the problem for tiny unit shares, with an explicit solution defined by an overage and an underage situation. The close similarity between the deterministic model's open-loop solution and the projected evolution of optimally regulated stochastic sales processes is measured. They derive sensitivity results for both models and find that optimal prices increase with time while advertising rates fall in the situation of positive holding costs. Furthermore, they demonstrate the outstanding performance of optimum feedback policies of deterministic models when applied to stochastic models analytically.

3. Materials and methods

The overall demand should be estimated first using the MLSP's request. The section consists of the problem of lot-sizing that we considered. We have '*N*' products to produce in '*T*' periods over a planning horizon to meet a demand prediction. The planning horizon of each item in a multistage production system is dependent on the production of other things at lower levels. Production and setup resources are inadequate, and lead times are considered to be zero. There are no shortages allowed, and demand is predetermined. For the integration problem, mathematical models for distinct lot-sizing challenges are created using capacity limits, sequence-dependent setup costs, andtimings. The limitations of machine capacity, non-simultaneity, and the classical inventory balance equation are all included in the formulation. The simplest model in the inventory lot-sizing problemsis the single uncapacitated item no shortages allowed and single-level lot-sizing model. Thefollowing goal function is used in the lot-sizing formulation for this type of lot-sizing problem.

$$Min \sum_{l=1}^{m}\left(Xa_l + yB_l\right)$$

$$l = 1, 2, 3, ...m$$

$$B_l = 0$$

$$B_{l-1} + a_l P_l - B_l = R_l$$

$$B_l \geq 0$$

$$P_l \geq 0$$

$$a_l \in \{0,1\}$$

The simplest model in the inventory lot-sizing problems is the single incapacitated item no shortages allowed and single-level lot-sizing model. The following objective function is used in the lot-sizingformulation for this type of lot-sizing problem:

$$Min \sum_{l=1}^{m}\left(Xa_l + yB_l\right)$$

$$l = 1, 2, 3, ...m \tag{1}$$

Where,
m = number of months i.e. 12
X = ordering cost per month and
y = holding cost per unit per month

Subject to

$$B_l = 0 \quad (2)$$

$$B_{l-1} + a_l P_l - B_l = R_l \quad (3)$$

$$B_l \geq 0 \quad (4)$$

$$P_l \geq 0 \quad (5)$$

$$al \in \{0,1\} \quad (6)$$

Where,
Rl = Net requirement for month l,
Pl = Order quantity for month l,
Bl = Projected inventory balance for month l,
xl = 1 if an order is placed in month l and xl = 0 otherwise.

A penalty X is levied for each order placed, and a penalty y is imposed for each unit carried in inventory throughout the next period in the first equation. The second equation ensures that there isno initial inventory. The inventory balance equation, in which the order quantity Pl covers all requirements until the next order, is the third equation. The fourth equation satisfies the requirementof no shortages. Finally, the fifth equation demonstrates that the choice variable al is either 1 (makean order) or 0 (don't place an order) (do not place an order). It's worth noting that the initial inventoryis zero, Bl= 0, which means that if $Rl > 0$, $a1$=0 by equation-3. Because the problem is a minimizationproblem, the ending inventory at each period is kept to a minimum to avoid penalty y, especially when Bl= 0.

4. Results and Discussion

The following Table 1 shows the Red Chili allotment to the several districts of Northern Telangana for the year 2020, with the total allotment for each month in quintal. For the analysis, the ordering cost of Red Chili is Rs. 1,00,000/-, the carrying cost per quintal is Rs. 50/-, and the overall cost of Red Chilli is Rs. 5000/-.

Table 1. Red Chilli allotment of various divisions in Northern Telangana for 2020

Northern Telangana districts					
Adilabad	**Jagtial**	**Karimnagar**	**Mancherial**	**Siddipet**	**Total (Quintal)**
48930	21789	23785	13284	21503	129291
46924	22621	24281	12846	24228	130900
47238	22468	24624	14280	34060	142685
46607	21937	32542	26645	20965	157396
46832	23565	24623	22543	13129	130692
47970	24010	24810	15280	24023	136101
44249	22346	19795	28753	22981	128124
42136	18020	24018	22468	17310	123952
45355	23255	23032	24670	16345	132657
43081	21721	22088	24410	12385	123685
49110	21280	26371	18205	28900	143874
43090	24990	25812	19010	39805	152707

Table 2. Total cost in rupees before execution of BPSO

Month wise Cost Difference in Rupees				
Month	**Total Costof Red chilli**	**Carrying Cost (Rs.50/Qtl)**	**OrderingCost**	**Total Cost**
Jan	100000000	323656	100000	100423656
Feb	100000000	331593	100000	100431593
Mar	100000000	30715	100000	100430715
Apr	100000000	340810	100000	100440810
May	100000000	352000	100000	100452000
Jun	100000000	210452	100000	100310452
Jul	100000000	353664	100000	100453664
Aug	100000000	362450	100000	100462450
Sep	100000000	340325	100000	100440325
Oct	100000000	376540	100000	100476540
Nov	100000000	381760	100000	100481760
Dec	100000000	392800	100000	100492800

Execution of BPSO Model for Red Chilli allotment and variable costs:

The actual demand for the year 2020 in northern Telangana districts has been obtained. The ordering and carrying inventory have been estimated using the ordering decision month by month, as shown in Table 3. Every month, the allotment of red chillies is computed using binary values (1, 0). The binary character '1' denotes an order and the ordering cost incurred at that time, while the binary digit '0' denotes no order, i.e., the carrying cost of Red chilli is incurred at that time. The ordering inventory of 426540 quintals of Red chilli is ordered in March 2020 to supply in April and May. Similarly, in June 2020, 653402 quintals of Red chilli were ordered as part of the total ordering inventory for July, August, September, and October 2020.

Table 3. Demand and order decision matrix during the year 2020

Month	**Demand (Quintals)**	**OrderingCost**	**Inventory (Ordering)**	**Inventory (Carrying)**
Jan	129291	1	129291	0
Feb	130900	1	130900	0
Mar	142685	1	426540	283855
Apr	157696	0	0	130692
May	136092	0	0	0
Jun	136101	1	653402	517301
Jul	138124	0	0	380294
Aug	123952	0	0	256342
Sep	132657	0	0	123685
Oct	123685	0	0	0
Nov	143874	1	143874	0
Dec	152707	1	152707	0

The month wise preserved inventory for ordering and carrying inventory for the year of 2020 has been identified and given in the following figure 2.

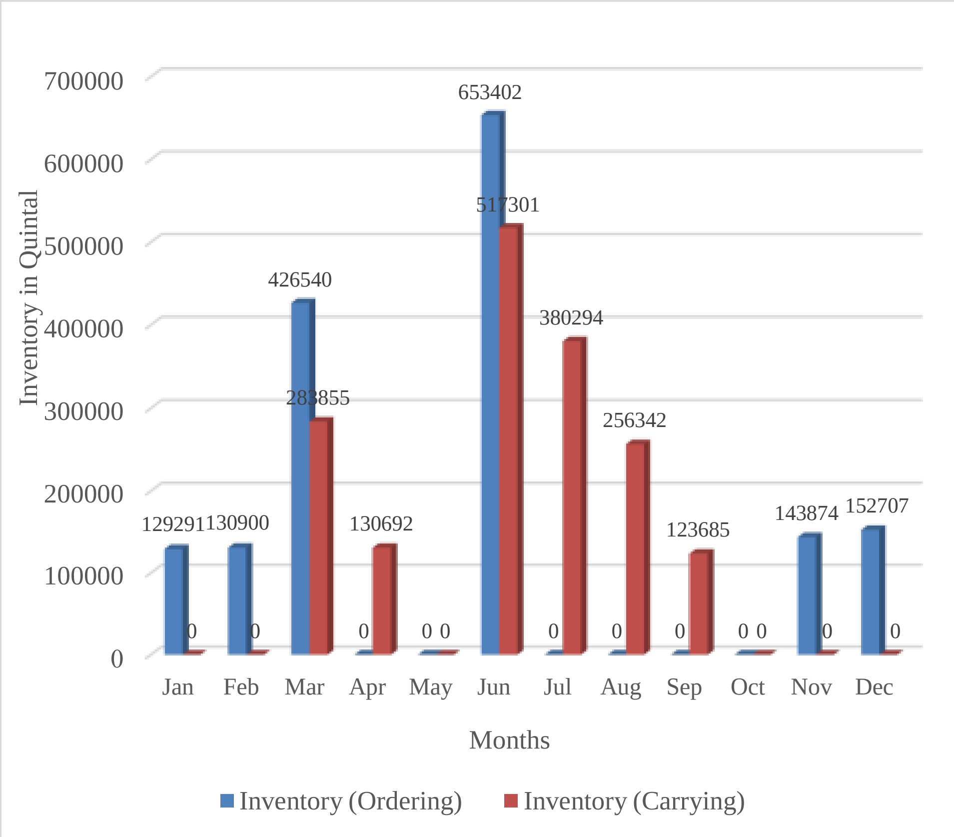

Fig. 2 Ordering and carrying inventory-2020

Table 4. Demand and order decision matrix during the year 2020 (Turmeric)

Month	Demand (Quintals)	OrderingCost	Inventory (Ordering)	Inventory (Carrying)
Jan	139291	1	139291	0
Feb	140900	1	140900	0
Mar	152685	1	526540	383855
Apr	167696	0	0	140692
May	146092	0	0	0
Jun	146101	1	753402	617301
Jul	148124	0	0	480294
Aug	133952	0	0	356342
Sep	142657	0	0	223685
Oct	133685	0	0	0
Nov	153874	1	153874	0
Dec	162707	1	162707	0

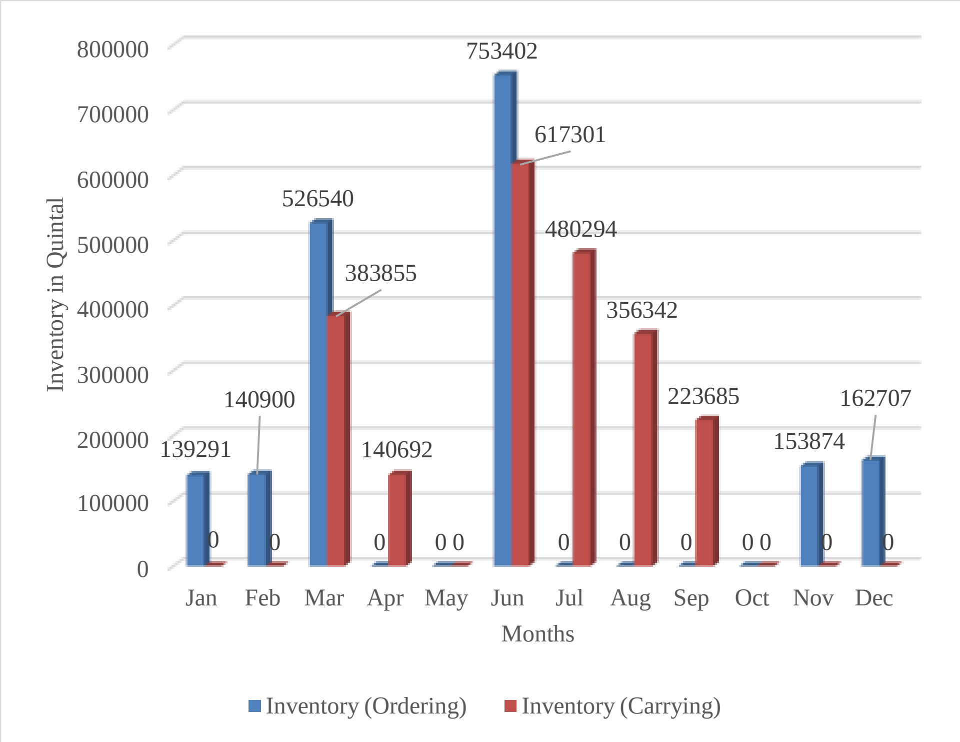

Fig. 3 Ordering and carrying inventory-2020

Table 5. Various costs after execution of BPSO

Month	Red chilli Cost	Ordering Cost	CarryingCost (Rs.5/Quintal)	Total Cost
Jan	63638050	100000	0	63738050
Feb	67342000	100000	0	67442000
Mar	216024600	100000	1297110	217421710
Apr	0	0	897540	897540
May	0	0	0	0
Jun	316520700	100000	2828515	319449215
Jul	0	0	1783280	1783280
Aug	0	0	1329510	1329510
Sep	0	0	776455	776455
Oct	0	0	0	0
Nov	67827900	100000	0	67927900
Dec	65314680	100000	0	65404680

Evaluation of carrying, ordering and total costs:

From the calculated ordering and carrying costs, the total cost of the Red Chilli after implementing the BPSO was calculated. The government determined the Red Chilli's carryingcost based on the desire rate. The total cost of the Red Chilli after BPSO is shown in table 5. The graphical depiction of the total cost after BPSO is shown in figure 4.

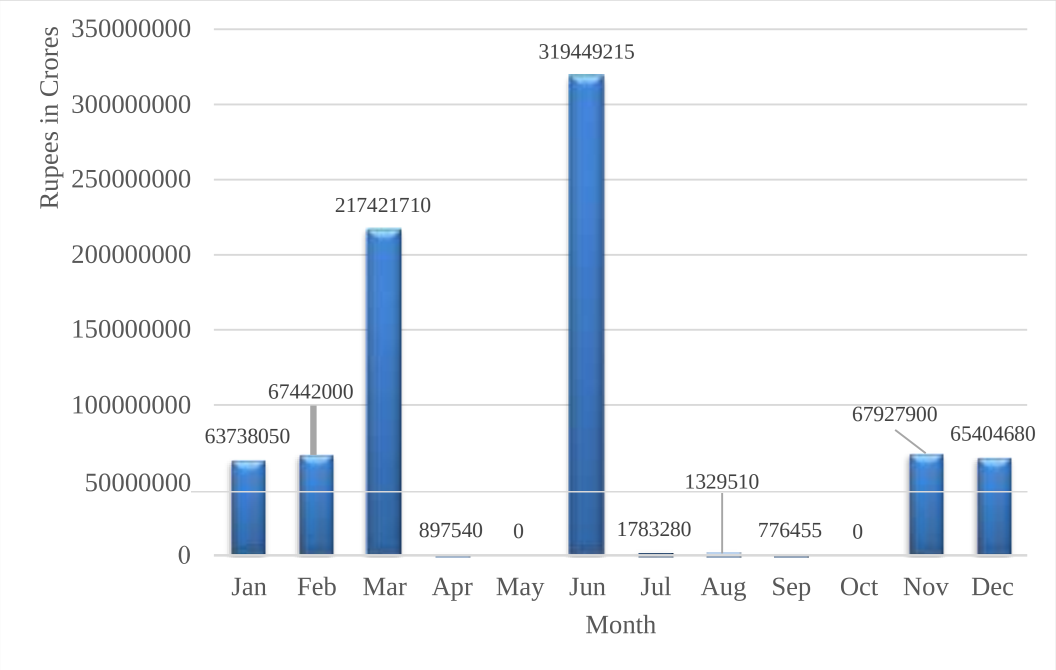

Fig. 4 Total cost after execution of BPSO

Comparison of Results before and after execution of BPSO:

The total costs of the Red chilli before and after BPSO were compared, and the percentage of reduction was computed using the data. The following table 6 shows a comparison of month- by-month cost and percentage reduction, as well as a graphical representation of the month - by-month % reduction in figure 5.

Table 6. Comparison of total cost before and after BPSO execution

Month wise Cost Difference in Rupees				
Month	**Before BPSO**	**After BPSO**	**Difference**	**% of Reduction**
Jan	100423656	63738050	36685606	37
Feb	100431593	67442000	32989593	33
Mar	100430715	217421710	-116990995	-117
Apr	100440810	897540	99543270	100
May	100452000	0	100452000	100
Jun	100310452	319449215	-219138763	-219
Jul	100453664	1783280	98670384	99
Aug	100462450	1329510	99132940	99
Sep	100440325	776455	99663870	100
Oct	100476540	0	100476540	100
Nov	100481760	67927900	32553860	33
Dec	100492800	65404680	35088120	35

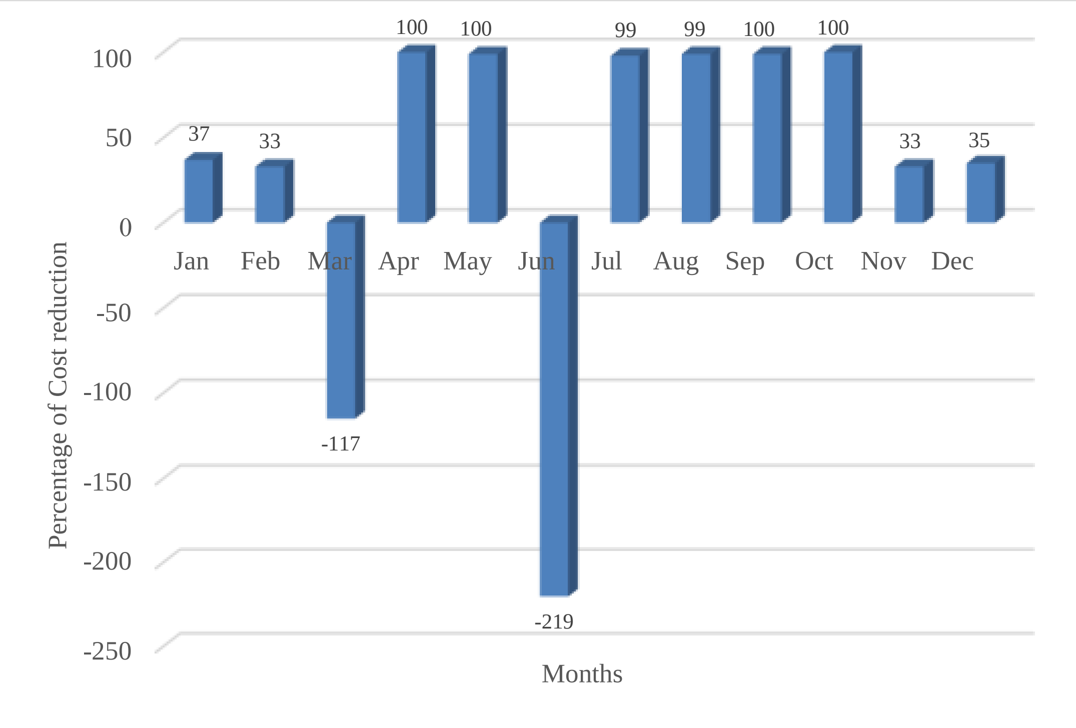

Fig.5 Month wise Percentage of Reduction for the year of 2020

5. Conclusion

From the analysis above, it can be inferred that the BPSO model delivers the lowest total annual inventory cost in all scenarios in this analysis. A suitable mathematical model was proposed for the problem of total variable cost/expenses reduction of the PDS through certain limits. Using realistic accessible data to execute the BPSO technique, the model has set at FCI, the optimum inventory after each time period, and the total variable cost estimate for FCI. The total cost was lowered for single item single-level competence problems by successfully implementing the BPSO approach. When comparing the total cost of the PDS problem under consideration by the BPSO approach to the total cost of the existing system, it is observed that the total cost is reduced by about forty cores or 33.47%.

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