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Case

Optimal Movement Plan of Rice in the State of Andhra Pradesh in India

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Abstract. The case discusses an optimal movement plan for food grains (rice) by a state sponsored agency, the Food Corporation of India (FCI) in the State of Andhra Pradesh in India. There are five resource locations and eleven demand locations in this distribution network. Resource capacity and demand requirement for the three product (rice) variants at each location are known. There is no storage capacity restriction either in the demand or source location. Information related to rail network, its connectivity, distance in kilometers between origin-destination pairs, cost of transportation per tonne of food grain by rail or road are known. The primary issue is to develop a monthly movement plan to minimize the overall transportation costs subject to meeting the demand-supply restrictions. The total supply available for distribution and the total requirement at various locations are both equal at the product variant and aggregate level. The secondary issue is to develop an alternative movement plan to fulfil the demand requirements at a location, Karimnagar, which does not have a direct rail connection. Few plans are proposed to resolve the issues; the case encourages analysis of the problem situation and evaluation of the alternate resolution plans.



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Keywords: multi-commodity movement • transportation model

Introduction

In April 2015, Ms. Swati Bhargava reached the regional headquarters of the Food Corporation of India (FCI) in Hyderabad, Andhra Pradesh, and met with the HR department to begin her internship. After completing the necessary paper work, she was asked to meet with the General Manager (Operations), Mr. Sreenivasa Ranga Rao (S.R. Rao), her assigned internship advisor.

Swati Bhargava was pursuing a master's degree in business administration (MBA) at a renowned Institution in India. Inspired by a convocation address delivered at the University where she studied earlier, she had sought and obtained an internship in the FCI, a Government of India Public Sector Undertaking. Ms. Bhargava had studied mathematics for three years and earned a bachelor's degree in science. She went on to earn a master's degree in operations research, before pursuing an MBA.

Food Corporation of India:

The Food Corporation of India (FCI) was set up by the Government of India in 1963 under special legislation. FCI was mandated to safeguard the welfare of farmers through appropriate market intervention to stabilize food grain prices. It was also charged with

maintaining an adequate buffer stock of food grains and using that stock to supply public distribution systems to maintain a stable food security system.

The major operation of FCI is movement of food grains from surplus regions to deficit regions. FCI transports about 50 million tonnes of food grains per year through a network of 2,000 (owned and hired) storage depots. The primary mode of transportation is railways. If needed, FCI moves food grains via transshipment using multimodal connectivity to locations where direct rail links are not available.

Storage operations are very important to FCI because of the requirement to maintain a large inventory of food grains over extended periods. Adequate storage is a pre-requisite to fulfill FCI performance objectives.

As of 2015, FCI employed 48,988 workers and reported a turnover of Rs. 134,003 Crores (Rs. 1,340 Billion).

The Problem Context

Ms. Bhargava met with Mr. Rao who briefed her on the assignment.

FCI has been mandated in planning and executing the food grains movement plan. The office in Hyderabad

is responsible for the planning and distribution of food grain (rice) in the state of Andhra Pradesh. Our primary objective is to minimize the overall transportation cost in accomplishing a movement plan while meeting the demand requirements and off-take restrictions. Often we need to be prepared for contingencies that may arise out of nonavailability of transport vehicles (trucks, rail) and short-term discontinuity of rail service to some destinations. I am delighted to note that a person of your calibre has taken interest in the affairs of FCI. We hope that you will be able to find appropriate solutions to our operational challenges, as part of your internship assignment. Of course, we will be more than happy to provide you with the required data and information.

Rao: As General Manager of Operations, I need to decide the quantity of food grains (rice) to be moved from our sourcing warehouses to our depots at demand locations on a monthly basis. Our sourcing and depot locations are shown in Figure 1.

Bhargava: I need to formulate an optimization model to respond to the core issue that you mentioned. Will you be able to confirm, with current data, that there is adequate supply to meet the demand?

Rao: Our supplies are sufficient to fulfill our need. My concern is on two fronts; (a) we do not want our available resource, i.e., foodgrain, to be left unutilised and (b) we want all our demand requirements to be fulfilled. We also want to operate in the most cost efficient manner.

Bhargava: I will attempt to develop a movement plan towards this objective. Do you have data related to the quantity of rice that is being transported from various resource locations to destination depots?

Rao: We have data on the quantity of rice required at demand locations and available at source locations on a monthly basis. The movement plan for a typical month is presented in Figure 1.

Bhargava: A closer examination of the data provided in Figure 1 indicates that there are three varieties of rice (coarse, fine and superfine). Am I right in understanding this?

Rao: Yes, you are right. We deal with three rice varieties.

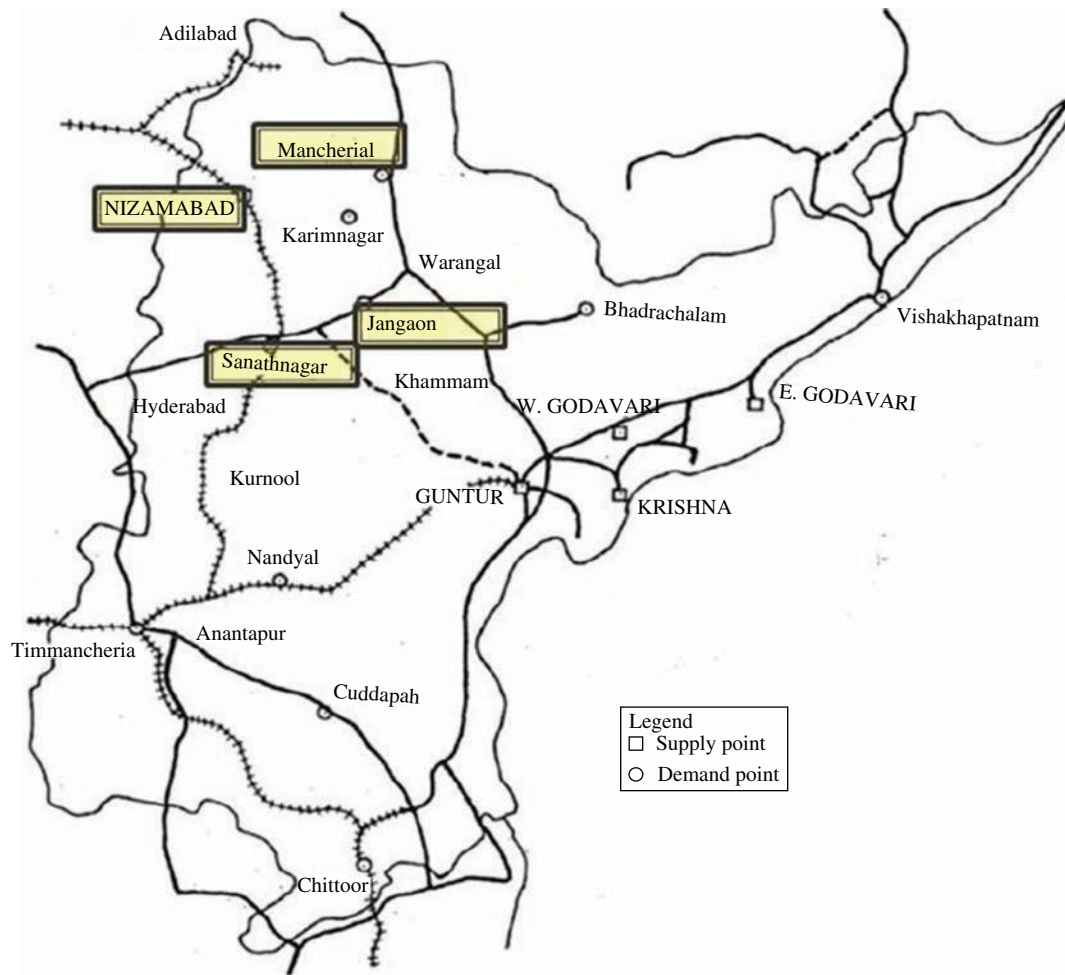
Bhargava: I also notice that the demand and availability for individual varieties of rice grain are different. Also the total available supply of all varieties is equal to the aggregate demand. What are the specific requirements of the system? For example, if a particular location needs a specific quantity of superfine variety, is it admissible to meet this expectation from another variety, say, coarse and vice-versa?

Rao: Swati, you have raised an important feature of our operating plan. Ideally, we would like to meet the demand requirements of a particular variety in total, unless there is a shortage. We would not like to substitute the demand for a particular Rice variety by another Rice variety.

Figure 1. Monthly Movement Plan of FCI in Andhra Pradesh

From district	To district /Depots	Quantity in tonnes			
		Coarse	Fine	S fine	Total
East Godavari	Vishakapatnam		10,500	3,500	14,000
West Godavari	Vishakapatnam		3,500		3,500
	Anantpur	8,750	8,750		17,500
	Hyderabad			3,500	3,500
Krishna	Hyderabad	5,250	3,500	5,250	14,000
	Adilabad	1,750			1,750
	Khammam	1,750			1,750
	Karimnagar	4,375			4,375
	Warangal	875			875
Guntur	Kurnool	5,250	1,750		7,000
	Cuddapah	875	875		1,750
	Chittoor	1,750	1,750		3,500
Nizamabad	Chittoor	1,750			1,750
Total		32,375	30,625	12,250	75,250

Figure 2. Andhra Pradesh State Rail Network



Source. Modified from the Case, Food Corporation of India, M. Ragahavachari and G. Raghuram, IIMA, 1992.

Notes. 1. E. Godavari denotes East Godavari and W. Godavari denotes West Godavari. 2. Karimnagar has road access from the four highlighted locations (Mancheria, Sanathnagar, Jangaon, and Nizamabad). 3. The possible connections to Karimnagar from the source locations (Krishna, East Godavari, West Godavari, Guntur, Nizamabad) are: Krishna—Mancheria (in Adilabad)—Karimnagar; Krishna—Jangaon (in Warangal)—Karimnagar; East Godavari—Jangaon (in Warangal)—Karimnagar.

Bhargava: I understand. A quick examination of data reveals that the demand-supply quantities not only match at the aggregate level, but also at the variety level. Therefore, it should be possible to formulate an optimization model that minimizes the total transportation cost, while satisfying the operational constraints. To proceed further, would it be possible to know the distance between various locations? Also, I would like to know the transportation cost and the permissible transportation modes.

Rao: We have this information. Figure 2 provides a railway map of Andhra Pradesh state. The current freight rates of the Indian Railways are presented in Figure 4. Figure 5 depicts all FCI resource and demand locations on a contour map of Andhra Pradesh. Figure 6 is an illustration of supply demand distribution possibilities for the coarse variety rice.

Bhargava: Thank you. Are there any capacity limitations on storage, either in supply or source locations? If so, I would seek data related to these restrictions.

Rao: There is adequate storage capacity in all our operating locations. These locations are used for storing a variety of food grains including rice. Since rice accounts for only 20% of the total volume handled by FCI, there is adequate capacity to handle food grains in FCI operational locations. Therefore, for all practical purposes, there are no storage capacity restrictions. Should there be a need, we can hire additional storage capacity in privately owned warehouses.

Bhargava: What is the preferred mode of transport in FCI? Are all sourcing and demand locations served by railheads? How does FCI deal with a situation when a particular location is not served by rail?

Rao: We predominantly use rail as a mode of transportation for operationalizing the movement plan. It is

Figure 3. Distance Matrix Between the Various FCI Supply and Demand Locations

Distance in Kms														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0													
2	150													
3	243	100												
4	335	185	94											
5	375	235	135	53										
6	680	526	440	489	305									
7	958	642	718	633	446	147								
8	721	538	481	399	346	176	161							
9	819	637	578	497	444	204	270	162						
10	610	433	370	285	271	454	359	413	574					
11	723	510	514	429	452	630	553	608	770	175				
12	510	309	305	270	293	489	509	563	690	144	224			
13	391	230	185	137	160	402	545	431	604	193	334	119		
14	699	376	493	469	492	677	658	713	875	274	200	190	307	0

Legend:

1. Vishakhapatnam	8. Cuddapah
2. East Godavari	9. Chittoor
3. West Godavari	10. Hyderabad
4. Krishna	11. Nizamabad
5. Guntur	12. Warangal
6. Kurnool	13. Khammam
7. Anantapur	14. Adilabad

Road transportation rate is Rs. 5.50 per tonne per kilometre

the most inexpensive mode for transporting bulk quantity of food grains. Occasionally, we use trucks to ferry materials to manage contingencies. If a particular location is not connected by rail network, FCI uses road transportation to serve that location.

Bhargava: Thank you. Due to economic reasons, movement by rail is preferred. Can you specify your demand locations which are not connected by rail link?

Rao: I am glad that you asked this question. Fortunately, all our demand locations, but for Karimnagar, are connected by rail.

Bhargava: Therefore the movement plan as a mathematical formulation should be simple and feasible. However, I need to know the current practice of meeting the demand at Karimnagar, which is not connected by rail.

Rao: Ms. Swati, I am so glad that you identified the most difficult and tricky situation for FCI, Andhra Pradesh. As of now, we are supplying the requirements of Karimnagar from resource location, Krishna by road. The cost per km.tonne by road is Rs. 5.50 and the total transportation cost to meet Karimnagar demand of 4,375 MT is Rs. 229,042.00. We are not sure

if this is the best solution. Maybe, experts like you, can examine and advise us.

Bhargava: I understand the challenges arising out of infrastructure connectivity constraints in meeting demand at Karimnagar location. To optimize the overall costs, is it possible for you to share with me the road distance between supply-demand pairs? And also, the applicable road transportation cost?

Rao: We can certainly do this. The distance data between origin—destination pairs is presented in Figure 3.

Bhargava: Thank you, Mr. Rao. Before I begin my analysis, I need to clarify with you one more contextual data. I understand that Karimnagar needs 4,375 tons of coarse rice per month. There is no rail connectivity to this location. It is now being served by road from source, Krishna. Is it possible to let me know the nearest rail heads to Karimnagar which are connected by rail to the supply points of FCI, Andhra Pradesh?

Rao: The four rail heads Mancherial, Sanathnagar, Jangaon, and Nizamabad are all close to Karimnagar, as presented in Figure 2. Mancherial is in district Adilabad, Sanathnagar is in district Hyderabad and Jangaon is in district Warangal. Nizamabad is a rail-head

Figure 4. Transportation Cost Matrix Between the Various FCI Supply and Demand Locations

Rate (in Rs)/Tonne														
	1	2	3	4	5	6	7	8	9	10	11	13	14	15
1	0													
2	259.4													
3	391.1	212.7												
4	524.1	325.1	212.7											
5	591	391.1	259.4	212.7										
6	997.5	795.2	658.8	726.6	491									
7	1,396.1	930.5	1,065.2	930.5	658.8	259.4								
8	1,065.2	795.2	726.6	591	524.1	325.1	290.7							
9	1,197.9	930.5	863.1	726.6	658.8	356.9	425.3	290.7						
10	930.5	658.8	557.3	459	425.3	692	557.3	625.1	863.1					
11	1,065.2	795.2	795.2	658.8	692	930.5	863.1	930.5	1,131.5	325.1				
12	795.2	491	491	425.3	459	726.6	795.2	863.1	997.5	259.4	356.9			
13	591	391.1	325.1	259.4	290.7	625.1	795.2	658.8	930.5	325.1	524.1	212.7		
14	997.5	591	726.6	692	726.6	997.5	997.5	1,065.2	1,264.1	425.3	356.9	325.1	491	0

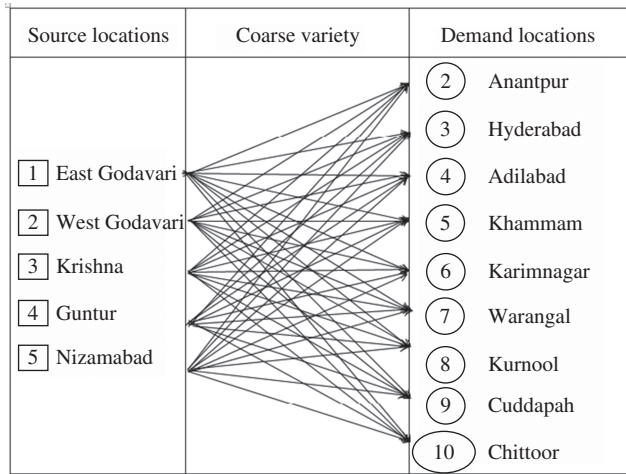
Legend:

1. Vishakhapatnam	8. Cuddapah
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6. Kurnool	13. Khammam
7. Anantapur	14. Adilabad

Road transportation rate is Rs. 5.50 per tonne per kilometre

Figure 5. FCI Source and Demand Locations on the Map of Andhra Pradesh (Not to Scale)



Figure 6. Illustrative Network Diagram of Coarse Rice Grain Movements

itself. These four transit locations are connected to the source locations by rail and to Karimnagar by road. The road distances in km. between these locations and demand location (Karimnagar) are 84, 163, 120, and 153, respectively.

Bhargava: Thank you for this clarification. In my proposed model, I would evaluate the consequences of serving Karimnagar via, any one of the cities Mancherial, Sanathnagar, Jangaon and Nizamabad by a combination of rail and road. This would mean that there will be a material handling at the transit point incurring some additional expense. I would like to know from you, if transshipment is acceptable to FCI?

Rao: I understand the implications of your proposed solution. I recognise that there will be some handling expenses at the transit location. But, in my view the magnitude of such a handling cost would be marginal. Therefore you can go ahead and develop a plan using a combination of road and rail.

Bhargava: Before I leave your office, one final clarification please: Is there a concession on the freight rates based on the volume of rice transported? Since FCI is handling three different rice varieties, is there a combination package that would economize freight charges? If there is, the model needs to be modified accordingly.

Rao: There is some concession possible on the tariff depending on the distance between the demand supply pair on a pan India basis. Since your project focusses only on movement in Andhra Pradesh state and the distance between origin, destination pairs is less than 1,000 km, telescopic freight rates are not applicable. Therefore, it is reasonable to assume a linear tariff structure for both rail and road transportation.

Further, there is no obligation on FCI to combine different varieties of rice for transportation to gain any concession on tariff. Tariff rates are additive on volume transported. I hope this clarifies your query.

Bhargava: I think I have now all the information that is required to formulate an optimal plan. If I miss something or if I need any additional information I shall get back to you in the next few days.

Rao: You are very welcome. How long do you think you will need to develop an optimal plan?

Bhargava: Since I have all the data, I can do this rapidly. I would be ready with an optimal plan in the next seven days. Once the plan is ready, I would like to have a detailed discussion with you in understanding the challenges in executing the plan.

Rao: I appreciate your enthusiasm to help us in optimizing the overall transportation cost subject to the requirements of meeting the variety-wise demand at various locations. I look forward to your advice in developing an optimal movement plan and operationalizing the same.

Reflections by Ms. Bhargava:

Ms. Bhargava was excited by the opportunity to address a real-life situation using formal optimization methods. In the current system, 75,250 tons of rice is moved each month at an estimated cost of Rs. 51,333,625.00. Optimization to save about 10% of the total cost of transportation would be significant.

In her opinion, the situation was amenable to modelling as a transportation problem. However, she noted that there are three varieties of rice and that they are not substitutable to meet demand expectations. The complications of disaggregate grain movement in the transportation modelling problem were not immediately clear to Ms. Bhargava. She wanted to refer to her OR notes to find an approach to model this situation.

She wanted to explore potential savings in the overall transportation cost if demand at various locations was met at the aggregate quantity basis with or without considering the variety-based demand quantities.

Ms. Bhargava knew that the most challenging task was to optimize the transportation cost to serve Karimnagar, which is not connected by rail. She noted, however, that the problem was somewhat simpler because it concerned only the coarse rice variety. She wanted to create multiple scenarios using formal transportation models, methods based on the locational advantage of sources to supply Karimnagar, and a combination of these methods based on the contextual information provided by Mr. Rao.

After careful consideration, she decided to focus on three approaches to meet the demand expectations of Karimnagar. Clearly, there were two components of transportation cost to be considered: One corresponds to rail transport and the other to road transport.

There are multiple rail heads in Andhra Pradesh that connect to Karimnagar by road. One possible approach is to plan shipment to Karimnagar to optimize rail transportation cost after predetermining the source point for Karimnagar, using a greedy approach for road transportation.

Another approach was to let the transportation model decide which source would supply Karimnagar. This optimizes rail transportation cost in an unbalanced problem as Karimnagar demand is not considered in the movement plan.

The third alternative was to develop a comprehensive model with the lowest transportation cost, i.e., destination pair by a combination of rail and road, wherever applicable.

Ms. Bhargava would explore each of these options and their implications for overall transportation cost to identify the monthly movement plan.

Assignment questions:

1. Identify the challenges faced by FCI in developing a monthly food grain movement plan.
2. Formulate the FCI movement plan as a transportation plan: Identify source, demand locations, quantities, distances, origin, i.e., destination transportation cost, etc. (Assume that Karimnagar would be supplied by road from Krishna.)

3. What are the implications of three different rice varieties in the formulation in (2).

4. Formulate three different transportation models for the approaches proposed by Ms. Bhargava.

5. Using appropriate software, generate solutions to the models proposed in items (2) to (4).

6. What are your critical observations? Which plan would you recommend and why?

7. Is there any approach (other than a transportation model) that you would like to consider for the FCI movement plan.

Acknowledgments

This case is based on the problem context discussed in the Food Corporation of India (FCI) by Professor M. Raghavachari, Indian Institute of Management Ahmedabad, and revised in 1992 by Professors M. Raghavachari and G. Raghuram. The authors acknowledge the permission of the Indian Institute of Management Ahmedabad to use the context cited above.