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# Multi-Objective Transportation Models: A Case Study

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**Abstract:** Transportation problem (TP) is a special case of linear programming problem (LPP) in which cost optimization has been made on the base of demand and resources. Optimization of cost is a common objective in TP. There is a lot of work on different objectives by various researchers has been published such that minimize shipping cost, minimum deterioration while transportation, minimize delivery time, etc. Combing of more than two objectives are multi-objective transportation problem. Different approached for methods solving multi-objective transportation problem (MOTP) also discusses by various authors viz. Goal programming problem, fuzzy techniques, genetic algorithm, etc. In the present paper, we have analyzed the transportation of Urea from different Ports of Karaikal, Tuticorin and Vizagapattinam in the state of Tamil Nadu and Andhra Pradesh in India by using Multi Objective Transportation Problem to minimize the total distance as well as time and cost.

**Key words:** Fertilizers, Urea, Multi Objective Transportation problem

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## I. INTRODUCTION

In many countries the fertilizer transportation like import, export, and transit are done via maritime boundaries where ports are highly developed, implemented, and maintained through latest technology. Thereafter internal transportation system from the port to various destinations within the state and neighboring states via truck and railroad systems are highly challenging to finding the best way to reduce the cost, time and distance. The government should bear the investment by tendering to the contracting company to expand their capacity in reducing the expenses. We have analyzed Multi- objective transportation model which provides the best way to transport the fertilizer from the ports at Karaikal, Tuticorin, and Vizagapattinam in the state of Tamil Nadu and Andhra Pradesh in India and from its warehouses to a number of destinations. The study is formulated as a multi-objective transportation problem where the objective function considers minimizing total transportation cost, time and distance. Many Researchers have undergone researches in this field. Tzeng et al. (1995) solved the problem of how to distribute and transport the imported Coal to each of the power plants on time in the required amounts and at the required 18 qualities under conditions of stable and supply with least delay. Dinesh Kumar Shukla (1998) observes that to explore the dynamics of interaction between the fertilizer and the transportation system and to present a broad outline of the changes that may take place in the field of the fertilizer logistics in the wake of a probable decontrol of the distribution and movement of urea in India. Wahed et al (2001) presented a fuzzy programming approach to determine the optimal compromise solution of a multi-objective transportation problem and tested the approach performance by measuring the degree of closeness of the compromise solution to the ideal solution using a family of distance functions. Horst et al (2005) reviewed theory and algorithms for solving the multiple objective minimum cost flow problem and both the continuous and integer case exact and approximation algorithms are presented. Costa et al, (2008) developed a multi-objective Hub location problem in which the first objective minimizes the total transportation cost, while the second objective minimizes the maximum service time of the hub nodes. Tanveer Hussain et al. (2011) transportation of raw material optimization of production system and reliability a paper production plant, for this we have to evaluate all those factors which are involved in the process, for example, transportation of raw material, production and delivery of final products. Maria Kalinina, Leif Olsson and Aron Larsson (2013) have developed a multi-objective chance constrained programming model for the matching of goods and intermodal transports alternatives in the presence of conflict between time, cost and emission under uncertainty in the delay time. Mohammed N.A.R, Lahji A.A and Syed J.K (2013) observed that transportation of perishable item is so essential to minimize cost and to minimize breakages that occur during transportation. Gaurav Sharma, Abbas and Vijay Kumar Gupta (2015) also introduced multi-objective transportation problem of Procter and Gamble to reduce the transportation cost and time of goods from one source to another source.

In this paper, we have studied about the transportation of Urea from different Ports of Karaikal, Tuticorin and Vizagapattinam in the state of Tamil Nadu and Andhra Pradesh in India. Moreover, we have clearly analyzed the study area of transporting Urea, mode of transport system, import level of Urea and formulation of transporting urea into Multi-objective transportation Problem.

## II. ROLE OF TRANSPORTING UREA IN INDIA

Fertilizers play a significant role on frugality of the global agricultural economy. Production and consumption of fertilizer has been increased due to scarcity of land and intensive need for agricultural development. It gracefully became prominent from the past 50 years and currently holds third place in the world. At present, we have 30 large units of urea manufacturing plants in our country. The phenomenal of the fertilizers department is to ensure acceptable quality and on time delivery. India ranks the second largest importer of fertilizer on the basis of development of the agriculture and third largest consumer in the world. The shortage of raw materials and the subsequent dependency on getting fertilizers makes the unpredictable cost in the fertilizer industry. However, the revised policies may help us to stabilize the cost of raw material during the upcoming years. The fertilizer market has been categorized on the basis of type and the crop application. Those markets has different sections such as nitrogen, phosphorus, potash and other macro fertilizers, whereas nitrogen-based fertilizers hold the highest share and also ranks as the largest sector in the Indian market. On the basis of application, the market is segmented into crop and non-crop. According to the new fertilizer policy, the urea market is also expected to enrich at fast pace.

The estimate for the demand of urea such as production count of urea and also the left over ground stocks from the plants of each state are calculated. Urea imports are planned accordingly which acts as a bridge between the availability and the demand. For ECA purposes, a quota will be allocated for each plant in each state. A company cannot import the urea beyond its share. The urea transport processes are keenly monitored by the Department of Fertilizers which in turn provides the state wise movement plan for plants. This process provides the rapid growth in the fertilizer production, and has avoided demands and also avoids the regional imbalances in the aspect of availability of the fertilizer. Meanwhile the ECA allocation process may give an impression that a lot of intersection movement of fertilizer is involved due to the forenamed system on the plant state linkage. This aforementioned movement is not found on facts. During the ECA regime, the lead of fertilizer moved on railway network has been declined continuously. The following Graph shows the average lead of fertilizer transport by rail as shown below:

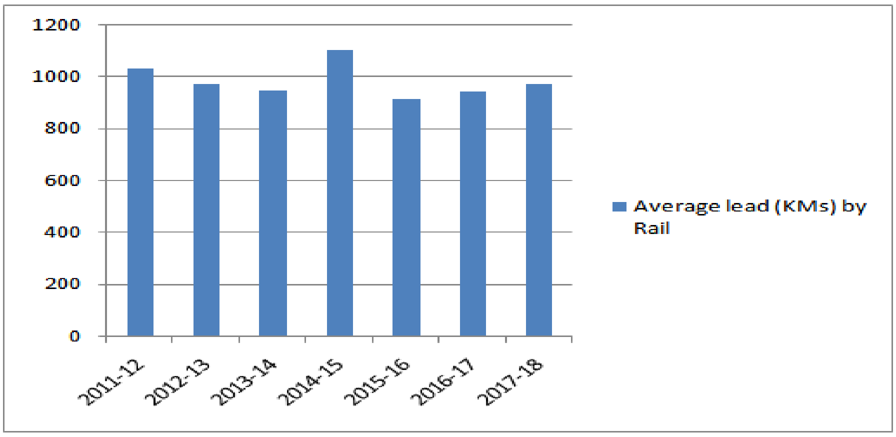



**Figure 1: Average of lead transportation by Rail**

Warehouse allows the fertilizer pre-positioning which causes for the continuous production and will make it ready for availability. The fertilizer industry utilizes the warehousing facility given by the Central and State Warehousing Corporations (CWC & SWC) and other corporative private agencies. Those agents act as handling agents for the rake unloading, local cartage and also as a Secondary movement of transporters.

### 2.1 Mode of Transport System

On the basis of transportation characteristics the commodities, select their modal matrix in which some of the characteristics are given below [1].

(i) The spatial distribution of fertilizer production commodities.
(ii) Distances between the production commodities and the demand locality.
(iii) To predict whether the fertilizer production and the quantity of demand are perennial or seasonal.
(iv) Quantities to be shifted from warehouse.

(v) The Stuck-in strength of the commodity to remain undamaged the rapid transit hazards etc.

The transportation characteristics of fertilizers cannot be examined either it is permanent or seasonal. It has to be gathered properly and should be distributed to various centers from one place to various regions all over the country. It can be moved in bags of 50kg or 75 kg in huge quantities through rail transport to main locality and from there through road transport to many sub localities.

The various steps of fertilizer movement from plant to farm-gate follow the steps below:

(i) Primary movement from fertilizer plant to railway transport.

(ii) Secondary movement from main locality warehouse to the supplier by roadways.

(iii) Delivery from main locality warehouses to the consumer door-step by roadways.

(iv) Primary movement from plant to warehouses within a radius of 130-200 kms from the main plant using roadways

The figure illustrates that the inter modal mix of rail-cum-road transport of fertilizer from the year 2011 to 2018 is given below [18]

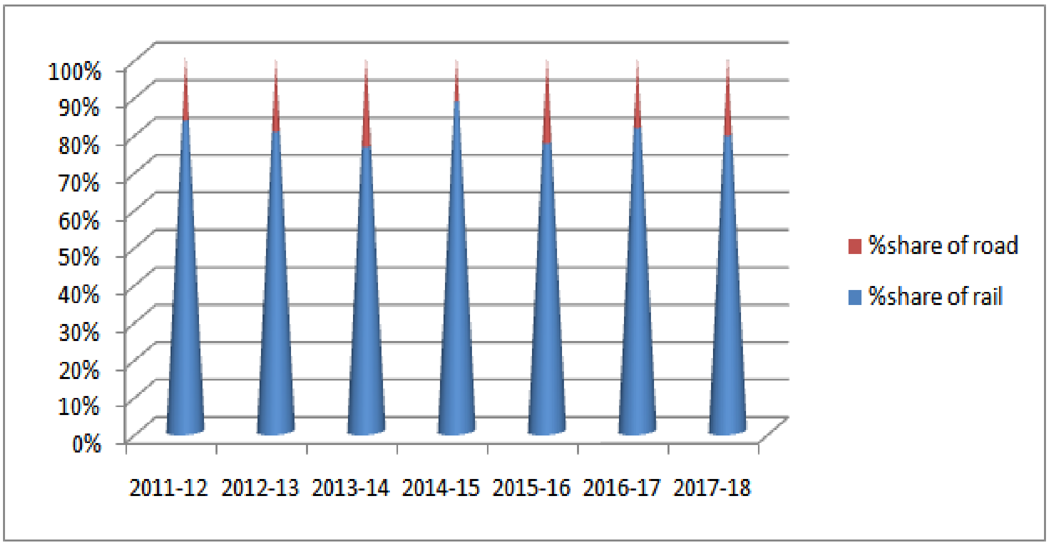



**Figure 2: Inter modal mix of fertilizers transportation**

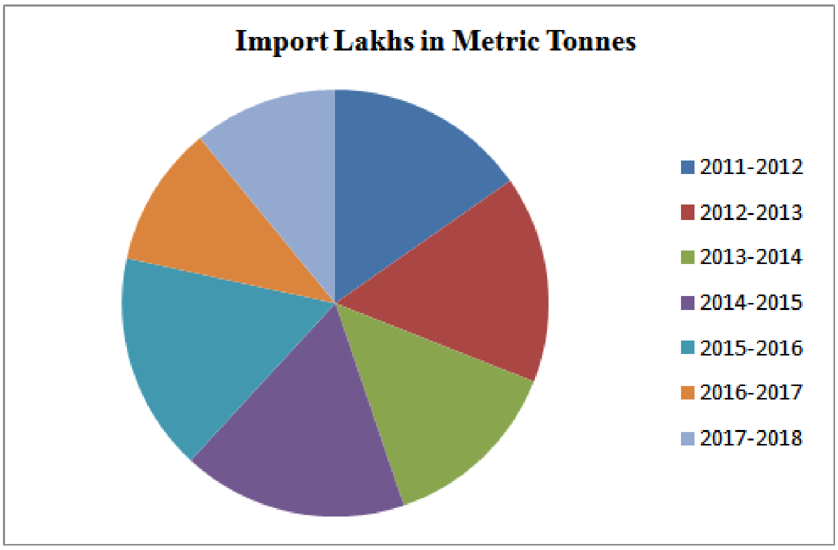
In India, Fertilizer transportation has been carried out by railways and roadways in certain case it is carried out by coastal ways. Railways play a vital role on the main stress of fertilizer movement and also many fertilizer manufacturers have a contract with private railway system inside their fertilizer plants.

### 2.2 Import level of Urea

Urea is the richest source of nitrogen among the common dry fertilizers and is the most commonly used fertilizer in India. India relies largely on imports to meet its fertilizer requirement. The government of India controls fertilizer import procedures whereby the Department of Fertilizers estimates import requirements for fertilizer and fertilizer raw material (FRM) and selects approved importers and direct them to arrange fertilizer imports only through ports designated by the Department of Fertilizers. While decisions on the choice of import port are generally guided by logistical considerations such as the proximity of destination markets to the port, the selection process historically favored the Major ports controlled by the Central Government. Recently, however, following aggressive marketing efforts by private ports to promote their superior port infrastructure (usually more modern, sophisticated and hence more efficient than those at the Government-owned ports), fertilizer import volumes are also being allocated to private ports. Specifically, In addition to Tuticorin and VOCP, the Karaikal port has also been designated for handling urea and other fertilizer imports. Fertilizer imported at Tamil Nadu ports are usually sent to a various destination for Tamil Nadu, Karnataka, Andhra Pradesh, Kerala and Pondicherry as per the rail transportation subsidy from port/plant up to nearest rake point which is fully reimbursed on the basis of Railway Receipt (RR) issued by Indian Railways.

Import of urea in India is permitted to three State Trading Enterprises (i) MMTC Limited (ii) State Trading Corporation of India Limited (iii) Indian Potash Limited. Other fertilized import is free those fertilizers are imported under Open General License (OGL) as per their demand. Our Indian government has taken many initiatives to boost up the indigenous production of fertilizer at a reasonable price. The process and principles to import Fertilizers may differ from one port to other port in a country. Some of the common procedures are given below: (i) Importing permission has been directly assigned by government agencies (ii) There should be a prior update notice to the country from the port (iii) A necessary certificate of origin should be there on the exporting countries which must be approved by concern authorities (iv) There should be proper guidelines to import the fertilizer on each port.

The annual import of urea in India in the corresponding year Apr 2011- 2018 is given below:




## III. CASE STUDY AND NUMERICAL RESULTS

Ports are maritime facility for international trade. The coastal ports and shipping industry plays an important role in maintaining growth in the country. Ports act as a bridge between sea and land. These ports are considered as a gateway to the transport for cargo commodity. It occupies the place where vessels will dispatch or export the materials in cargo. India's coastline measures 7517 kilometer across western and Eastern Ghats of the mainland and islands. India has 13 major ports under which seven are located on the west coast and six on the east coast of the country and 200 minor ports. Trade business in India includes importing and exporting trade in many commodities such as crude oil, petroleum products, iron-ore and coal, fertilizer etc. Here, we have considered the transportation of Urea from the Ports of Karaikal, Tuticorin and Vizagapattinam in the state of Tamil Nadu and Andhra Pradesh in India.

### 3.1 Study Areas

#### 3.1.1 Karaikal Port

Karaikal Port Private Limited (KPPL) is on build by MARG Group, Operate and Transfer format under Public private partnership in terms of the concession awarded by the government of Puducherry and the port is an all-weather port. It is located on the east coast of India in Karaikal within the Union Territory of Puducherry. The Port is in operation since 2009 and it handled over 32 million tonnes of various cargoes. The port handles multiple cargoes of which the majority is coal and fertilizer import. The handling procedure for fertilizer consists of (i) Grabs is provided which transfer cargo to silos with hoppers (ii) taken to the warehouse by trucks where they are bagged using machines or manually (iii) The bags are loaded, weighed/counted and transported to the various destination. It has regular activities of dispatching fertilizer and coals in an average of 4-5 rakes per day. In addition, bagged cement, project cargo, and edible oils are handled including loading of offshore supply vessels. This port has multi-railway connectivity and has good roadway facilities to major cities.

#### 3.1.2 Tuticorin Port

Tuticorin port is located in the Gulf of Mannar at 540 km south-west of Chennai and 135 km from Madurai in Tamil Nadu. In India, there are thirteen major ports. Among them, Tuticorin has been declared as the 10th major Indian port. It has nine cargo berths namely four general cargo berths, two open area berths for landing bulk cargo and three container vessel berths with a container terminal. It has shallow water berth, passenger jetty and oil jetty for the import of furnace oil and naptha and two coal jetties for the import of coal for the thermal power station. The present capacity of the Tuticorin port is 20.55 million tons. Tuticorin port has crossed 10 million tons of traffic handling from April 1$^{st}$ to September 13, 2008 is greater than the corresponding previous year handling of 8.96 million tons and registering a growth rate of 12.08%. The port has registered high records in productivity and cargo handling. It is expanding and progressing justifying the confidence of port users. Since the commencement of the port operations in 1974, there has been steady all around growth in its performance. This was the first Indian port to obtain the prestigious ISO 9002 certificate issued by the Indian register quality systems, accredited by the Dutch Council Certification. The quality management system of Tuticorin has been assessed and certified under ISO 9001:2000 standard for port facilities and related support services for seaborne transportation. The port is well connected to various trade centers within Tamil Nadu by a network of roads, railroads, connected to southern Railway system, and by airlines, and the neighboring states of Kerala, Karnataka and Andhra Pradesh by national and state highways. Designed by Indian engineers and spread over 1250 acres, the port facilities allow handling of all types of commodities. It also has modern flotilla and adequate cranes for effective operations; above all modern communicative facilities are also available in the port.

### 3.1.3 Vizagapattinam port

Visakhapatnam Port is one of 13 major ports in India and the only major port of Andhra Pradesh. It ranks second largest in volume of cargo handled. The major commodities carried out at this port are Iron ore, manganese ore, steel products, general cargo, coal and crude oil. Visakhapatnam Port handles a bulk cargo process with a fair share of all cargoes i.e., DAP, MOP, UREA, COKE, SULPHUR, Manganese Ore, Silicon, Manganese, Rice, Timber logs, Cement, Rock Phosphate, Industrial Salt, Refractory Raw Material, Steel Cargoes, Blast Furnace slag etc. The export company handles two new cargoes of the port and the country. These are useful in handling Bulk Fertilizers which has covered accommodation and thus they require additional baggage facility which includes mechanized fertilizer bagging plant facility. Port has good Railway Siding to the warehouse complex in order to improvise the operations with least amount of time. This supervises that the cargo received are stored, stacked, bagged as per the Material Safety Data Sheet handling procedures and those products are prevented contamination. It has an adverse effect on the weather conditions to safe guard the quality of products.

The year wise import of urea in these three ports for the year 2011 – 2018 is shown below [12].

**Quantity lakhs in Metric tonnes**

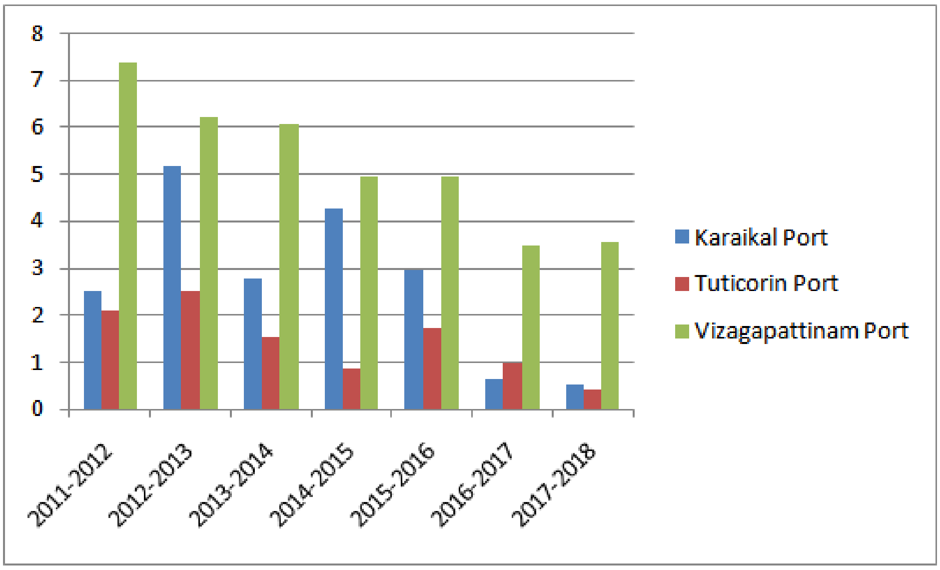



**Figure 4: Year wise import of urea in three ports during 2011-2018**

## IV. MULTI-OBJECTIVE TRANSPORTATION MODEL FORMULATION

The purpose of developing this model for three major ports is illustrated and the need for minimizing the cost of transportation by rationalizing the movement. The objective is to minimize the transportation costs, time and distance to avoid the crisscross movement for fertilizer products through a rationalized allocation plan.

### 4.1 Notations

Let $x(i, j, k)$ denote quantity product (k) transported from port (i) to destination (j)
$a(i, k)$ = availability of product $(k)$ of port $(i)$
$b(j, k)$= demand on product $(k)$ of destination $(j)$
m = the number of ports.
n = the number of destinations.
P= be the number of product.

$c(i,j)$= the cost of transportation from port $(i)$to destination $(j)$
$t(i,j))$ = time of transportation from port $(i)$ to destination$(j)$
$d(i,j)$= distance (km) from port $(i)$to destination $(j)$

**4.2 Formulation of Mathematical Model**
The deterministic Multi-Objective mathematical model formulated as follows:

Minimize $Z_1 = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{p} [c(i,j,) * x(i,j,k)]$ (4.2.1)

$Z_2 = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{p} [t(i,j,) * x(i,j,k)]$ (4.2.2)

$Z_3 = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{p} [d(i,j,) * x(i,j,k)]$ (4.2.3)

Subject to

$\sum_{j=1}^{n} x(i,j,k) = a(i,k) \, \forall \, i,k$ (4.2.4)

$\sum_{i=1}^{m} x(i,j,k) = b(j,k) \, \forall \, j,k$ (4.2.5)

$x(i,j,k) \geq 0 \, \forall \, i,j,k$ (4.2.6)

The first objective function of the model (4.2.1) aims to minimize the total transportation cost from port to various destinations to deliver the product. The second objective function of the model (4.2.2) aims to minimize the total travelling time. The third objective function of the model (4.2.3) aims to minimize the total distance. In constraints (4.2.4), the actual volume sent from the supplier (i, k) to the customer (j, k) equals the demand from suppliers (i, k) at customer (j, k) minus the amount that can't be sent due to limits in the transportation system. Constraints (4.2.5) guarantee that the actual volume sent from the supplier (i, k) to the customer (j, k) is equal to the demand minus the unspent amount.

Thus, the Multi Objective transportation model can be formulated using the equations (4.2.1), (4.2. 2), (4.2.3), (4.2.4), (4.2.5), (4.2.6) as described above.

## V. CONCLUSION

In this paper, we have studied and analyzed the three different Ports of transporting Urea from the state of Tamil Nadu and Andhra Pradesh. A Multi Objective Transportation model is developed to minimize transportation cost and time and distance. Demand and availability of urea from three ports of two southern states are considered in this model. It is concluded that the above mathematical model can be adopted for making allocation of products of all ports all over India using the model explained earlier, which proved to minimize transportation cost and time and it is advantageous over the proposed models earlier.

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