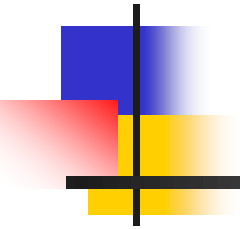
BlueSky Airlines

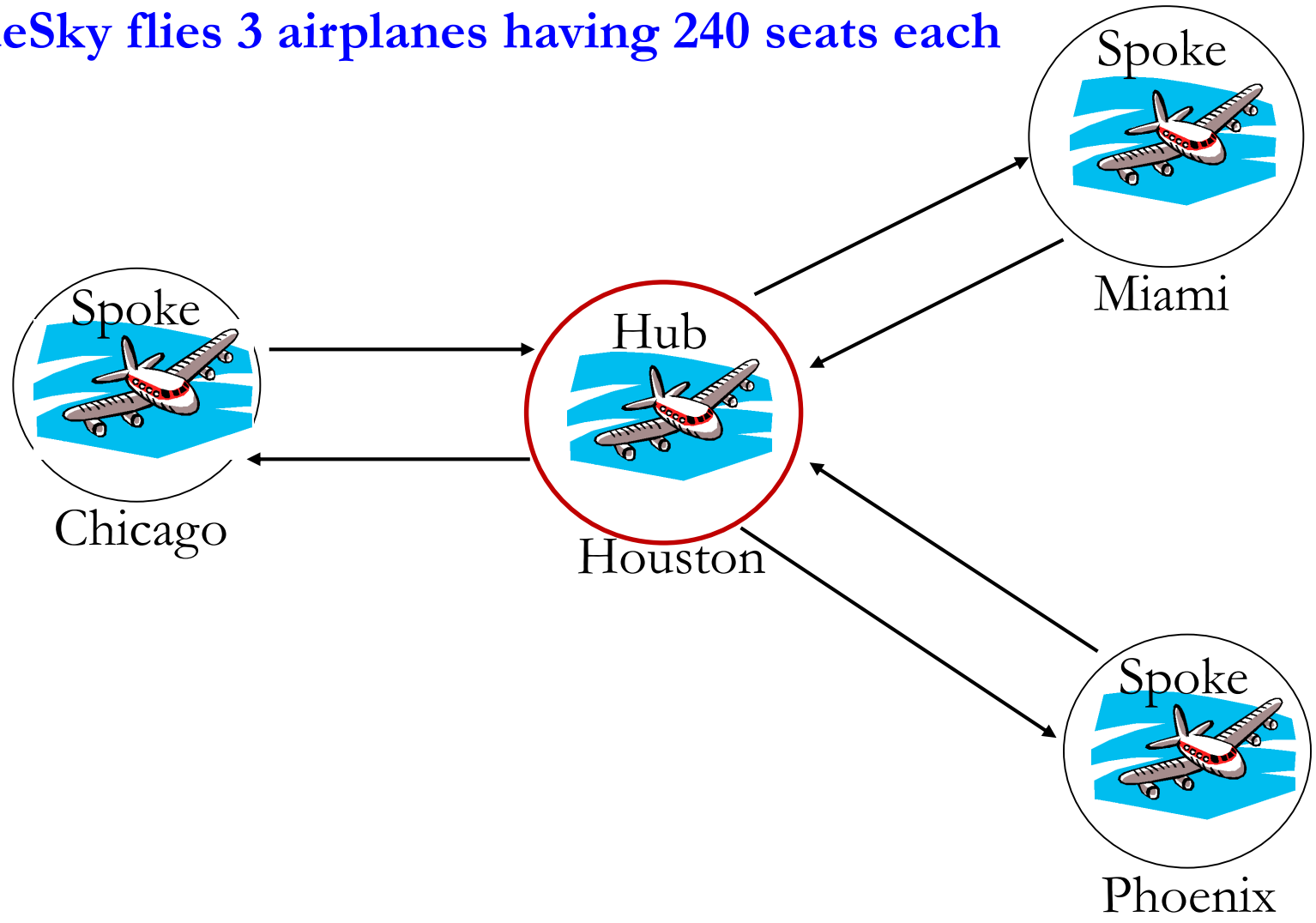


Network Revenue Management

Sachin Jayaswal
(sachin@iima.ac.in)

Hub-and-Spoke Network

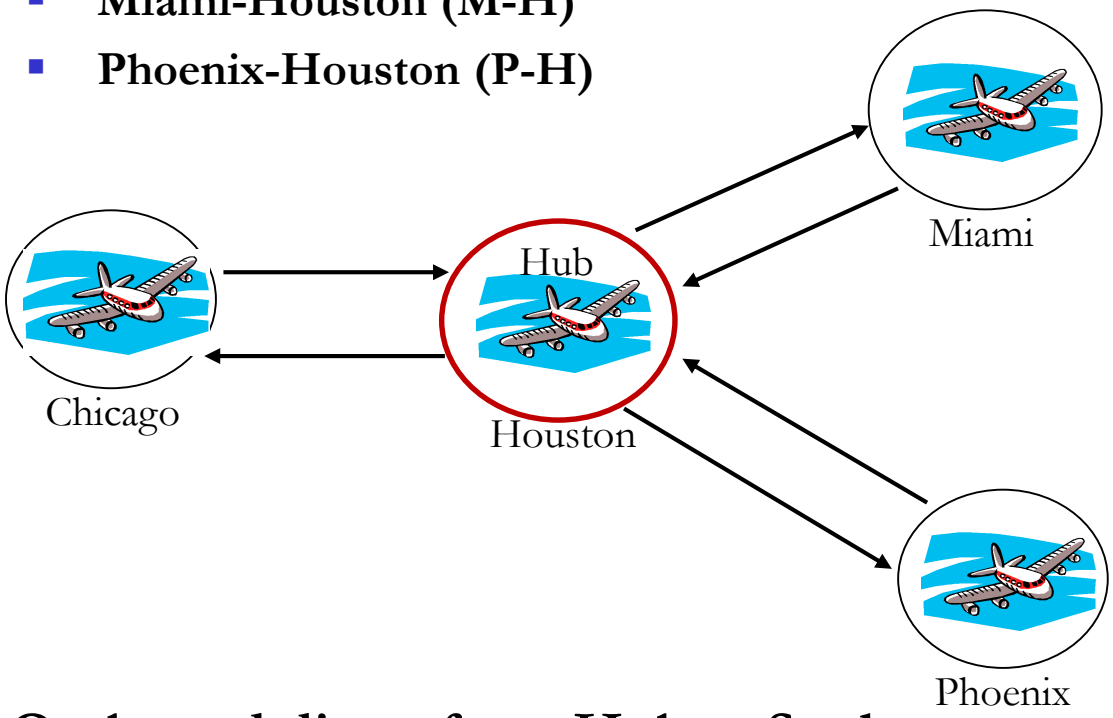
- **BlueSky flies 3 airplanes having 240 seats each**



Routes

Inbound direct from Spoke to Hub:

- Chicago-Houston (C-H)
- Miami-Houston (M-H)
- Phoenix-Houston (P-H)



Spoke to Spoke via Hub

- Chicago-Miami (C-M)
- Chicago-Phoenix (C-P)
- Miami-Chicago (M-C)
- Miami-Phoenix (M-P)
- Phoenix-Chicago (P-C)
- Phoenix-Miami (P-M)

Outbound direct from Hub to Spoke:

- Houston-Chicago (H-C)
- Houston-Miami (H-M)
- Houston-Phoenix (H-P)

Bank: 1 set of 6 flights (3 inbound to Houston and 3 outbound from Houston)

Price and Demand

Demand During One Bank

Origin	Destination				Total	
	Houston	Chicago	Miami	Phoenix		
Houston	0	123	80	110	-	
Chicago	130	0	98	88	316	(C-H)
Miami	72	105	0	68	245	(M-H)
Phoenix	115	90	66	0	271	(P-H)
Total	-	318 (H-C)	244 (H-M)	266 (H-P)		

Price for Each Passenger Route

Origin	Destination			
	Houston	Chicago	Miami	Phoenix
Houston	-	$197	$110	$125
Chicago	$190	-	$282	$195
Miami	$108	$292	-	$238
Phoenix	$110	$192	$230	-

Price and Demand

Demand During One Bank

Origin	Destination				Total	
	Houston	Chicago	Miami	Phoenix		
Houston	0	123	80	110	-	
Chicago	130	0	98	88	316	(C-H)
Miami	72	105	0	68	245	(M-H)
Phoenix	115	90	66	0	271	(P-H)
Total	-	318 (H-C)	244 (H-M)	266 (H-P)		

- **Are there enough seats on every flight?**
- **The airline needs to decide whether to accept/reject a demand on a particular route.**
- **How should BlueSky decide how many tickets to sell on each route?**

Paper Recycling

A paper recycling plant processes box board, tissue paper, newsprint, and book paper into pulp that can be used to produce three grades of recycled paper. The prices per ton and the pulp contents of the four inputs are shown in the Table below.

	Box board	Tissue paper	Newsprint	Book paper
Cost per ton	$5	$6	$8	$10
Pulp content	15%	20%	30%	40%

- **Any of the two methods, de-inking or asphalt dispersion, can be used to process the four inputs into pulp.**

Glassey C. R. and Gupta V. K. 1974. A linear programming analysis of paper recycling. Management Science, 21 (4), 392-408.

Paper Recycling

- It costs $20 to de-ink a ton of any input. The process of de-inking extracts 90% of the original pulp.
- It costs $15 to apply asphalt dispersion to a ton of any input. The asphalt dispersion process extracts 80% of the input's pulp.
- The asphalt dispersion process or the de-inking process can separately process at most 3000 tons of input.
- Grade 1 paper can be produced only with newsprint or book paper pulp; grade 2 paper only with book paper, tissue paper, or box board pulp; grade 3 paper only with newsprint, tissue paper, or box board pulp.
- To meet its current demands, the company needs 500 tons of pulp for grade 1 paper, 500 tons of pulp for grade 2 paper, and 600 tons of pulp for grade 3 paper.
- Determine how to minimize the cost of meeting the demands for pulp.

The Freight Allocation Problem with Lane Cost Balancing Constraint

We consider a problem faced by a buying office for one of the largest retail distributors in the world. The buying office plans the distribution of goods from Asia to various destinations across Europe. The goods are transported along shipping lanes by shipping companies, many of which have collaborated to form strategic alliances. Each lane must be served by no less than a given number of companies belonging to no less than a given number of alliances. The task involves purchasing freight capacity from shipping companies for each lane based on projected demand, and subject to minimum quantity requirements for each selected shipping company, such that the total transportation cost is minimized. In addition, the allocation must not assign an overly high proportion of freight to the more expensive shipping companies serving any particular lane, which we call the lane cost balancing constraint. … Our approach was developed into an application that is currently employed by decision-makers at the buying office in question.

Lim A., Qin H. and Xu Z. 2012. The freight allocation problem with lane cost balancing constraint. European Journal of Operational Research, 217, 26-35.

Freight Allocation Problem

- **Consider a shipper that needs to select carriers to carry its freight on various shipping lanes. There are 8 carriers and 3 shipping lanes.**

- **The projected demands of freight to be shipped are 650, 775 and 880 units for lane 1, 2 and 3, respectively.**

Freight Allocation Problem

- **Price quoted by each carrier to transport a unit of freight demand on each lane is as given in the table below:**

Carriers	Lane 1	Lane 2	Lane 3
1	392	368	311
2	268	265	202
3	208	215	299
4	315	279	347
5	340	340	279
6	249	375	397
7	324	363	328
8	264	285	370
Project demand	650	775	880

Freight Allocation Problem

- **Minimum Quantity of Freight quoted by each carrier below which it will not participate (Minimum Quantity commitment (MQC)) is 1,000 units.**

- **Amount of freight allocated to each carrier servicing a lane cannot be more than 60% of the total freight demand on the lane.**

- **The carriers have formed the following alliances among them:**

  - **Alliance A comprises: carriers 1,2,3,4**

  - **Alliance B comprises: carriers 5,6,7,8**

- **Vessel sharing is a common form of inter-organizational cooperation among carriers in the same alliance.**

Freight Allocation Problem

- **Amount of freight allocated to each alliance servicing a lane cannot be more than 90% of the total freight demand on that lane.**

- **Total cost of freight shipping on any lane should not exceed the lowest possible cost (among selected carriers) for that lane by more than 35%. For example, the total cost for lane 1 should not exceed 1.35 * (x*650) where x is the minimum cost quoted for lane 1 among the carriers that are selected.**

Selecting Telecommunication Carriers to Obtain Volume Discounts

During 2001, many European markets for mobile phones reached saturation. Hence, mobile phone operators have shifted their focus from growth and market share to cutting costs. One way of doing so is to reduce spending on international calls, which are routed via network operating companies (carriers). These carriers charge per call-minute for each call destination, and may use a discount on total business volume to price their services. We developed a software system that supports decisions on allocating destinations to carriers. Our system solves the operational problem to optimality and performs what-if analyses and sensitivity analyses. A major telecommunication services provider implemented the system, realizing two benefits: it has structured the business process of allocating carriers to destinations and cut the costs of routing international calls.

Klundert J. Van de, Kuipers J., Spieksma F. C. R. and Winkels M. 2005. Selecting telecommunication carriers to obtain volume discounts. Interfaces, 35 (2), 124-132.

Inputs

- The (forecasted) no.of call-minutes for destination d in month t.
- Price per call minute for destination d from carrier c in price interval i in month t.
- The lower and upper thresholds for price interval i of carrier c.
- The lower and upper limits on capacity for carrier c in month t.
- The penalty per call-minute (to discourage poor-quality options) for carrier c to destination d in month t.
- Of course, it hopes to take advantage of price discounts offered by the carriers. The Tables below provide inputs for $T = 2$, $C = 3$, $D = 5$, and $I = 3$.

Penalties per call minute										
	Month-1					Month-2				
	D-1	D-2	D-3	D-4	D-5	D-1	D-2	D-3	D-4	D-5
C-1	2					2				
C-2			2					2		
C-3		3					3			

Price intervals	Lower limit	Upper limit
C-1: Price Interval 1	0	2000
Price Interval 2	2000	4000
Price Interval 3	4000	50000
C-2: Price Interval 1	0	2500
Price Interval 2	2500	5000
Price Interval 3	5000	50000
C-3: Price Interval 1	0	2000
Price Interval 2	2000	3500
Price Interval 3	3500	50000

Lower and upper bounds on capacity				
	Month 1		Month 2	
	Lower bound	Upper bound	Lower bound	Upper bound
Carrier-1	0	2000	0	2000
Carrier-2	500	2000	500	2000
Carrier-3	0	2500	0	2500

Forecast Volume	Dest. 1	Dest. 2	Dest. 3	Dest. 4	Dest. 5
Month 1	500	1000	800	12000	900
Month 2	700	1000	6000	1500	700

Unit Prices	Month-1					Month-2				
	D-1	D-2	D-3	D-4	D-5	D-1	D-2	D-3	D-4	D-5
C-1: i1	9	12	15	10	15	9	12	15	10	15
C-1: i2	8	10	13	8	13	8	10	13	8	13
C-1: i3	7	8	10	5	10	7	8	10	5	10
C-2: i1	10	13	17	11	16	10	13	17	11	16
C-2: i2	9	11	15	9	14	9	11	15	9	14
C-2: i3	8	9	13	5	12	8	9	13	5	12
C-3: i1	8	14	17	12	14	8	14	17	12	14
C-3: i2	7	12	13	10	12	7	12	13	10	12
C-3: i3	6	10	9	8	9	6	10	9	8	9

Problem

Develop an optimization model that helps V-Mobile allocate its international calls in a cost-efficient manner and report the solution. The solution should report number of call-minutes routed through carrier *c* to destination *d* in price interval *i* in month *t*.

Supply Chain Management

Globe Electronics, Inc. manufactures 2 styles of remote control cable boxes (the G50 and the H90) that various cable companies supply to their customers when cable service is established. Different companies require different models. During the late 1980s and early 1990s, due to an explosion in the demand for cable services, Globe expanded rapidly to 4 production facilities located in Philadelphia (the original plant), St. Louis, New Orleans, and Denver. The manufactured items are shipped from the plants to regional distribution centers located in Cincinnati, Kansas City, and San Francisco; from these locations they are distributed nationwide.

Because of a decrease in demand for cable services and technological changes in the cable industry, demand for Globe's products is currently far less than the total of the capacities at its four plants. As a result, management is contemplating closing one or more of its plants.

Supply Chain Management

Each plant has a fixed operating cost, and, because of the unique conditions at each facility, the production costs, production time per unit, and total monthly production time available vary from plant to plant, as summarized in the Table.

Plant	Fixed Cost/month ($1000)	Production Cost ($/unit)		Production Time (min/unit)		Available Hrs./month
		G50	H90	G50	H90	
Philadelphia	40	10	14	3.6	3.6	640
St. Louis	35	12	12	4.2	4.8	960
New Orleans	20	8	10	5.4	4.2	480
Denver	30	13	15	3	5.4	640

Supply Chain Management

Current monthly demand projections at each distribution center for both products are given in the Table below.

	Demand		
	Cincinnati	Kansas City	San Francisco
G50	2000	3000	5000
H90	5000	6000	7000

The transportation costs (per 100 units) between each plant and each distribution center, which are the same for either product, are shown in the Table below.

	To		
From	Cincinnati	Kansas City	San Francisco
Philadelphia	200	300	500
St. Louis	100	100	400
New Orleans	200	200	300
Denver	300	100	100

Supply Chain Management

Globe management wants to develop an optimal distribution policy (i.e., minimize total cost) while also determining whether or not to close any of the production facilities. If transportation cost per 100 units between a pair of cities is, let's say, 200, then you may treat this as 2 per unit.

Assembly Line Balancing

An assembly line is used to continuously manufacture large quantity of the same product. It consists of locations, called workstations, and one or more tasks may be performed at each workstation in the process of completing the manufacture of a product.

Assume there are 6 tasks in all that a product must go through the assembly line from workstation 1 to workstation 2 and so on, to the final workstation. Each task i requires t_i minutes to perform at any workstation. Each task needs to be performed completely at one of the workstations, i.e. it cannot be split between two or more workstations. Further, a workstation can process more than one task, provided the combined time of all tasks assigned to it does not exceed 10 minutes, which is called the Cycle Time of the line. Certain tasks must be performed before others. This is indicated by the use of precedence relations in the table below.

Assembly Line Balancing

Task (i)	Immediate Predecessor	Task Duration (ti) in minutes
1	None	5
2	None	6
3	1	2
4	2, 3	5
5	1, 2	4
6	4	3

For example, the table suggests that Task 3 cannot start until Task 1 has finished. The factory space can accommodate a maximum of 4 workstations.

https://www.youtube.com/watch?v=6n9ESFJTnHs

https://www.youtube.com/watch?v=WmAwcMNxGqM

AmazingDeal.com: Growth Strategy for Future

It is the first day of a 2-month summer internship at AmazingDeal.com's Bangalore office for Krishna Kumar. He is equally excited and nervous about the challenges that lie ahead in his first corporate experience. Krishna, a 1st year MBA student at one of the prestigious institutes of Management in India, accepted the internship offer from AmazingDeal, preferring it to some of the bigger brands in the retail industry, so as to be a part of the phenomenal growth story of one of the India's fastest growing companies. He has been asked to report to Jhanvi Sarkar, an Associate Director (AD), who is currently in a meeting with the Vice President (VP) of Operations.

"Hello, I am Jhanvi, welcome to AmazingDeal - India's largest and fastest growing e-retailer", greeted a lady in early 30's. "You have joined AmazingDeal at an exciting moment. We recently crossed $1 billion in sales by GMV (Gross Merchandise Value), and now aim to achieve $10 billion by 2020. To achieve this, we have to provide an expansion plan for our Fulfilment Centres (FCs). Moreover, as competition is getting more intense, we need to expand our Next Day Delivery (NDD) and Same Day Delivery (NDD) services to more cities. Our Marketing team has already done extensive research on the demand potential of various cities, based on various factors like internet penetration, mobile usage, credit card, population, literacy etc. They have finally listed 500 cities, which have been classified as Metros, Tier 1, Tier 2 and Tier 3 based on their demand potential and population. In such cities, the saving in transportation cost from opening an FC is greater than its operations cost. But, we don't want to open FCs in each of these cities. We have budget constraints, and we want to cover these cities with the minimum number of FCs. You will assist me in this project, which needs to be completed and presented to the VP within 2 months. So, let us get started. Please collect all the information about this project that you need from our Marketing and Operations teams, and let us meet again tomorrow."

About the Company

AmazingDeal, a brainchild of Mr. Bhushan Yadav and Kulbhushan Yadav, revolutionized the shopping behaviour of Indians and successfully shifted millions of users from Brick-and-mortar store to online shopping, which heralded the beginning of a whole new industry. It started in 2009 as an online portal to sell books with an initial investment of Rs. 5,00,000. Soon, the company expanded its presence in a wide range of categories including electronics, appliances, furnishing, stationery, sports & fitness, fashion & apparel, personal care. Growing at an unprecedented rate, the company reached $1 billion sales (GMV) in 2016, in less than 7 years since its inception. This phenomenal growth helped AmazingDeal attract funds from various venture capitalists like Accel Partners, Tiger Global, Naspers, Iconiq Capital and Morgan Stanley Wealth Management, among others. These funds also helped AmazingDeal make several significant acquisitions.

E-commerce in India

E-commerce, although still nascent in the Indian market, is rapidly changing the competition. Internet penetration is increasing at an ever growing rate in Tier II and Tier III cities, which is expected to give a fillip to the e-commerce business. As per a recent report by Accel Partners, e-

commerce in India is expected to reach from $2 billion in sales in 2013 to $8.5 billion in 2016, at a CAGR of 63%. In the same period, the number of online shoppers and the average order value are both expected to double, from 20 million and Rs. 1,800 to 40 million and Rs. 3,600, respectively. This has prompted several traditional retailers like Croma, Future Group, Arvind Group to expand into e-retailing to establish themselves into e-commerce space. Flipkart is currently holding the top spot in e-commerce market in India. However, it is facing intense competition from Amazon, which has recently made an investment of $2 billion in Indian operations, and Snapdeal, which has recently raised nearly $1 billion, largely from Japan's Softbank.

AmazingDeal's Business Model

AmazingDeal, like many other e-commerce sites in India, traditionally started as a pure e-retailer, with its own fulfilment centers from which products were shipped to the retail customers. Currently, AmazingDeal has four big FCs in Delhi, Mumbai, Kolkata and Bangalore. All the orders are processed by the nearest FC, and sent to customers by road or air based on the type of delivery needed, viz. Standard delivery, Next Day delivery (NDD) and Same Day delivery (SDD). NDD and SDD options earn AmazingDeal good premiums over the standard delivery. At the same time, they often require fulfilment by air mode, which is very expensive. Yet, NDD and SDD services allow AmazingDeal to carry perishable items in its catalogue besides charging a premium for the expedited delivery.

Most of the e-commerce sites in India, in an attempt to expand their product catalogues and reduce the cost of operation, have gradually shifted to the "Market Place" model, allowing 3rd party business partners to list their products on their websites. AmazingDeal also joined the bandwagon with the announcement of its own marketplace in 2013. It currently has 50 sellers on-board. The third party sellers need to stock their products in AmazingDeal warehouses before the orders are placed, so as to ensure quick deliveries and economy of scale of AmazingDeal can be utilized in term of packing and transportation of shipment.

AmazingDeal's Proposed Future Delivery Model

AmazingDeal's vision is to achieve $10 billion in sales by 2020. As a part of this vision, it is planning to expand its NDD and SDD services beyond Metros and Tier 1 cities. In this model, the four main supply hubs (in Delhi, Mumbai, Kolkata and Bangalore), called, "BIG FCs", would procure all the goods. The goods procured would then be supplied to their respective Forward Fulfilment Centres (FFCs), which would hold the inventory needed to cover their respective regions under SDD and NDD. This is in line with the global players like Amazon (USA), and JD (China), which have already decentralized their bigger warehouses into smaller warehouses to move closer to the customers. Amazon has around 65 FCs in the USA, which are located in places with very high population and internet penetration. Similarly, JD has around 84 FCs in China. This also enables them to provide expedited delivery for a premium. Moreover, moving closer to the customers has enabled them to add even perishable items like fruits and vegetable to their basket of offerings.

AmazingDeal has identified the top 500 potential cities, based on factors like internet penetration, mobile usage, credit card, population, literacy etc., for expansion of its NDD and SDD services. It would like to locate its FFCs such that these cities are served under NDD and

SDD options by road, as opposed to the more expensive air mode. Exhibit 2 gives the market potential of the top 8 cities that are currently not within NDD zone from any of the four FCs, and the pairwise travel time by road between them.

Next Morning

Armed with the required background information about AmazingDeal, its current and proposed delivery models, Krishna met Jhanvi. He also brought with him a spreadsheet containing the road distances between all pairs of the 500 cities, which he had developed using Google map.

"Good!" said Jhanvi, "let us begin our analysis for the sample data in Exhibit 2, and plan for the following:

1. Where should the next FC be located so as to serve the maximum potential market using NDD service?

2. Where should the next 2 FCs be located so as to serve the maximum potential market using NDD service?

3. What is the minimum number of FCs required and where should they be located so as to serve all the cities using NDD service?

Based on the average speed of 50 km/hour on inter-city highways, NDD to a city is possible only from an FC within a distance of 400 km (8 hours by road). Similarly, SDD to a city is possible only from an FC within 100 km (3 hours by road) (Exhibit 3)."

Exhibit 1: Sales growth

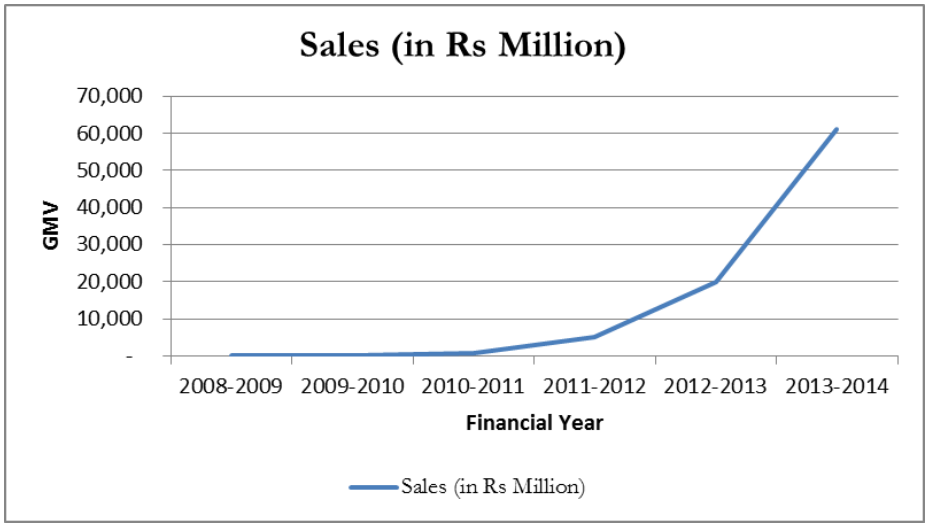


Exhibit 2: Travel times and Potential Market

Travel times (hours)										
From\to	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**		Potential Market
1	0	9	10	12	14	15	14	16		40000
2	9	0	11	10	14	12	18	15		30000
3	10	11	0	8	8	9	11	13		35000
4	12	10	8	0	9	8	11	10		20000
5	14	14	8	9	0	8	8	10		15000
6	15	12	9	8	8	0	9	8		50000
7	14	18	11	11	8	9	0	8		45000
8	16	15	13	10	10	8	8	0		60000

Exhibit 3: Typical timelines in NDD and SDD

Service	Delivery Promise	Transport time*
Standard Delivery	3-10 days (Based on location)	2-8 days
Next Day Delivery(NDD)	Maximum 24 hrs.	8 hours
Same Day Delivery(SDD)	Maximum 12 hrs.	3 hours

* -- Transport time left after different operations carried out for inbound and outbound activities. Speed of transportation is assumed to be 50 km/hour for NDD and 30-35 km/hour for SDD (since intra-city traffic is considered in SDD, as opposed to inter-city traffic in NDD).

Aggregate Production Planning (APP) for Red Tomato Inc.

Sachin Jayaswal
sachin@iima.ac.in

An Example

RED TOMATO INC. TOOLS CASE:

The demand for Red Tomato's gardening tools is highly seasonal, peaking in the spring as people plant their gardens. Red Tomato has decided to use aggregate production planning to overcome the obstacle of seasonal demand at minimum cost.

The options Red Tomato has for handling the seasonality are

1. adding workers during the peak season,
2. subcontracting out some of the work,
3. building inventory during the slow months, or
4. building up a backlog of orders that will be delivered late to customers.

How can Red Tomato best use these options?

Use aggregate production planning to help Red Tomato answer this.

Other relevant information are given below:

Demand Forecast at Red Tomato Tools	
Month	Demand Forecast
January	1,600
February	3,000
March	3,200
April	3,800
May	2,200
June	2,200

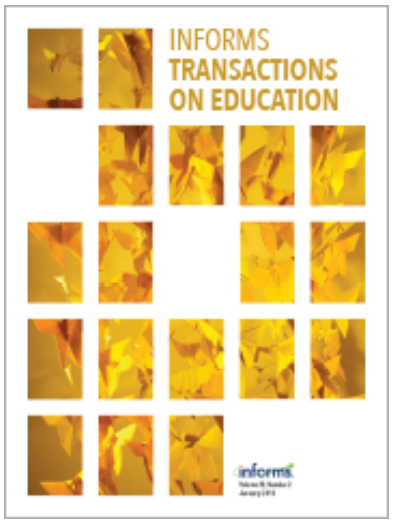
Costs for Red Tomato	
Item	Cost
Material cost	$10/unit
Inventory holding cost	$2/unit/month
stockout/backlog cost	$5/unit/month
Hiring and training costs	$300/worker
Firing cost	$500/worker
Labour hours required	4hours/unit
Regular time cost	$4/hour
Overtime cost	$6/hour
Cost of subcontracting	$30/unit

- Red Tomato sells each tool for $40
- Starting inventory in January = 1,000 tools
- Workforce at the beginning of January = 80 employees
- Working days = 20 days/month
- Working hours = 8 hours a day and any remaining hours performed on overtime
- Due to labor rules, no employee works more than 10 hours of overtime per month
- Machine capacity does not limit the capacity of production operation, and capacity of production operation is determined primarily by the total labor hours worked.

- Currently, Red Tomato has no limits on subcontracting, inventories, and stockouts/backlogs.
- All stockouts are backlogged and supplied from the following month's production.
- Inventory costs are incurred on the ending inventory in the month.
- The goal of the Operations Manager at Red Tomato is to obtain the optimal aggregate plan that allows Red Tomato to end June with at least 500 units.

Remarks:

- The optimal aggregate plan is one that results in the minimum total cost.



INFORMS Transactions on Education

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

Case—Integrating Network Design Models for a Global Supply Network

Yong Wu

To cite this article:
Yong Wu (2022) Case—Integrating Network Design Models for a Global Supply Network. INFORMS Transactions on Education 22(3):176-177. https://doi.org/10.1287/ited.2019.0237cs

http://pubsonline.informs.org/journal/ited

INFORMS TRANSACTIONS ON EDUCATION
Vol. 22, No. 3, May 2022, pp. 176–177
ISSN 1532-0545 (online)

Case

Integrating Network Design Models for a Global Supply Network

Yong Wu[a]

[a] Department of Business Strategy and Innovation, Griffith University, Gold Coast Campus, Queensland 4222, Australia
Contact: yong.wu@griffith.edu.au, https://orcid.org/0000-0003-2206-8594 (YW)

Received: February 3, 2020
Revised: April 27, 2020
Accepted: June 24, 2020
Published Online in Articles in Advance: October 30, 2020

https://doi.org/10.1287/ited.2019.0237cs

Keywords: spreadsheet modeling • teaching optimization • teaching supply chain management • network design

1. Introduction

Managers from Oz Sourcing Limited (Oz Sourcing) are worried about the recent uncertainty and volatility in business environment. Oz Sourcing operates across Australia in the following five major cities: Adelaide, Brisbane, Melbourne, Perth, and Sydney. Traditionally, Oz Sourcing has been relying on an overseas supplier, Ovis Supply Limited (Ovis for short), for a stereo system that is quite popular among its customers. Oz Sourcing has been asking Ovis to sea transport all the stereo systems to the warehouses in the five major cities. When there are changes in demand among the five cities, Oz Sourcing will either need to incur road transportation cost if it decides to redirect the stereo systems from one city to another within Australia or forgo the additional demand, as the long lead time from Ovis does not allow a quick delivery.

The top management at Oz Sourcing sees the opportunity to address this issue when a company, Domes Manufacturing Systems (Domes for short), approaches them to offer manufacturing services. Domes can offer fully flexible manufacturing services; that is, it can produce any number of stereo systems in any major city in Australia as demanded by Oz Sourcing, as long as the number does not exceed an agreed-upon cap and the location of manufacturing does not change.

To start with this transition, Oz Sourcing decides to commission 500 fully flexible units to Domes every month. The location of manufacturing, however, still needs to be determined. Oz Sourcing adopts and operates on a monthly ordering cycle. Table 1 lists the monthly demand for each city, the Domes production cost (which depends on the city of production—e.g., "Domes Adelaide" means the production is in Adelaide, and the unit cost of $450 applies), and the unit cost from Ovis (delivered cost—i.e., delivered duty paid, which means Ovis is responsible for arranging carriage and delivering the goods, cleared for import and all applicable taxes and duties paid).

2. Transport Cost and Lead Time

Sea transport is used for the shipments from Ovis, whereas road transport will be used for transportation within Australia. For sea transport, Oz Sourcing can choose to use either a 40′ or a 20′ container, depending on the volume shipped. Each 40′ container can hold 200 units; each 20′ container can hold 100 units. Because of loading and safety constraints, containers must be fully loaded at all times. If the number of units is not enough to fill a full container, the less-than-container load (LCL) option, where special safety measures are taken, must be used.

Oz Sourcing needs to pay its supplier up front, which means that Oz Sourcing needs to bear the inventory

Table 1. Monthly Demand at Each City and Location-Based Unit Production Cost

Demand location	Units	Production location	Unit cost ($)
Adelaide	420	Domes Adelaide	450
Brisbane	870	Domes Brisbane	480
Melbourne	1,250	Domes Melbourne	505
Perth	930	Domes Perth	490
Sydney	1,310	Domes Sydney	515
		Ovis (delivered)	440

Table 2. Sea Transport Cost and Lead Time from Ovis to the Five Major Cities

Location	$/40′ container	$/20′ container	$/LCL unit	Lead time (days)
Adelaide	2,000	1,200	25	30
Brisbane	1,600	1,000	20	21
Melbourne	1,800	1,100	23	28
Perth	1,200	700	15	18
Sydney	1,650	1,050	22	25

holding cost when the freight is being transported from Ovis. Table 2 presents the unit transport costs for a 40′ container, a 20′ container, and a unit transported via LCL. The lead time of sea transport between Ovis and each major city is also listed in the table. The accounting department of Oz Sourcing mentions that an annual interest rate of 15% would be reasonable to be used to calculate the inventory holding cost.

Within Australia, road transport will be used. The unit transport cost between each pair of cities is shown in Table 3. The inventory holding cost for the duration of road transport can be safely ignored because of the relatively short lead times for road transport.

Table 3. Road Transport Cost per Unit Between Cities (in Dollars)

	Destination				
Origin	Adelaide	Brisbane	Melbourne	Perth	Sydney
Adelaide	0	35	10	35	25
Brisbane	35	0	25	70	15
Melbourne	10	25	0	45	15
Perth	35	70	45	0	55
Sydney	25	15	15	55	0

3. The Road Ahead

The management team at Oz Sourcing now wants to conduct a cost-benefit analysis on engaging Domes. In order to do that, Oz Sourcing will need to know, on a monthly basis, the following:

1. How much does it cost for Oz Sourcing to ship directly from Ovis to each city?
2. If Oz Sourcing does not engage Domes, is the current shipping practice the best for Ovis?
3. In which city should Oz Sourcing ask Domes to manufacture?
4. How much could Oz Sourcing save, if engaging Domes prove to be cost beneficial?

Table 1. Monthly Demand at Each City and Location-Based Unit Production Cost

Demand location	Units	Production location	Unit cost ($)
Adelaide	420	Domes Adelaide	450
Brisbane	870	Domes Brisbane	480
Melbourne	1,250	Domes Melbourne	505
Perth	930	Domes Perth	490
Sydney	1,310	Domes Sydney	515
		Ovis (delivered)	440

Table 2. Sea Transport Cost and Lead Time from Ovis to the Five Major Cities

Location	$/40′ container	$/20′ container	$/LCL unit	Lead time (days)
Adelaide	2,000	1,200	25	30
Brisbane	1,600	1,000	20	21
Melbourne	1,800	1,100	23	28
Perth	1,200	700	15	18
Sydney	1,650	1,050	22	25

Table 3. Road Transport Cost per Unit Between Cities (in Dollars)

	Destination				
Origin	Adelaide	Brisbane	Melbourne	Perth	Sydney
Adelaide	0	35	10	35	25
Brisbane	35	0	25	70	15
Melbourne	10	25	0	45	15
Perth	35	70	45	0	55
Sydney	25	15	15	55	0

The management team at Oz Sourcing now wants to conduct a cost-benefit analysis on engaging Domes. In order to do that, Oz Sourcing will need to know, on a monthly basis, the following:

1. How much does it cost for Oz Sourcing to ship directly from Ovis to each city?
2. If Oz Sourcing does not engage Domes, is the current shipping practice the best for Ovis?
3. In which city should Oz Sourcing ask Domes to manufacture?
4. How much could Oz Sourcing save, if engaging Domes prove to be cost beneficial?

Discrete Facility Location Problems

Set Covering Problem

Transport times (in hours) between cities

	To -->							
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	0	9	10	12	14	15	14	16
2	9	0	11	10	14	12	18	15
3	10	11	0	8	8	9	11	13
4	12	10	8	0	9	8	11	10
5	14	14	8	9	0	8	8	10
6	15	12	9	8	8	0	9	8
7	14	18	11	11	8	9	0	8
8	16	15	13	10	10	8	8	0

	To -->							
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	0	9	10	12	14	15	14	16
2	9	0	11	10	14	12	18	15
3	10	11	0	8	8	9	11	13
4	12	10	8	0	9	8	11	10
5	14	14	8	9	0	8	8	10
6	15	12	9	8	8	0	9	8
7	14	18	11	11	8	9	0	8
8	16	15	13	10	10	8	8	0

- What is the minimum number of Fulfilment Centre (FC) needed, and in which cities should they be located such that each city is covered within 8 hours from an FC?

Mars Incorporated: Online Procurement

Mars Incorporated: Online Procurement

❑ Items in the auction (all items can be oversupplied)

- Mars display boxes
  - 1,000 large
  - 2,500 medium
  - 4,000 small
- M&M display boxes
  - 800 large
  - 1,500 medium
  - 2,500 small
- Snickers display boxes
  - 400 large
  - 750 medium
  - 1,200 small
- Musketeers display boxes
  - 100 large
  - 100 medium
  - 50 small

First Round Bids Received

- 1:05 pm. Supplier 1 bids $2,050 to supply all Mars display boxes
- 1:06 pm. Supplier 2 bids $350 to supply Snickers small display boxes
- 1:10 pm. Supplier 3 bids $1,199 to supply all large display boxes
- 1:11 pm. Supplier 1 bids $220 to supply Snickers large, and all 3 Musketeers display boxes
- 1:14 pm. Supplier 4 bids $4,639 to supply everything
- 1:20 pm. Supplier 2 bids $199 to supply 3 Musketeers medium and small display boxes
- 1:26 pm. Supplier 5 bids $1,199 to supply all M&M, and 3 Musketeers medium and small display boxes
- 1:35 pm. Supplier 6 bids $1,350 to supply Mars, M&M and 3 Musketeers small display boxes
- 1:40 pm. Supplier 3 bids $350 to supply Snickers medium display boxes

First Round Bids Received

- 1:41 pm. Supplier 7 bids $2,200 to supply Mars and M&M large and medium display boxes
- 1:52 pm. Supplier 2 bids $999 to supply M&M medium and small boxes
- 1:59 pm. Supplier 5 bids $1,700 to supply all small display boxes
- 2:00 pm. Auction first round closes

Combinatorial Auction: Winner Determination

	Bid ->	1	2	3	4	5	6	7	8	9	10	11	12
	Supplier ->	1	2	3	1	4	2	5	6	3	7	2	5
Brand	**Item**												
Mars Display Boxes	1,000 large	1		1		1					1		
Mars Display Boxes	2,500 medium	1				1					1		
Mars Display Boxes	4,000 small	1				1			1				1
M&M Display Boxes	800 large			1		1		1			1		
M&M Display Boxes	1,500 medium					1		1			1	1	
M&M Display Boxes	2,500 small					1		1	1			1	1
Snickers Display Boxes	400 large			1	1	1							
Snickers Display Boxes	750 medium					1				1			
Snickers Display Boxes	1,200 small		1			1							1
3 Musketeers Display Boxes	100 large			1	1	1							
3 Musketeers Display Boxes	100 medium				1	1	1	1					
3 Musketeers Display Boxes	50 small				1	1	1	1	1				1
Bid Price		2,050	350	1,199	220	4,639	199	1,199	1,350	350	2,200	999	1,700

Milk Collection

A small milk processing company in the county of Dublin, Ireland is committed to collecting milk from 20 farms and taking it back to the depot for processing. The company has one tanker lorry with a capacity for carrying 80,000 litres of milk. 11 of the farms are small and need a collection only every other day. The other 9 farms need a collection every day. The positions of the farms in relation to the depot (numbered 1) are given in the Table together with the collection requirements.

Milk Collection

Farm	Position 10 miles		Collection Frequency		Collection Requirement (1000 litres)
	East	North			
1	0	0	-	-	-
2	-3	3	Every	day	5
3	1	11	Every	day	4
4	4	7	Every	day	3
5	-5	9	Every	day	6
6	-5	-2	Every	day	7
7	-4	-7	Every	day	3
8	6	0	Every	day	4
9	3	-6	Every	day	6
10	-1	-3	Every	day	5
11	0	-6	Every	other day	4
12	6	4	Every	other day	7
13	2	5	Every	other day	3
14	-2	8	Every	other day	4
15	6	10	Every	other day	5
16	1	8	Every	other day	6
17	-3	1	Every	other day	8
18	-6	5	Every	other day	5
19	2	9	Every	other day	7
20	-6	-5	Every	other day	6
21	5	-4	Every	other day	6

Milk Collection

Find the two tours (one for every day and the other for every other day) for the tanker lorry with the minimum combined tour length.

Mining

A mining company is going to continue operating in a certain area for the next five years. There are four mines in this area but it can operate at most 3 in any given year. Although a mine may not operate in a certain year, it is still necessary to keep it 'open', in the sense that royalties are payable, should it be operated in a future year. Clearly, if a mine is not going to be worked again, it can be closed down permanently and no more royalties need be paid. The yearly royalties payable on each mine kept 'open' are:

Mine No.	Annual Royalty (in millions £)
1	5
2	4
3	4
4	5

Mining

There is an upper limit to the amount of ore which can be extracted from each mine in a year. These upper limits are:

Mine No.	Upper Limit (in million tonnes)
1	2
2	2.5
3	1.3
4	3

Mining

The ores from different mines are of varying quality. This quality is measured on a scale such that blending ores together results in a linear combination of the quality measurements. For example, if equal quantities of two ores were combined, the resultant ore would have a quality measurement half way between that of the ingredient ores. Measured in these units, the qualities of the ores from the mines are given below:

Mine No.	Quality of Ore
1	1.0
2	0.7
3	1.5
4	0.5

Mining

In each year, it is necessary to combine the total outputs from each mine to produce a blended ore of exactly some stipulated quality. For each year these qualities are:

Year	Stipulated Quality
1	0.9
2	0.8
3	1.2
4	0.6
5	1.0

Mining

The final blended ore sells for a profit (revenue minus variable cost) of £10 per ton each year. Revenue and expenditure for future years must be discounted at a rate of 10% per annum. Assume whatever is mined is sold in the same year, and that all cash flows happen at the beginning of a given year.

Which mines should be operated each year and how much should they produce?

Motorola Supplier Selection

As the world market for telecommunications underwent a massive downturn in the early 2000s, Motorola Inc. needed to cut costs and increase productivity throughout its operations. It had to identify a method of reducing the time and effort required to prepare for and conduct negotiations with its suppliers, simplify their coordination, and optimize contract awards across sectors, to save costs. Motorola's global procurement function selected Emptoris's end-to-end Internet negotiations platform. Combining innovative bidding, online supplier negotiations, and scenario-based optimization analysis, it identifies the best procurement strategy while enhancing supplier relationships. Sourcing over $16 billion and saving more than $600 million, including $200 million specifically driven by the platform's advanced capabilities, Motorola changed its supplier negotiation paradigm and moved to a truly global process

Metty et al., 2005. Reinventing the supplier negotiation process at Motorola. Interfaces, 35 (1), 7-23.

Motorola Supplier Selection

This problem is based on Motorola's online method for choosing suppliers. Suppose Motorola solicits bids from 5 suppliers for 8 products. The list price for each product and the quantity of each product that Motorola needs to purchase during the next year are listed in the Table below.

Product	1	2	3	4	5	6	7	8
List price	$87	$63	$96	$40	$98	$51	$83	$55
Motorola's next year Req.	592	446	548	647	245	797	603	401

Motorola Supplier Selection

Each supplier has submitted the percentage discount it will offer on each product, which is also listed below in the second Table. For example, supplier 1 offers a 7% discount on product 1 and a 30% discount on product 2.

		Supplier				
		1	2	3	4	5
Product	1	7%	22%	25%	34%	35%
	2	30%	18%	18%	31%	26%
	3	21%	30%	34%	12%	14%
	4	27%	29%	30%	60%	6%
	5	31%	25%	10%	13%	30%
	6	23%	32%	15%	60%	9%
	7	6%	21%	18%	60%	28%
	8	17%	18%	6%	8%	31%

Motorola Supplier Selection

- **The following considerations also apply:**
  - **There is an administrative cost of $5,000 associated with setting up a supplier's account. For example, if Motorola uses three suppliers, it incurs an administrative cost of $15,000.**
  - **To ensure reliability, no supplier can supply more than 80% of Motorola's demand for any product.**
  - **A supplier must supply an integer amount of each product it supplies.**

Motorola Supplier Selection

- **Determine (i) which suppliers to select; and (ii) how much of each product to purchase from the selected suppliers such that the total cost (sum of its purchase and administrative costs) incurred to completely meet the next year demand is minimized.**

Power Generation

A number of power stations are committed to meeting the following electricity load demands over a day:

Time of Day	Electricity Load (in Megawatts)
00:00 – 06:00	15,000
06:00 – 09:00	30,000
09:00 – 15:00	25,000
15:00 – 18:00	40,000
18:00 – 24:00	27,000

Power Generation

There are three types of generating unit available. Each generator has to work between a minimum and a maximum level (in Megawatts).

Generator Type	No. of Generators	Min. Level (Megawatts)	Max. Level (Megawatts)
1	12	850	2,000
2	10	1,250	1,750
3	5	1,500	4,000

Power Generation

Starting up a generator involves a cost. There is also an hourly cost of running each generator at its minimum level. In addition, there is an extra hourly cost for each megawatt at which a unit is operated above its minimum level. All this information is given in the table below

Generator Type	Starting Cost	Cost/ hour at Min. Generation Level	Cost/hour/megawatt above Min. Generation Level
1	2000	1000	2.0
2	1000	2600	1.30
3	500	3000	3.0

Power Generation

In addition to meeting the estimated load demands, there must be sufficient generators working at any time to make it possible to meet an increase in load of up to 15%. This increase would have to be accomplished by adjusting the output of generators already operating within their permitted limits.

Which generators should be working in which periods of the day to minimize total costs?

Sinofert Distribution

Province\Quantity	Market size (ton/year)	Sales Budget (ton/year)	Min Sales Qty (ton year)	Average Selling Prices (RMB)
Heilongjiang	13,00,000	2,20,000	1,50,000	1,917
Jilin	12,00,000	4,00,000	3,00,000	1,864
Liaoning	11,00,000	1,80,000	1,20,000	1,880
Hebei	30,00,000	2,00,000	1,00,000	1,798
Henan	60,00,000	2,10,000	2,00,000	1,787
Shandong	45,00,000	5,00,000	2,70,000	1,812
Jiangsu	45,00,000	4,50,000	2,00,000	1,866
Anhui	22,00,000	2,30,000	1,10,000	1,842
Hubei	26,00,000	2,00,000	1,00,000	1,837
Hunan	23,00,000	2,00,000	80,000	1,901
Jiangxi	15,00,000	2,70,000	1,80,000	1,915
Fujian	12,00,000	1,80,000	90,000	1,960
Guangdong	12,00,000	2,30,000	1,70,000	1,930
Guangxi	16,00,000	1,00,000	18,000	1,917
Total	**3,42,00,000**	**35,70,000**	**20,88,000**	

Exhibit 1

Sinofert Distribution

2010 Yearly Contract with Key Suppliers (include own factories production)					
Supplier\quantity	Maximum Capacity (ton/year)	Contract Qty (ton/year)	Minimum Qty (ton/year)	Remark	Average Manufacturing Price (RMB)
Sinofert Pingyuan	9,80,000	9,80,000	9,80,000	self production	1700
Sinofert Changshan	3,00,000	3,00,000	3,00,000	self production	1750
Shanxi Fengxi	9,00,000	3,00,000	1,00,000	Out sourcing	1650
Shandong Lian meng	10,00,000	3,50,000	2,00,000	Out sourcing	1720
Shandong Ruixing	10,00,000	3,00,000	2,00,000	Out sourcing	1700
Shandong Lunan	6,00,000	1,20,000	50,000	Out sourcing	1700
Henan Xinlianxin	10,00,000	3,00,000	2,00,000	Out sourcing	1700
Henan Pingdingshan	4,00,000	1,00,000	30,000	Out sourcing	1700
Jiangsu Linggu	10,00,000	4,50,000	3,00,000	Out sourcing	1750
Hebei Zhengyuan	6,00,000	1,20,000	60,000	Out sourcing	1700
Hebei Jinghua	3,00,000	1,20,000	60,000	Out sourcing	1700
Anhui Haoyuan	3,00,000	1,00,000	80,000	Out sourcing	1750
Neimenggu Erduosi	10,00,000	3,50,000	2,00,000	Out sourcing	1650
Totals	**93,80,000**	**38,90,000**	**27,60,000**		

Exhibit 2

Sinofert Distribution

Sinofert Pingyuan	Sinofert Changshan	Shanxi Fengxi	Shandong Lianmeng	Shandong Ruixing	Shandong Lunan	Henan Xinlianxin	Henan Pingdingshan	Jiangsu Linggu	Hebei Zhengyuan	Hebei Jinghua	Anhui Haoyuan	Neimeng Erduosi
54,171	0	13,533	14,610	30,000	30,000	13,920	0	0	13,920	0	0	50,456
44,143	2,92,479	6,189	3,780	20,000	10,000	16,080	0	0	14,640	4,860	0	14,280
49,886	0	9,344	9,900	12,000	0	25,920	0	0	18,004	4,500	0	28,140
15,574	0	31,291	0	10,000	20,000	0	0	0	30,132	47,892	0	39,060
18,926	0	67,792	0	10,000	10,000	24,360	50,000	0	0	0	0	18,032
4,98,726	0	5,000	1,03,860	20,000	10,000	0	0	0	0	5,754	0	47,880
76,900	0	19,920	44,280	10,000	0	27,000	0	2,48,024	0	4,848	0	0
84,857	0	21,351	36,360	5,000	5,000	0	0	0	0	4,500	31,410	21,000
6,886	0	51,656	0	30,000	0	600	20,000	0	2,192	0	0	0
17,634	0	51,440	8,100	20,000	0	7,000	0	0	10,560	0	0	0
17,426	0	12,960	5,040	10,000	0	29,260	0	0	14,160	0	0	0
33,600	0	726	7,020	0	40,000	0	0	0	0	0	42,750	31,080
22,229	0	4,152	6,498	0	0	14,652	0	0	15,200	0	8,700	52,983
9,514	0	0	5,220	0	0	2,400	0	0	0	0	0	8,400
9,50,471	**2,92,479**	**2,95,353**	**2,44,668**	**1,77,000**	**1,25,000**	**1,61,192**	**70,000**	**2,48,024**	**1,18,808**	**72,354**	**82,860**	**3,11,311**

Exhibit 3

Sinofert Distribution

Average Freight From Factory to Each Province Market

Supplier	Sinofert Pingyuan	Sinofert Changsha n	Shanx i Fengx i	Shandong Lianmeng	Shandong Ruixing	Shandong Lunan	Henan Xinlianxin	Henan Pingdingsha n	Jiangsu Linggu	Hebei Zhengyua n	Hebei Jinghua	Anhui Haoyuan	Neimeng Erduosi
Heilongjiang	119	70	129	136	145	119	185	143	164	120	108	151	155
Jilin	101	40	110	119	128	102	167	123	147	101	90	133	137
Liaoning	81	60	91	98	107	82	148	105	126	82	69	112	118
Hebei	45	100	45	64	73	47	105	58	92	40	32	69	75
Henan	83	130	39	85	77	49	84	22	81	70	69	46	59
Shandong	58	110	50	53	61	36	119	64	77	62	46	58	89
Jiangsu	67	150	56	72	65	31	117	54	44	74	57	46	84
Anhui	69	140	53	73	65	31	114	41	43	75	58	36	81
Hubei	96	150	56	98	90	60	109	39	77	86	82	61	85
Hunan	122	160	86	122	114	81	141	74	85	114	107	80	110
Jiangxi	114	160	88	115	107	72	153	70	66	114	100	71	110
Fujian	129	170	102	129	124	86	171	84	66	128	114	85	124
Guangdong	164	170	126	164	161	126	162	119	117	158	149	125	151
Guangxi	156	160	109	157	168	133	152	93	127	148	142	132	144

The freight from factory to specific province is average freight because there are different rate to different points in the province.

Exhibit 4

Mathematical Modeling for Managerial Decisions

Sachin Jayaswal

Indian Institute of Management Ahmedabad

sachin@iima.ac.in

Worker scheduling model

- A post office requires different numbers of full-time employees on different days of the week.

Day of Week	Min. no. of Workers Required
Monday	17
Tuesday	13
Wednesday	15
Thursday	19
Friday	14
Saturday	16
Sunday	11

- Union rules state that each full-time employee must work 5 consecutive days and then receive 2 days off.
  - For example, an employee who works Monday to Friday must have Saturday and Sunday off.

Rothstein, M. 1973. Hospital manpower shift scheduling by Mathematical Programming. Health Services Research, 8 (1), 60-66.

Objective

- Find a schedule that meets all daily workforce requirements with the minimum number of workers.

- For the time being, assume fractional workers are permitted.