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TRANSPORTATION OF FRESH WATER FISHES: A CASE STUDY USING MULTI-OBJECTIVE TRANSPORTATION PROBLEM

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***Abstract**: Fish is one of the most perishable of human food materials and that it starts spoiling soon after death. In the present study, we consider the study of catch fish exporting in Nagapattinam and Thiruvarur district, Tamilnadu, India that is addressed in Multi-Objective Transportation Problem (MOTP). Also, in this paper we give the relation between distance, speed, time and spoilage percentage. Here, we use commercially available package LINGO software to solve the MOTP to get an optimal compromise solution.*

***Keywords:** multi-objective transportation problem (MOTP), distance, travelling time, spoilage, LINGO software*

1. INTRODUCTION

In real life, the most important and successful applications in the optimization refers to Transportation Problem. It is a special class of the linear programming in Operation Research where the objective is to minimize or maximize the cost, distance, time etc. The problem of transporting is how the production is transported efficiently from different sources to the different destinations. Milan et al. (2006) studied sugarcane transportation using a mixed integer linear programming model and solved the problem of cost minimization. He demonstrates the model is not only useful to minimize transportation cost, but also for scheduling daily cane road transport and harvesting quotas of cutting means. Mohammed et al. (2013) studied transportation of eggs using multi-objective transportation problem. Basically increasing speed, though, minimizes total transportation time but, there might be a high risk of increasing breakages. They proposed a method to minimize total distance as well as time and overall breakages. Sahin et al. (2009) presented an approach based on the economic analysis for transportation cost analysis of the alternative modes of passenger or cargo transportation. Kamala (2017) examined the effect of transportation in the marketing of agricultural products and gave the relationship between efficient transportation system and the cost of agricultural products. He also says that transportation plays an important role in the distribution of agricultural products, helps to reduce spoilage and wastage of farm products. Li and Leung (2011) developed a novel methodology for the determination of optimal routes for dangerous goods transportation using geographical information system. Pramanik et al. (2013) formulated a problem for damageable item using a multi-objective solid transportation problem (MSTP) and solved. They considered transportation costs, demands, resources and capacities of conveyances are random fuzzy in nature.

Kumar et al. (2008) had conducted a study in domestic fish marketing in India. In the case of marine species the marketing efficiency has been found more than freshwater species. In consumer’s rupee, the fisherman’s share has shown variations across fish species, marketing channels and markets. They highlighted the need for formulating a uniform market policy for fishes for easy operation and regulation. Ali et al. (2008) analyzed the economics of fresh fish marketing using descriptive statistic, linear regression and market margin. Jensen (1990) discusses transportation of warm water fish, condition variability of tolerance to loading, transport stress among species, and safe loading rate. Narayanakumar and Sathiadhas (2006) studied domestic fish marketing opportunities for marine fisheries sector and highlighted the growth of fish production which will be helpful in developing fish marketing system in India.

In aquaculture farming, small-scale farmers do not find an affordable income in export market since packing charges are high for too far distance. In order to get rid of this situation, this study of catch fishes transports to particular distance within time has been attempted. This paper describes a solution technique for Transportation Problems with multiple objective functions. Here, the problem of transportation of this fishes from the landing sources to the destination considering distances (kilometers) has been successfully solved. There are several other problems also must be considered, like speed and spoilage percentage. Spoilage depends on distance along with prevention using crushed ice which works well for short term preservation. Based on the information gathered related to these studies, spoilage percentage is collected from farm visits. In most of our fish landing centers, controlling of spoilage is quite essential to obtain the profit of fish from shooting up unduly. Before fishes are loaded into transport, seller must check whether it is in good condition and healthy or else fish in poor condition may die during transportation.

This paper is organized as follows. Following the introduction, Section 2 defines the multi-objective model and model is formulated in Section 2.1. In section 3, we formalize our multi-objective transportation problem and solved using LINGO 17.0 package. Finally, Section 4 includes results and discussions and Section 5 gives the conclusion.

2. MULTI-OBJECTIVE TRANSPORTATION PROBLEM

Many transportation problems are not single-objective, in real world situations. Here we consider the transportation problems which are characterized by multiple objective functions. The general mathematical model of a multi-objective optimization problem is:

$$min\ \ Z_r(x) = (z_1(x), z_2(x), \ldots z_r(x)), \qquad x = (x_1, x_2, \ldots, x_r)$$

Subject to

$$\left.\begin{matrix} u_i(x) \le 0, & i = 1,2,\ldots,m \\ v_i(x) \ge 0, & i = 1,2,\ldots,m \end{matrix}\right\} \text{(MOTP with inequality constraints)}$$

$$w_i(x) = 0, \quad i = 1,2,\ldots, \quad \text{(MOTP with equality constraints)}$$

where $z_1, z_2, \ldots z_r$ are the objective functions, $x_1, x_2, \ldots, x_r$ are decision variables and x is the decision vector.

2.1 MODEL FORMULATION

The mathematical model of multi-objective transportation problem can be stated as follows.

(1) $minimize\ Z_1 = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{ij} x_{ij}$

(2) $minimize\ Z_2 = \sum_{i=1}^{m} \sum_{j=1}^{n} t_{ij} x_{ij}$

(3) $minimize\ Z_3 = \sum_{i=1}^{m} \sum_{j=1}^{n} s_{ij} x_{ij}$

Subject to the constraints: $\sum_{j=1}^{n} x_{ij} = a_i$, $i = 1,2,\ldots,m$, and $\sum_{i=1}^{m} x_{ij} = b_j$, $j = 1,2,\ldots,n$

where x_{ij} : the allocation from source i to destination j and $x_{ij} \ge 0$ for all i, j.

d_{ij} : the distance from source i to destination j in kilometer.

t_{ij} : the travelling time from source i to destination j in hours.

s_{ij} : the percent spoilage from source i to destination j .

a_i : the commodity available on source 1,2, and 3.

b_j : the commodity required on demand at 1,2, and 3.

$S_i(i = 1,2,3)$: the sources where fishes are available S_1 = Sigar (7 *Lakhs*), S_2 =Thiruvarur (5 *Lakhs*), and S_3 = Velankanni (4 *Lakhs*).

$D_j(j = 1,2,3)$: the destinations where fishes are required D_1 = Kumbakonam (3 *Lakhs*), D_2 = Tanjore(4 *Lakhs*), and D_3 = Sirkali (6 *Lakhs*).

3. DATA ANALYSIS

A supplier supplies catch fishes each of one kg from different sources to different destinations. A survey is conducted in Nagapattinam and Thiruvarur district, Tamilnadu, India and the data has been collected by conducting questionnaire from whole sellers. There are 3 different suppliers (S_1, S_2, S_3) and 3 destinations (D_1, D_2, D_3). The problem constructed here is to minimize total distance, time and spoilage percentage. In order to demonstrate the problem discussed above, the distance of transporting fishes from i^{th} source to j^{th} destination given in the following table 1.

Origin(i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	53	76	75	7
S_2	42	62	65	5
S_3	85	100	78	4
Demand (in lakhs)	3	4	6	-

Table 1. Data for Distance

The proposed transportation model is not a balanced one. In order to make the problem balanced, we introduce a dummy variable say D_4 .

Origin (i)	Destination (j)				Supply (in lakhs)
	D_1	D_2	D_3	D_4	
S_1	53	76	75	0	7
S_2	42	62	65	0	5
S_3	85	100	78	0	4
Demand (in lakhs)	3	4	6	3	16

Table 2. Distance Matrix- Balanced

The above *table* 2 is solved using LINGO and the minimum distance from source (i) to destination (j) is 310 *km*.

Transportation cost (by road) for each fish per kilometre is ₹. 0.0015 and transportation cost per fish is ₹. $0.0015 \times 310 =$ ₹. 0.465 .

Transportation cost for total quantity =13,00,000 (*minimum requirement*) $\times$ 0.465 = ₹. 6,04,500.

Origin (i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	2.12	3.04	3.00	7
S_2	1.68	2.48	2.60	5
S_3	3.40	4.00	3.12	4
Demand (in lakhs)	3	4	6	-

Table 3. Time Matrix speed $25\ km/h$

The optimal solution for $table\ 3$ is $x_{11} = 2, x_{13} = 5, x_{21} = 1, x_{22} = 4, x_{33} = 1, x_{34} = 3.$

The minimum travelling time (speed $25\ km/h$) $= 2.12 + 3.00 + 1.68 + 2.48 + 3.12 = 12.4\ hours$

Origin (i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	1.77	2.53	2.50	7
S_2	1.40	2.07	2.17	5
S_3	2.83	3.33	2.60	4
Demand (in lakhs)	3	4	6	-

Table 4. Time Matrix speed $30\ km/h$

The optimal solution for $table\ 4$ is $x_{11} = 2, x_{13} = 5, x_{21} = 1, x_{22} = 4, x_{33} = 1, x_{34} = 3.$

The minimum travelling time (speed $30\ km/h$) $= 1.77 + 2.50 + 1.40 + 2.07 + 2.60 == 10.34\ hours$

Origin (i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	1.51	2.17	2.14	7
S_2	1.2	1.77	1.86	5
S_3	2.43	2.86	2.23	4
Demand (in lakhs)	3	4	6	-

Table 5. Time Matrix speed $35\ km/h$

The optimal solution for $table\ 5$ is $x_{11} = 2, x_{13} = 5, x_{21} = 1, x_{22} = 4, x_{33} = 1, x_{34} = 3.$

The minimum travelling time (speed $35\ km/h$) $= 1.51 + 2.14 + 1.2 + 1.77 + 2.23 == 8.85\ hours$

Origin(i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	1.33	1.90	1.88	7
S_2	1.05	1.38	1.63	5
S_3	2.13	2.5	1.95	4
Demand (in lakhs)	3	4	6	-

Table 6. Time Matrix speed $40\ km/h$

The optimal solution for $table\ 6$ is $x_{11} = 2, x_{13} = 5\ , x_{21} = 1\ , x_{22} = 4\ , x_{33} = 1\ , x_{34} = 3\ .$

The minimum travelling time (speed $40\ km/h$) $= 1.33 + 1.88 + 1.05 + 1.38 + 1.95 = = 7.59\ hours$

Origin (i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	2.28	4.02	3.71	7
S_2	1.68	3.15	3.30	5
S_3	6.15	6.5	4.67	4
Demand (in lakhs)	3	4	6	-

Table 7. Percent Spoilage Matrix speed $25\ km/h$

The optimal solution for $table\ 7$ is $x_{11} = 2, x_{13} = 5\ , x_{21} = 1\ , x_{22} = 4\ , x_{33} = 1\ , x_{34} = 3.$

The minimum spoilage with speed $25\ km/h = \frac{2.28+3.71+1.68+3.15+4.67}{5} = 3.1\%$

Origin (i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	2.1	3.71	3.42	7
S_2	1.55	2.91	3.05	5
S_3	5.67	6	4.13	4
Demand (in lakhs)	3	4	6	-

Table 8. Percent Spoilage Matrix speed $30\ km/h$

The optimal solution for $table\ 8$ is $x_{11} = 2, x_{13} = 5\ , x_{21} = 1\ , x_{22} = 4\ , x_{33} = 1, x_{34} = 3\ .$

The minimum spoilage with speed $30\ km/h = \frac{2.1+3.42+1.55+2.91+4.13}{5} = 2.82\%$

Origin (i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	1.93	3.4	3.13	7
S_2	1.42	2.66	2.8	5
S_3	5.2	5.5	3.95	4
Demand (in lakhs)	3	4	6	-

Table 9. Percent Spoilage Matrix speed $35\ km/h$

The optimal solution for $table\ 9$ is $x_{11} = 2, x_{13} = 5\ , x_{21} = 1\ , x_{22} = 4\ , x_{33} = 1, x_{34} = 3\ .$

The minimum spoilage with speed $35\ km/h = \frac{1.93+3.13+1.42+2.66+3.95}{5} = 2.62\%$

Origin (i)	Destination (j)			Supply (in lakhs)
	D_1	D_2	D_3	
S_1	1.75	3.1	2.85	7
S_2	1.29	2.42	2.54	5
S_3	4.77	5	3.61	4
Demand (in lakhs)	3	4	6	-

Table 10. Percent Spoilage Matrix speed $40\ km/h$

The optimal solution for $table\ 10$ is $x_{11} = 2, x_{13} = 5\ , x_{21} = 1\ , x_{22} = 4\ , x_{33} = 1\ , x_{34} = 3.$

The minimum spoilage with speed $40\ km/h = \frac{1.75+2.85+1.29+2.42+3.61}{5} = 2.38\%$

4. RESULTS & DISCUSSIONS

The results obtained through LINGO software for MOTP's for minimization of distance, time and spoilage cost.

The minimum distance = $310\ kms$

Transportation cost for total fishes $=$ ₹. 6,04,500

The minimum travelling time with speed $25km/h$ is $12.4\ hours$, speed $30km/h$ is $10.34\ hours$, speed $35km/h$ is $8.85\ hours$ and speed $40km/h$ is $7.59\ hours$. Also, the minimum spoilage with speed $25km/h$ is 3.1%, speed $30km/h$ is 2.82%, speed $35km/h$ is 2.62% and speed $40km/h$ is 2.38%.

From the results, it is observed that, if the distance increases then spoilage also increases and if the distance decreases therefore spoilage also decreases. Hence , $distance \propto spoilage$. That is distance and spoilage are directly proportional to each other. Also to minimize total time one must drive at maximum speed. Hence if speed increases then spoilage decreases. Therefore $time \propto \frac{1}{spoilage}$.

5. CONCLUSION

With the liberalization of aquacultural markets in India, the number of small-scale farmers exports fish is increasing. In this study, we not only involve minimum transportation cost but it will minimize the consumption of fuel, minimize transporting time and reduce spoilage.

Conflict of Interests: The author declared no conflict of interests.

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