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TRANSPORTATION OF EGGS: A CASE STUDY USING MULTI-OBJECTIVE TRANSPORTATION PROBLEM (MOTP)

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Abstract- Transportation of perishable/deteriorating item is so essential to minimizes cost and to minimize breakages that occur during transportation. In transportation problem time plays crucial role as it is set to be minimum that is achieved with keeping high or maximum speed during transportation. Increasing speed, though, minimizes total transportation time but, there might be a high risk of increasing breakages. Such situations can be considered as Multi-objective transportation problem (MOTP), where objectives are set to be minimum breakages with minimizing the transportation time. More breakages lead to more loses. So in this study an attempt is made to minimize total distance as well as overall breakages and time. Proposed model is applied for eggs transportation from various cities of the state Andhra Pradesh to various cities of Maharashtra state so as to minimize total breakages along with other objectives.

Keywords- Deteriorating items, Multi-objective transportation problem (MOTP), distance matrix, total travelling time, percent breakages, VAM, MODI method, TORA software.

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Introduction

It is well known that eggs are so important in everyday life. As it is cheap and easy available commodity but more careful handling is necessary for the same. Usually eggs are transported by trucks or big lorries for miles and miles away. These long distance drive might be reason for breakages of eggs. Breakages of egg(s) make its value zero, that is a loss to manufacturer. Because breakages of egg(s) deteriorate completely and can not be used partly. So in this situation minimum breakages of egg(s) nothing but profit to manufacturer. Such situations where more than one objective under consideration, a Multi objective transportation problem is suitable. MOTP had shown significant rule and importance to dealt with above mentioned problem.

In the classical transportation problem (TP) of linear programming, the traditional objective is one of minimizing the total cost. In general, the real life problems are modelled with multi-objectives which are measured in different scales and at the same time in conflict. In actual TP's, the multi-objective functions are generally considered, which includes average delivery time of the commodities, reliability of transportation, product deterioration and so on. The bi-criteria TP is the basis in processing multi-objective TP, which had been proposed by Aneja and Nair [5]. Isermann, [11] introduced an algorithm for solving linear multipleobjective TP, which provides effective solutions. Ringuest and Rinks, [14] have made a mention of the existing solution procedures for the multiobjective TP. Bit *et al.* [8] have shown the application of fuzzy programming to multicriteria decision making classical TP. Yang and Gen, [16] have proposed an approach called evolution program for bi-criteria TP. Gen *et al.*, [10] introduced a hybrid genetic algorithm for solving bi-criteria TP. Waiel F. Abd El-Wahed, [15] developed a fuzzy programming approach to determine the optimal compromise solution of a multi-objective TP. Pandian and Natarajan [13] have introduced the zero point method for finding an optimal solution to a classical TP without using any optimality checking methods.

Multi-objective Transportation Problem (MOTP)

Consider the following Multi-objective transportation problem (MOTP):

(P) $$\text{Minimize } Z_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$$

$$\text{Minimize } Z_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{ij}x_{ij}$$

Subject to

$$\sum_{j=1}^{n} x_{ij} = a_i, \quad for \quad i = 1,2,\ldots,m$$

$$\sum_{i=1}^{m} x_{ij} = b_j, \quad for \quad j = 1,2,\ldots,n$$

$x_{ij} \geq 0$, for all *i* and *j* are integers where a_i is the amount of the material available at ith source; b_j is the amount of the material required at *j*th destination; c_{ij} is the cost of transporting a unit from *i*th source to *j*th destination; d_{ij} is the deterioration of a unit while transporting from *i*th source to *j*th destination; x_{ij} is the amount transported from *i*th source to *j*th destination.

Literature Review

Since we know that egg is deteriorating item because after breakage or partial breakage the cost of egg is zero and it is in loss, similarly H.P.V. Rupasinghe, B.C.N. Peiris and R.S.W. Wijerathnam [1] is obtained that when we transport tomato if it is breakage partially or fully then value of the product is zero. in similar case Mr J.L. Hine and S.D. Ellis [2] in their research study has done the role that road transport has to play in maintaining rural development and food security. It is argued that transport costs play a critical role in identifying the link between accessibility and agricultural development. In W. Ritha and J. Merline Vinotha [3] is obtained that in multi objective problem Transportation models have wide applications in logistics and supply chain for reducing the cost. In this study, Fuzzy geometric programming approach is used to determine the optimal compromise solution of a multi-objective two stage fuzzy transportation problem, in which supplies, demands are trapezoidal fuzzy numbers and fuzzy membership of the objective function is defined. P. Pandian and D. Anuradha [4] has proposed new Dripping method for finding a set of efficient solutions to a bi-objective transportation problem which differs from all existing methods. The percentage level of satisfaction of a solution for a transportation problem is introduced. In Y.P. Aneja and K.P.K. Nair [5] the computational complexity arises from the fact that each of the method finds the set of non dominated extreme points in the solution space where such extreme points are many in his research he has develop a method of finding the non dominated extreme points in the criteria space. Horst W. Hamacher, Christian Roed Pedersen and Stefan Ruzika [6] in his research the theory and algorithms for solving the multiple objective minimum cost flow problem are reviewed. For both the continuous and integer case exact and approximation algorithm are presented. In S.A. Rahman and A. Yakubu [7] study was conducted in Nasarawa South geo-political zone of Nasarawa State to examine the status of poultry egg production, distribution and consumption.

Materials and Methods

This case study has done in two phases' phase 1, Surveying and phase 2 Mathematical Analysis.

Phase 1

A survey was conducted in November and December, 2012 in Maharashtra and Andhra Parades State in India. Where the Maharashtra district Aurangabad, Nanded and Latur has select randomly which required the egg in big quantity. The data has been collected by taking the interview of the hole sellers. The maximum quantity was purchased from Andhra pradesh in the cities Hyderabad, Kareem Nagar and Nizamabad.

Phase 2

In phase two we will apply the TORA software to find the optimum solution for minimizing the total distance, over all breakages and minimizing the total time these will done by using multi-object transportation problem (MOTP) to minimize the total cost.

As egg is an perishable/deteriorating item therefore if the distance increases breakages of eggs is increases if the distance is decreases breakages is decrease therefore the distance and the breakages are directly proportional to each other.

For minimizing the total time we must drive at maximum speed, but if speed increases then breakages also increases. To deal with the problem arises due to above mentioned cases a MOTP approach has been considered.

For the sake of simplicity it is assumed that:

Only single item (egg) is transported from various origin to various destination

Breakage of eggs gives no partial gain (its breakage values zero return)

Cost (c_{ij}), Distance (d_{ij}) and allotment (x_{ij}) are nonnegative real variables.

Mathematical Model

With the usual notations described the mathematical formulation of MOTP is:

(P1) Minimize $z = \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}d_{ij}$ subject to the constraints:

$$\sum_{j=1}^{n} x_{ij} = a_i \quad i = 1,2,\ldots,m$$

$$\sum_{i=1}^{m} x_{ij} = b_j \quad j = 1,2,\ldots,n$$

(P2) Minimize $z = \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}c_{ij}$ subject to the constraints:

$$\sum_{j=1}^{n} x_{ij} = a_i \quad i = 1,2,\ldots,m$$

$$\sum_{i=1}^{m} x_{ij} = b_j \quad j = 1,2,\ldots,n$$

$x_{ij} > 0$ for all *i* and *j* x_{ij} denotes allocation from origin *i* to destination *j*.

d_{ij} are the distance in kilometre from origin *i* to destination *j* and c_{ij} is the cost from origin i to destination *j*, a_i is the commodity available on origin 1,2 and 3. b_j is the commodity required on demand at 1,2 and 3.

Where S_i (*i*=1,…,3) are origins where eggs are available. S_1 = Hydrabad (8,00,000), S_2 = Nizamabad (3,00,000) and S_3 = Karimnagar (5,00,000). And D_j (*j*=1,…,3) are demands, where eggs are required D_1 = Aurangabad (5,00,000), D_2 = Nanded (3,00,000), D_3 = Latur (2,00,000) Eggs required 5,00,00, 3,00,000 and 2,00,000.

Transportation table for minimize the distance, where supply and demand present in lacks.

The above Transportation Model solved by using TORA Software System. In this model we minimize the total Distance, to minimize the total Cost.

The Proposed Model is not a balanced problem to make it a balanced problem we considered a dummy variable that is called D_4

The solution is obtained by TORA Optimum System Software of above transportation model:

X_{13}=2, X_{14}=6, X_{21}=2, X_{22}= 3 and X_{31}= 3

Table 1- Distance Matrix (d_{ij})

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	551	314	280	8
S_2	521	267	341	5
S_3	396	142	193	3
Demand in Lacks	5	3	2	

Table 2- Distance Matrix (d_{ij})

Destination/ Origin	D_1	D_2	D_3	D_4	Supply in Lacks
S_1	551	314	280	0	8
S_2	521	267	341	0	5
S_3	396	142	193	0	3
Demand in Lacks	5	3	2	6	

From [Table-1] and [Table-2] minimum distance from origin *i* to destination *j* is

Minimum distance = 280 + 521 + 267 + 396 = 1464

We know the transportation cost for each egg of each kilometre ₹ = ₹ 0.000190

Transportation cost for per egg is = 0.00019 × 1464 = ₹ 0.2784

Transportation cost for total quantity = 10,00000 × 0.2784 = ₹ 2,78,400.

Now another objective is considered for minimization of travelling time of eggs. Entries of cost matrix d_{ij} (distance between *i* & *j*) replaced with the time t_{ij} (travelling between *i* and *j*).

Table 3- Time Matrix (t_{ij}) Speed 30 km/h

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	18.36	10.46	9.33	8
S_2	17.5	8.9	11.36	5
S_3	13.25	4.73	6.43	3
Demand in Lacks	5	3	2	

Table 4- Time Matrix (t_{ij}) Speed 35 km/h

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	15.74	8.97	8	8
S_2	14.89	7.63	9.74	5
S_3	11.31	4.06	5.51	3
Demand in Lacks	5	3	2	

Table 5- Time Matrix (t_{ij}) Speed 40 km/h

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	13.78	7.85	7	8
S_2	13.03	6.68	8.53	5
S_3	9.9	3.55	4.83	3
Demand in Lacks	5	3	2	

Table 6- Time Matrix (t_{ij}) Speed 45 km/h

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	12.24	6.98	6.22	8
S_2	11.58	5.93	7.58	5
S_3	8.8	3.16	4.29	3
Demand in Lacks	5	3	2	

From [Table-3], Optimum Solution of travelling time (Speed 30 km/h) is:

$X_{13} = 2$, $X_{14} = 6$, $X_{21} = 2$, $X_{22} = 3$ and $X_{31} = 3$.

Therefore Minimum Travelling time (Speed 30 km/h)

= 9.33 + 17.5 + 8.9 + 13.25

= 48.98 hours

From [Table-4], Optimum Solution of travelling time (Speed 35 km/h) is:

$X_{13} = 2$, $X_{14} = 6$, $X_{21} = 2$, $X_{22} = 3$ and $X_{31} = 3$.

Minimum Travelling time (Speed 35 km/h)

= 8 + 14.89 + 7.63 + 11.10

= 41.62 hours

From [Table-5], Optimum Solution of travelling time (Speed 40 km/h) is:

$X_{13} = 2$, $X_{14} = 6$, $X_{21} = 2$, $X_{22} = 3$ and $X_{31} = 3$.

Minimum Travelling time (Speed 40 km/h)

= 7 + 13.03 + 6.68 + 9.9

= 36.61 hours

From [Table-6], Optimum Solution of travelling time (Speed 45 km/h) is:

$X_{13} = 2$, $X_{14} = 6$, $X_{21} = 2$, $X_{22} = 3$ and $X_{31} = 3$.

Minimum Travelling time (Speed 45 km/h)

= 6.22 + 11.58 + 5.93 + 8.8

= 32.53 hours

Now the last objective is considered for minimization of percent breakages of eggs. Entries of cost matrix d_{ij} (distance between *i* & *j*) replaced with the percent breakages p_{ij} (breakages between *i* and *j*).

Table 7- Percent Breakages Matrix (p_{ij}) Speed 30 km/h

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	5	2.85	2.54	8
S_2	4.77	2.42	3.1	5
S_3	3.61	1.29	1.75	3
Demand in Lacks	5	3	2	

Table 8- Percent Breakages Matrix (p_{ij}) Speed 35 km/h

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	5.5	3.13	2.8	8
S_2	5.2	2.66	3.4	5
S_3	3.95	1.42	1.93	3
Demand in Lacks	5	3	2	

Table 9- Percent Breakages Matrix (p_{ij}) Speed 40 km/h

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	6	3.42	3.05	8
S_2	5.67	2.91	3.71	5
S_3	4.13	1.55	2.1	3
Demand in Lacks	5	3	2	

Table 10- Percent Breakages Matrix (p_{ij}) Speed 45 km/h

Destination/ Origin	D_1	D_2	D_3	Supply in Lacks
S_1	6.5	3.71	3.3	8
S_2	6.15	3.15	4.02	5
S_3	4.67	1.68	2.28	3
Demand in Lacks	5	3	2	

Optimum Solution by TORA software for percent Breakages of eggs is given as:

From [Table-7], Optimum Solution of percent breakages with speed 30 km/h is:

$X_{13} = 2$, $X_{14} = 6$, $X_{21} = 2$, $X_{22} = 3$ and $X_{31} = 3$.

Minimum Breakages with speed 30 km/h

= (2.54 + 4.77 + 2.42 + 3.61)/4

= 3.34 % Breakages

From [Table-8], Optimum Solution of percent breakages with speed 35 km/h is:

$X_{13} = 2$, $X_{14} = 6$, $X_{21} = 2$, $X_{22} = 3$ and $X_{31} = 3$.

Minimum Breakages with speed 35 km/h

= (2.8 + 5.2 + 2.66 + 3.92)/4

= 3.65 % Breakages

From [Table-9], Optimum Solution of percent breakages with speed 40 km/h is:

$X_{13} = 2$, $X_{14} = 6$, $X_{21} = 2$, $X_{22} = 3$ and $X_{31} = 3$.

Minimum Breakages with speed 40 km/h

= (3.05 + 5.67 + 2.91 + 4.31)/4

= 3.99 % Breakages

From [Table-10], Optimum Solution of percent breakages with speed 45 km/h is:

$X_{13} = 2$, $X_{14} = 6$, $X_{21} = 2$, $X_{22} = 3$ and $X_{31} = 3$.

Minimum Breakages with speed 45 km/h

= (3.30 + 6.15 + 3.15 + 4.67)/4

= 4.32 % Breakages.

Results

All results obtained through TORA software for MOTP's

Results obtained for minimization of distance and total cost:

Minimum distance = 1464 km.

Transportation cost for total quantity = ₹. 2,78,400.

Results obtained for Minimization of travelling time:

Minimum travelling time (speed 30 km/h) = 48.98 hours.

Minimum travelling time (speed 35 km/h) = 41.62 hours.

Minimum travelling time (speed 40 km/h) = 36.61 hours.

Minimum travelling time (speed 45 km/h) = 32.53 hours.

Results obtained for minimization of percent breakages:

Minimum breakages with speed 30 km/h = 3.34 % Breakages.

Minimum breakages with speed 35 km/h = 3.65 % Breakages.

Minimum breakages with speed 40 km/h = 3.99 % Breakages.

Minimum breakages with speed 45 km/h = 4.32 % Breakages.

Discussion

From the results it is observed that, for deteriorating items like eggs it is necessary to minimise distance as a general transportation dose. But here for eggs to maintain profitability there is a need of minimum breakages of eggs as it is a direct loss. Therefore, proposed model was so developed that also taken into consideration the speed of vehicle. To maintain level of breakages low different speeds of vehicle observed and studied by proposed model.

Conclusion

If this above proposed mathematical model is adopted by the suppliers and wholesalers of Eggs in Marathwada region and Andhra Pradesh it would not only involve minimization of the transportation cost but it would minimize the consumption of fuel breakages of eggs minimizes the time in transporting the goods by the different carriers on the other hand. The optimal solution of proposed model is obtained by using TORA Software, in which basic feasible solution obtained by Vogel approximation methods.

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