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Determination of Cold Storage Location in Odisha for Minimum Transportation Cost

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Abstract

This paper is a case study of facility location problem implementing PMP and PCP with the help of genetic algorithm in MATLAB. The study is about determining locations of cold storage facilities in the different districts of Odisha which are the major producers of vegetables and fruits. The work consists of selecting the demand nodes or locations and finding out the locations of the new cold storage facilities to be established. Here the work concentrates on developing a program code which can take the input as the demand locations and with the help of genetic algorithm can find the locations of cold storage facilities as output and the allocations of them to the demand nodes subjected to the constraints. The work aims to determine the locations of facilities such that the availability will be maximized and the total transportation cost will be minimized between the demand nodes and the facilities allocated to them. The facility location problem is formulated on the basis of PMP and the objective as of PCP is added to the problem for the improvement in the result of FLP.

Keywords: *PMP (P-median Problem), PCP (P-centre Problem), Genetic algorithm, FLP (Facility Location Problem)*

1.Introduction

Location problems aim to determine the best locations for facilities such as hospitals, emergency stations, banks, ports, warehouses, fire stations, military installations, etc. Many studies have focused on the facility location problems (FLPs), while various models and solution techniques have been developed to respond to different needs and objectives. Here the facilities are the cold storages and the demand nodes are the major production areas of Odisha. The objective of the work is to create a cold storage network in Odisha in order to minimize the cost of transporting and to encourage farmers for better production of crops.

As we know supply chain management is applied in every industry nowadays, but there is lack of supply management in the food production industry, especially in the field of supply of crops produced from farmers to wholesalers or distributors. Due to this there is huge fluctuation in the prices of the agricultural products (mostly vegetables) in India. The supply chain from producers (farmers) to customers is facing problems due to the insufficient number of cold storage facilities in several states of India. Farmers have to forecast the demand and to produce according to the forecast. If there will be high demand then there will be a hike in the price of products and if there will be less demand then the prices of the products will be reduced and farmers will suffer the loss. To avoid this there should be a cold storage network with the sufficient number of cold storage facilities. Odisha is a major producer of agricultural products in India and facing the same problem as stated above. This paper intends to work on a case study i.e. to create an optimized network of cold storages in Odisha to reduce the fluctuation of product prices and encourage farmers for higher production.

2.Literature Survey

Mumtaz Karatas et. al. in his study presents a novel methodology for solving facility location problem incorporating p-median model, Maximal Covering Location Problem (MCLP) model and p-centre model aiming to find a set of Pareto optimal solutions. Fabiano Fernandes Bargos et. al. used the data from CANSAT project which maps the cultivation of sugarcane in Brazil and formulate binary linear programming for p-median model and compared it with a greedy heuristic algorithm in order to find out the better method. Then he used this method to find out the locations of ethanol mills in Brazil. Marianov and Revelle develop a probabilistic MCLP formulation structure for locating healthcare and medical emergency service facilities in which availability is computed utilizing queue theory. In another study. Fabio Colombo et. al. introduced the Multimode Covering Location Problem which is a generalization of the Maximal Covering Location Problem that consists in locating a given number of facilities of different types with a limitation on the number of facilities sharing the same site. In another study, D.Serra and Marianov used PMP model to investigate the problem of locating fire stations in the city of Barcelona. The authors also consider demand uncertainty and stochastic travel times between demand and facility locations. Revelle and Hogan develop a PCP model to determine locations of emergency service systems with the objective of minimizing the maximum distance between demands and stations. In his study. M.H. Fazel Zarandi et.al. in his paper presents a customized Genetic Algorithm (GA) to solve MCLP instances, with up to 2500 nodes to solve the real life situations with higher nodes.In another emergency station application. Stummer et. al. used a multi-objective search algorithm to determine the locations and sizes of medical facilities in a hospital network. They show the performance of their solution approach on a numerical example based on hospital data from Germany. Rajali Maharjana et.al. described in his journal a modified version of maximal covering location problem to determine optimal number and locations of warehouses in Nepal for humanitarian relief to improve overall responsiveness and efficiency. Chumpol Monthatipkul in his paper developed a mathematical model to estimate the location of a second warehouse for a case study in Bangkok. A non-linear program was developed based on the Load Distance Technique. The objective function was to minimize the sum of weighted straight-line distances from the first or second warehouse to either vendors or customers.

3. Objective of The Study

A typical facility location problem is choosing the best places among the potential sites to establish facility subjected to constraints such that the demands at several points must be served by the established facilities. The objective is to find facilities so that the total cost will be minimized. The total cost consists of the total transportation cost and the cost of opening new facilities. In this paper, the problem is of locating cold storage facilities in Odisha to minimize the total transportation cost. The location of major producing places in Odisha will be considered as demand nodes to be served by the cold storage facilities.

4. Research Methodology

In Odisha there are 30 districts in which the production of crops and the types of crops cultivated are different from each other. To find out the cold storage facilities in all over Odisha is a huge task which will be difficult to work out in this research paper. To reduce the amount and complexity of data the area of focus is restricted to certain districts of Odisha. The wholesale markets of the selected districts are considered as the demand points or nodes which will act as input. As a wholesale market is a symbol of a major producing area, the wholesale markets can be taken as the reference for demand nodes. Here the longitudes and latitudes of the demand nodes are taken as the input.

4.1. Model Formulation

The structure of the location problem includes major producing places of Odisha (representing demand) that are already positioned in a two-dimensional discrete space and a set of facilities to be positioned by a decision maker. Our goal is to find an optimal solution set for the FLP problem in which the decision maker seeks to:

- Minimize the average distance between demand nodes and their nearest facilities (PMP)

- Minimize the maximum distance (PCP)

Hence, this section provides mathematical formulations of PMP and PCP which form the basis of our iterative approach:

Parameters:

$i \in I$: set of demand points.

$j \in J$: set of candidate locations.

m = number of candidate sites ($m = |J|$)

p = number of facilities to be located

n = number of demand locations ($n = |I|$)

w_i = weight of demand i

d_{ij} = distance between locations i and j

r = maximum range of a facility

Decision variables:

x_{ij} = (1, demand i is assigned to a facility at location j or 0, otherwise)

y_j = (1, a facility is opened at location j or 0, otherwise)

d_{max} = the maximum of the distances between each demand and their nearest facilities.

4.2. P-Median Problem Formulation

The PMP model is formulated with objective function and constraints as explained below:
Objective Function:
Min. $z_{PMP}=1/n \sum_{i\epsilon I} \sum_{j\epsilon J} w_i d_{ij} x_{ij}$
Constraints:
i. $\Sigma Y_j \leq p$
ii. $\Sigma X_{ij} = 1, \forall i \in I$
iii. $X_{ij} \leq Y_j, \forall i \in I, j \in J$
iv. $X_{ij} \geq 0, \forall i \in I, j \in J$
v. $Y_j \in \{0, 1\}, \forall j \in J$
The objective function aims to minimize the average weighted distance between demands and their nearest facilities. Constraint $\Sigma Y_j \leq p$ limits the number of opened facilities to p. Together with the objective function and constraint $\Sigma X_{ij} = 1, \forall i \in I$ ensures that each demand is assigned to its nearest facility. Constraint $X_{ij} \leq Y_j, \forall i \in I, j \in J$ ensures that demand i cannot be covered by a location j if no facility is installed at that location. Constraint $X_{ij} \geq 0, \forall i \in I, j \in J$ declares the variable domains.

4.3. P-Centre Problem Formulation

The PCP model is formulated with objective function and constraints explained below:

Objective Function:
Min. $z_{PCP} = d_{max}$
Constraints:
i. $\Sigma Y_j \leq p$

ii. $\Sigma X_{ij} = 1, \forall i \in I$

iii. $X_{ij} \leq Y_j, \forall i \in I, j \in J$

iv. $d_{ij} x_{ij} \leq d_{max}, \forall i \in I, j \in J$

v. $x_{ij}, y_j \in \{0, 1\}, \forall i \in I, j \in J$

In PCP Formulation, the objective function aims to minimize the maximum distance between demands and their nearest facilities. Constraints $\Sigma y_j \leq p$,

$\Sigma x_{ij} = 1, \forall i \in I$ and $x_{ij} \leq y_j, \forall i \in I, j \in J$ are similar to $\Sigma y_j \leq p$, $\Sigma x_{ij} = 1, \forall i \in I$ and $x_{ij} \leq y_j, \forall i \in I, j \in J$. Together with the objective function ,constraint set $d_{ij} x_{ij} \leq d_{max}, \forall i \in I, j \in J$ assigns the maximum distance to the objective function value. Finally, constraint set $x_{ij}, y_j \in \{0, 1\}, \forall i \in I, j \in J$ declares the variable domains.

5. Genetic Algorithm Used to Develop Facility Location Problem

As discussed in methodology the facility location problem is formulated on the basis of PMP (p-median problem) and PCP (p-centre problem) and the programme is written in MATLAB-2016b using genetic algorithm to solve the FLP.To develop the programme code to solve the FLP an algorithm is prepared at first and is described below.

- Create random population in which each chromosome or solution will carry two parts, one part for the location information and the other part will carry the allocation details. Again the first part of solution, which carries the location details have two parts, one is for latitude and other is for longitude.
- Provide limits to the first part of population to the limits of latitudes and longitudes and the second to zero and one. (If there is allocation the value will be zero, otherwise it will be zero)
- The input should be provided by the locations of wholesale markets.
- Create a fitness function to determine the total distance between the cold storage facilities and its allocated demand locations and the maximum distance between them which have to be minimized.

- Provide constraints to the solutions so that the one demand should not be served by more than one cold storage facility and the number of cold storages should be restricted.

6. Data Analysis and Interpretation

This study has been restricted to certain districts of Odisha such as Cuttack, Puri, and Mayurbhanj. Following assumptions were taken during the data analysis.

- There is proper road access to everywhere in the districts.
- There are no existing cold storages in the above districts.
- The allocation of facilities can be shifted within the tolerance limit to locate them in a suitable place.
- The cold storage facilities can afford any amount of storage.

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6.1 Analysis of Cuttack District

Location and allocation of cold storage facilities in Cuttack district is computed by the programme and the results are given below.

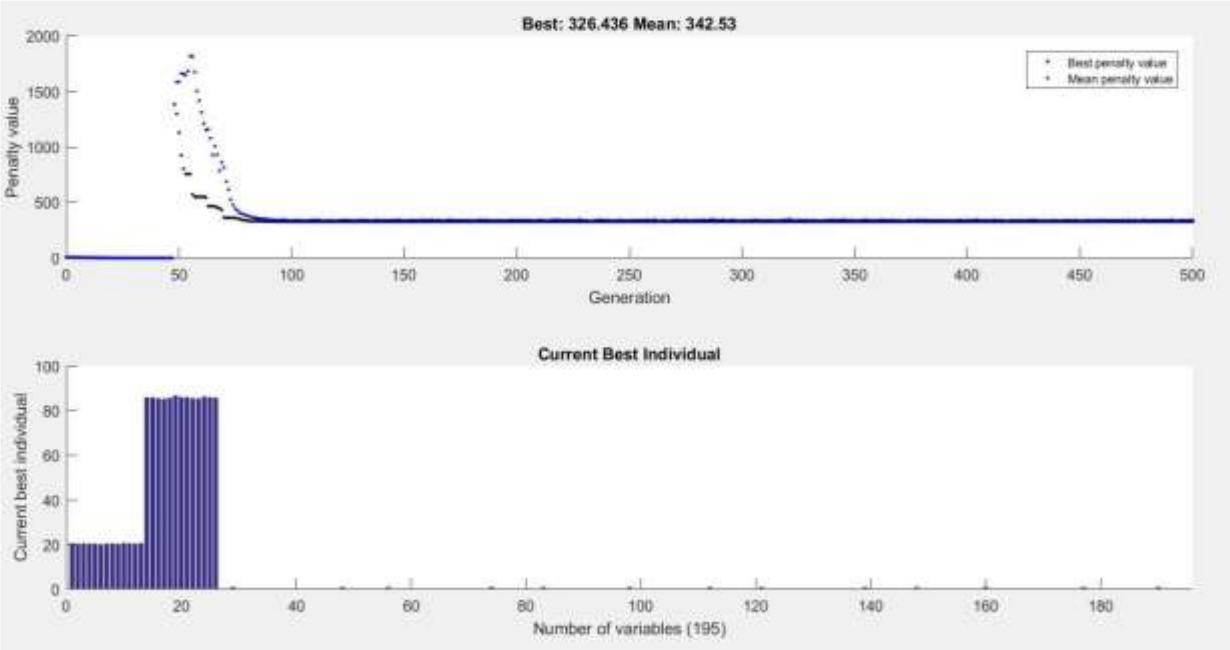

Figure 1: Simulation results for Cuttack District

Table 1: The Locations of Cold Storage Facilities in Cuttack District

Cold storage location coordinates		Allocated wholesale markets
Latitude	Longitude	
20.5173954	85.630640	Athagarh
20.3913182	85.408188	Baraput, Narasinghpur, Nuapatna
20.3923309	85.813998	Kalapathar, Nischintakoili
20.4685824	86.145922	Kendupatna
20.5113546	86.116913	Mahanga, Salipur, Tangi
20.3209411	85.626440	Banki, Champeswar , Niali

From the above table of Cuttack district the number of cold storage facilities allocated is 6 and the locations are allocated to the markets such that the maximum distance from a market to the allocated cold storage facility is limited to 49.52 km and the average distance between a market and the allocated facility is 21.3 km.

6.2 Analysis of Puri District

Location and allocation of cold storage facilities in the district of Puri is computed by the programme and the results are shown below.

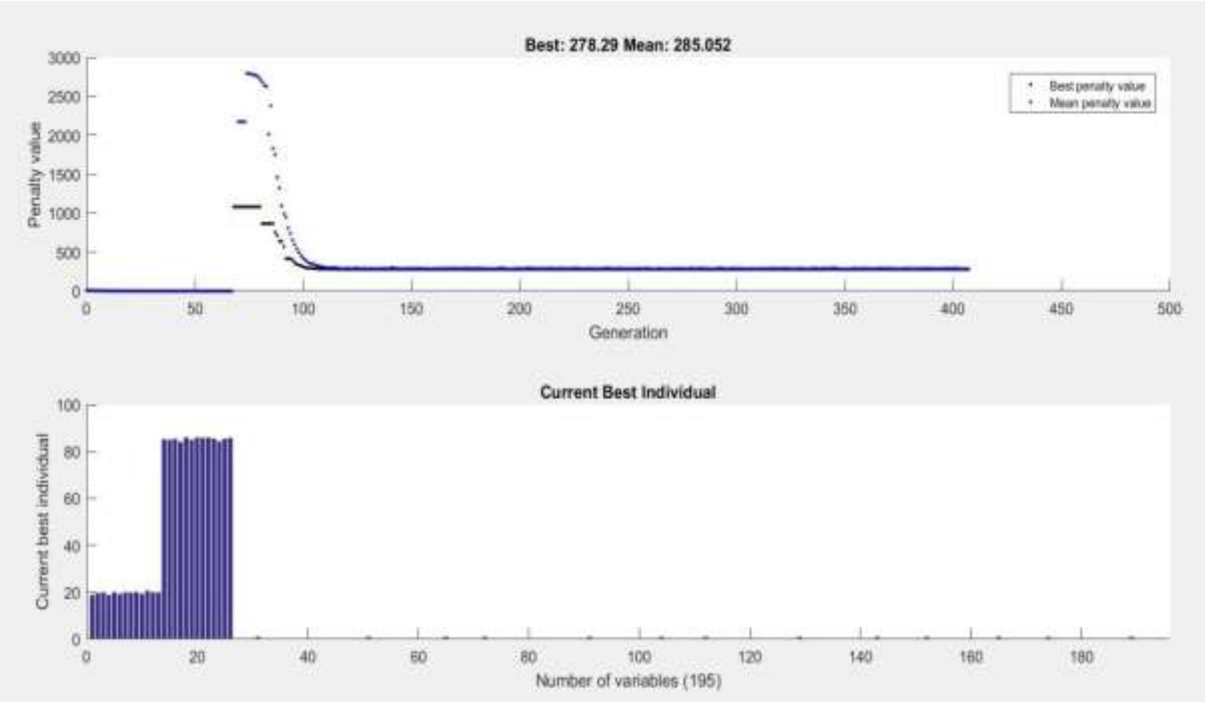

Figure 2: Simulation results for Puri District

Table 2: The Locations of Cold Storage Facilities in Puri District

Cold storage location coordinates		Allocated wholesale markets
Latitude	Longitude	
19.9625692	86.0269380	Astarang, Sakhigopal
19.9969207	85.9770660	Kakatpur, Satsankh
19.8872813	85.8140627	Malatipatapura
20.0742112	85.9448476	Nimapara, Pipli
20.0350235	85.5004821	Bhramagiri, Mandarbasta
19.9867868	85.8623549	Gabkunda, Kans, Konark, Nayahat

In case of Puri district the number of cold storage facilities allocated is 6 and the locations are allocated to the markets in such a way that the maximum distance from a market to the allocated cold storage facility is limited to 29.78 km and the average distance between a market and the allocated facility is 19.12 km.

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6.3 Analysis of Mayurbhanj District

Location and allocation of cold storage facilities in Mayurbhanj district is computed by the programme and the results are given below.

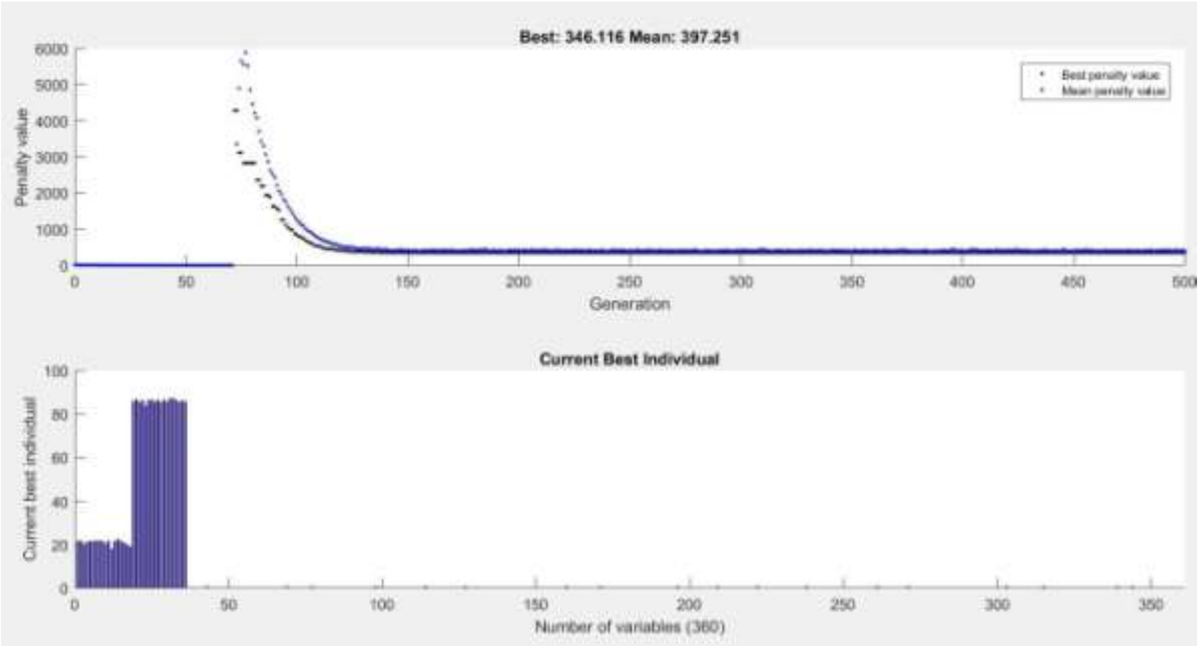

Figure 3: Simulation results for Mayurbhanj District

Table 3: The Locations of Cold Storage Facilities in Mayurbhanj District

Cold storage location coordinates		Allocated wholesale markets
Latitude	Longitude	
21.7536812	86.1384740	Barmail, Karnjia
22.0282320	86.9448841	Suliapada
21.5139670	86.5324925	Kaptipada
21.6360512	84.0986459	Bagahada
21.8132459	86.6384798	Balijoda, Kuliana
21.9322338	86.7516942	Baripada
21.9102466	85.8972262	Bangiriposi
21.8726361	86.5571420	Betanati, Khunta, Rairangpur
22.0332289	86.8157579	Deuli
21.7276167	86.7408503	Badsahi, Manatri, Sarskana
21.0008142	85.7896590	Baisinga, Dantiamunha

For Mayurbhanj district the number of cold storage facilities allocated is 11 and the locations are allocated to the markets such that the maximum distance from a market to the allocated cold storage facility is limited to 59.6 km and the average distance between a market and the allocated facility is 15.92 km.

7. Conclusion

The location coordinates of cold storage facilities which have been generated from computation using genetic algorithm producing the average distance between facilities and the allocated demand points in a range of 15 to 22 km and maximum distance between a demand and the facility from which it is served in a range of 30 to 60 km. The ratio of the number of cold storages to the demand nodes is lowest for Cuttack district and the maximum distance from a cold storage to its allocated demand nodes is lowest in Puri district. It is because the demand nodes in these districts are more close to each other. Hence the target for achieving minimum transportation cost is achieved.

8. Scope for Further Research

The scope is one can work on capacity restricted facility location problems. There is also a scope for work in facility location problems for locating different facilities such as hospitals, fire stations, schools, gas stations, ATM.

9. References

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