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Supply Chain Management

BioPharma Case Study

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Table of Content

Abstract

This report is based on a paper on Production Capabilities Decision Making: Biopharama, Inc, StudyCase. By Dr. S. Rick Fernandezand & Dr. J. Pablo Betancur (Aug,2013).
It considers two companies from different countries participating in joint production to reduce some costs. The prospect of iterative integration of simulations creates a dynamic, in so far as the actions companies take today affect the cost and effectiveness of different actions soon. Repetitive interactions also facilitate the use of informal agreements, but through the ongoing value system of strategic network relationships. It is a transportation problem that requires a problem-solving approach to help in making appropriate decisions. It describes the optimal network agreement in this dynamic trading platform which points out that an optimal trading platform has a simple form regardless of the end period. The optimal trading platform may require companies to terminate their networks with a positive probability due to poor performance. Showing how process visibility, which allows companies to better gauge what's going wrong, can dramatically improve the performance of business networks. The mathematical model formulated has adopted the concept of the new capacitated transportation model because; the company's shipments are directly from a supply point to a demand point. The extent to which visibility of the deregulation process is prohibited regarding the nature of the moves: if the buyer's actions do not affect the dynamics, the need for termination is eliminated; otherwise, termination may be necessary for a business combination.

Introduction

Supply chain management (SCM) represents an effort by suppliers to develop and implement supply chains that are as efficient and economical as possible. Supply chains encompass everything from manufacturing to product creation, as well as the information systems required to coordinate these activities. It attempts to centrally control or link the production, shipment, and distribution of a product. Companies can decrease costs and deliver items to customers faster by optimizing the supply chain. This is accomplished by maintaining tighter control over internal inventories, internal manufacturing, distribution, sales, and company vendor stocks.

Biopharma is a global manufacturer of bulk chemicals used in the pharmaceutical industry. The company owns patents on two chemicals called Highcal and Relax in-house. The chemicals are used internally and are also sold to other drug manufacturers.

- The Japanese factory is the technology leader in the Biopharma network in terms of its ability to manage legal and environmental issues. Some developments from the Japanese plant have been carried over to other plants in the network.
- German factory leads in production capacity. Highest productivity in the global network.
- Brazil, India and Mexico factories are overwhelmed by technology and need to be updated.
- Stable market, only Asia without Japan forecast sales growth of 20% year over the next 5 years.

Two options are being seriously considered:

- Closing the Japanese factory
- Limit factory in Germany to a single chemical

Problem statement

BioPharma, Inc. which is owned by Phillip Landgraf faced several glaring problems in the financial performance of this company

- A sharp decline in profits.
- Very high costs at its plants in Germany and Japan.
- It has a surplus capacity in its global production network which overwhelms the company.

Objective

This is a special type of Linear Programming and capacitated facility location problem.

- To minimize the cost by using effective network model
- to satisfy the company's customers

Assumptions

We assume that,

- The plant capacity of production can be assigned to chemical as long as the plant is capable of purchasing both.
- The demand for the company's sales for the two products will be stable for all parts of the world, except for Asia without Japan.
- In the region of Asia without Japan, sales are expected to grow by 20% annually for five years consecutively before stabilizing.

	Highcal	Relax	Total	Capacity
Brazil - L. America	7.0	7.0	14.0	18
Germany - Europe	15.0	12.0	27.0	45
India - Asia(-Jpn)	5.0	3.0	8.0	18
Japan - Japan	7.0	8.0	15.0	10
Mexico - Mexico	3.0	3.0	6.0	30
US - US	18.0	17.0	35.0	22
Total Sales	55.0	50.0	105.0	143.0

Table 1: Sales by region and production/Capacity By plant of Highcal and relax in (Million Kilograms)

A preliminary examination of the facts presented above shed more light on the BioPharma issue. The company has six plants, one in each of the six regions. This creates a logistic supply chain structure. The system can help in reduction of transport costs and avoidance of import duties on products if they were to be imported from other regions. However, it has some drawbacks in that plants are often sized to fit local demand and do not attempt to fully leverage economies of scale.

If we look at the above Table 1, the capacity of six plants consolidated together equals 143,000 kilograms, while the total sales were 105,000 kilograms.
This imply that the six plants together had extra capacity for more customers totaling to
143,000 – 105,000 = 38,000 kilograms.

Nevertheless, demand for chemicals in Japan and the US appear to be greater than the plant capacities located in Japan and the US. Theoretically it is possible for the unmet demand in the regions to be supplied by other sources but at a risk of a rise of total cost due to transportation and tariffs.
Table 1 also shows that; the four plants of Brazil, Germany, India and Mexico supply below their specific capacities. The trend is more serious in Mexico and India whose sales equal to 20% and 44% of their capacities respectively. The actual data in Table 1 show that; the actual shipment plan of the company had a capacity utilization of more than 73%. The ratio may be encouraging, yet profitability depends more on the set up of the network flow system that can minimize the total transport costs. Thus, the optimal network flow model is required to cut down cost in the company.

Cost Structure

Fixed Cost

- Each plant incurs an annual fixed cost that is independent of the level of production in the plant.
- Each plant that can produce either Highcal or Relax also incurs a product related fixed cost that is independent of the quantity of each chemical produced.
- If a plant maintains the capability to produce a particular chemical, it incurs the corresponding product-related fixed cost even if the chemical is not produced at the plant.

Variable Cost

- The variable production cost of each chemical consists of four components. Raw materials, production costs, transportation costs and Import Duties.
- The variable production costs are incurred in proportion to the quantity of chemical produced and includes direct labor and scrap.
- Import Duties are driven only by the destination. Local production within each region is assumed to result in no import duty.
- Thus, production from Brazil, Germany and India can be sent to Latin America, Europe and the rest of Asia without Japan respectively, without incurring any import duties.

	Plant Fixed Cost (milliions $)	Highcal Fixed Cost (milliions $)	Relax Fixed Cost (milliions $)
Brazil	20	5	5
Germany	45	13	14
India	18	4	4
Japan	17	6	6
Mexico	30	6	6
U.S.	21	5	5

Table 2: Plant and Product Fixed Costs at each BioPharma Plant (US$)

CA_ij	HIGHCAL	Raw materials, Production and Transportation Costs (US$/Kg)					
Region		Latin America	Europe	Asia w/o Japan	Japan	Mexico	U.S.
Latin America	Brazil	8.9	9.15	9.2	9.2	9.1	9.15
Europe	Germany	11.35	11.1	11.25	11.3	11.2	11.2
Asia w/o Japan	India	8.6	8.45	8.3	8.4	8.6	8.55
Japan	Japan	11.9	11.8	11.7	11.5	11.85	11.85
Mexico	Mexico	9	8.9	9.1	9.05	8.8	8.85
U.S.	U.S.	9.05	8.9	9.05	9.05	8.85	8.8
CB_ij	**RELAX**	Raw materials, Production and Transportation Costs (**US$/Kg**)					
Region		Latin America	Europe	Asia w/o Japan	Japan	Mexico	U.S.
Latin America	Brazil	11.4	11.65	11.7	11.7	11.6	11.65
Europe	Germany	13.95	13.7	13.85	13.9	13.8	13.8
Asia w/o Japan	India	11	10.85	10.7	10.8	11	10.95
Japan	Japan	14.6	14.5	14.4	14.2	14.55	14.55
Mexico	Mexico	11.5	11.4	11.6	11.55	11.3	11.35
U.S.	U.S.	11.45	11.3	11.45	11.45	11.25	11.2

Table 3 : Variable Production cost at each Biopharma Plant (US$)

Table 2 and Table 3 summarizes the BioPharma company fixed costs, Raw materials, production, and transportation costs at different plants. The company costs fall into two main classes: Fixed and Variable costs. A fixed cost is the portion of the total cost that is independent of the production volume; this cost tends to remain irrespective of the production.

On the other hand, the variable cost is the portion of the total cost that depends on and varies with the production volume. The variable costs which depend on the volume produced and shipped to the demand regions can be minimized by use of the linear programming (LP) method.

Solution

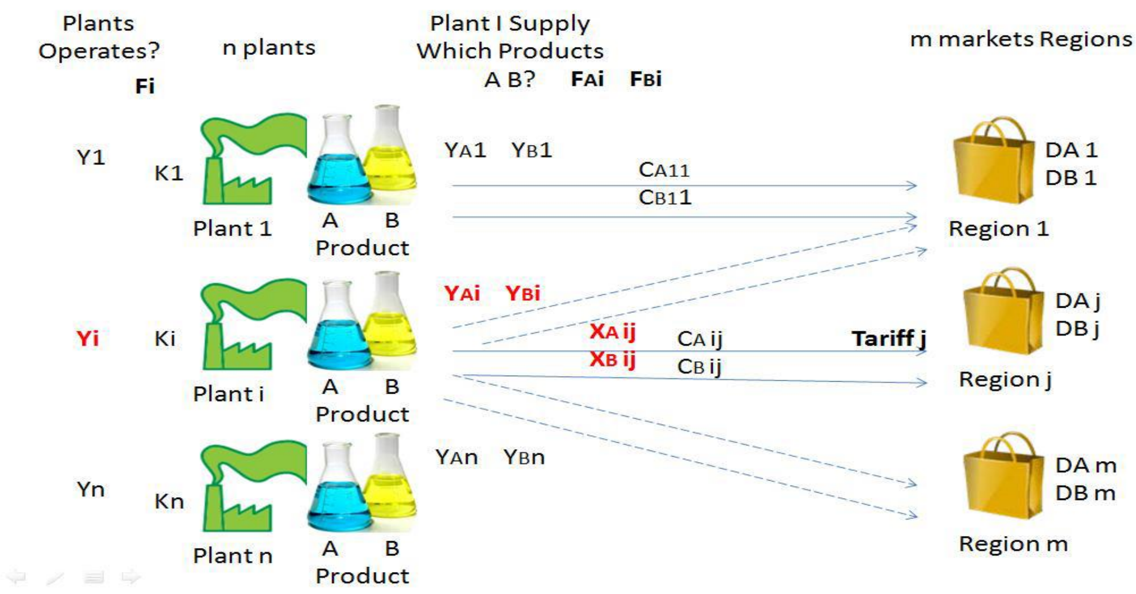

Figure 1: Model Diagram

The above figure shows the pictorial representation of the inputs and model formulation of this LP model

Inputs

I: index{1,2...5} corresponding to Plant i;

J: index {1...5} corresponding to market j in region;

A: Sub index that indicates product chemical Highcal;

B: Sub index that indicates product chemical Relax;

K_i**:** Capacity of Plants I (in million Kg);

F_i: Annualized fixed cost of keeping factory I open(in Million $US);

F_{Ai}: Annualized fixed cost related to idled for Produce A at factory I;

F_{Bi}: Annualized fixed cost related to idled for Produce B at factory I;

C_{Aij}: Cost of producing and shipping product A from factory i to market region j in $US/Kg;

C_{Bij}: Cost of producing and shipping product B from factory i to market region j in $US/Kg;

D_{Aj}: Annual demand of product A from market j (in million Kg);

D_{Bj}: Annual demand of product B from market j (in million Kg);

T_j: Tariff of import product A or B to market j (Duties apply only to raw material,production and transportation cost);

Decision Variables

X_{Aij}: Quantity of product of A shipped from plant i to market j (in million Kg);

X_{Bij}: Quantity of product of B shipped from plant i to market j (in million Kg);

Y_i: 1 if plant I is open, 0 otherwise;

Y_{Ai}: 1 if plant i is idled to produce product A, 0 otherwise ;

Y_{Bi}: 1 if plant i is idled to produce product B, 0 otherwise;

Model Formulation

Cost is divided into fixed cost and variable cost.

Fixed Cost

Closing down a plant, plant eliminates all variable costs and saves 80% of the annual fixed cost:

$$F_i * (0.2 + 0.8 * Y_i)$$

Produce only one chemical, the plant saves 80% of the fixed cost associated with that chemical:

$$F_{Ai} * (0.2 * Y_i + 0.8 * Y_{Ai}) + F_{Bi} * (0.2 * Y_i + 0.8 * Y_{Bi})$$

So, the total fixed cost is the sum of the 2 equation above:

$$\sum_{j \in J} (F_i * (0.2 + 0.8 * Y_i) + F_{Ai} * (0.2 * Y_i + 0.8 * Y_{Ai}) + F_{Bi} * (0.2 * Y_i + 0.8 * Y_{Bi}))$$

Variable Cost

Import duties are based on the regional trade agreements and the local production with each region is assumed to result in no import duty:

$$\sum_{j \in J} \Big(\sum_{\substack{i \in I \\ i \neq j}} C_{Aij} * X_{Aij} * \left(1 + T_j\right) + C_{Bij} * X_{Bij} * (1 + T_j) \Big)$$

Objective Function is sum of fixed cost and variable cost:

$$Z = \sum_{j \in J} \left(F_i * (0.2 + 0.8 * Y_i) + F_{Ai} * (0.2 * Y_i + 0.8 * Y_{Ai}) + F_{Bi} * (0.2 * Y_i + 0.8 * Y_{Bi}) \right)$$
$$+ \sum_{j \in J} \Big(\sum_{\substack{i \in I \\ i \neq j}} C_{Aij} * X_{Aij} * \left(1 + T_j\right) + C_{Bij} * X_{Bij} * (1 + T_j) \Big)$$

Constraints

1） Plant Capacity Constraint**:**

$$\sum_{j \in J} X_{Aij} + X_{Bij} \leq K_i * Y_i \quad for\ \forall i$$

2） Demand Constraint:

$$\sum_{i \in I} X_{Aij} = D_{Aj} \quad for\ \forall j$$
$$\sum_{i \in I} X_{Bij} = D_{Bj} \quad for\ \forall j$$

3) For secure X_{Aij} to be 0 when Y_{Ai}=0, and secure X_{Bij} to be 0 when Y_{Bi}=0

$$X_{Aij} \leq D_{Aj} * Y_{Ai} \quad for\ \forall i, j$$
$$X_{Bij} \leq D_{Bj} * Y_{Bi} \quad for\ \forall i, j$$

4) Other Constraints:

$$Y_i \leq Y_{Ai} + Y_{Bi} \quad for\ \forall i$$
$$Y_{Ai} \leq Y_i \quad for\ \forall i$$
$$Y_{Bi} \leq Y_i \quad for\ \forall i$$
$$X_{Aij}, X_{Bij} \geq 0\ for\ \forall i, j$$
$$Y_i, Y_{Ai}, Y_{Bi} \in [0,1] binary \quad for\ \forall i$$

Region	Plant	Capacity	Highcal		Relax	
			Sales	Production	Sales	Production
Latin America	Brazil	18	7	11	7	7
Europe	Germany	45	15	15	12	0
Asia W/O Japan	India	18	5	10	3	8
Japan	Japan	10	7	2	8	0
Mexico	Mexico	30	3	12	3	18
US	US	22	18	5	17	17

Table 4 : Sales by region and production

5) With Given Production the model

P_{Ai}: Production of A at plants I

P_{Bi}: Production of B at plants I

$$\sum_{j\in J} X_{Aij} = P_{Ai} * Y_{Ai} \quad for\ \forall\ i$$

$$\sum_{j\in J} X_{Bij} = P_{Bi} * Y_{Bi} \quad for\ \forall\ i$$

Results

There are 90 variables and 120 constraints.

1) Result in RStudio

````
{r}
solve(lpec1)
get.variables(lpec1)

```
````

```
[1] 0
 [1] 1.0e+00 1.0e+00 1.0e+00 1.0e+00 1.0e+00 0.0e+00 1.0e+00 1.0e+00 1.0e+00 1.0e+00 1.0e+00 0.0e+00 1.0e+00 1.0e+00 1.0e+00
[16] 1.0e+00 1.0e+00 1.0e+00 7.0e+06 7.0e+06 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 4.0e+06 0.0e+00
[31] 0.0e+00 0.0e+00 1.5e+07 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
[46] 0.0e+00 5.0e+06 3.0e+06 5.0e+06 5.0e+06 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00
[61] 2.0e+06 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 1.2e+07 0.0e+00 0.0e+00 0.0e+00 3.0e+06 3.0e+06
[76] 3.0e+06 9.0e+06 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 0.0e+00 5.0e+06 1.7e+07
```

The total cost of production

````
```{r}
get.objective(lpec1)/1000000+4+9+3.6+3.4+6+4.2
```
````

```
[1] 1314.193
```

Figure 2. Result in R

The total cost of production is nearly 1.3 trillion dollars.

2) Result in Excel

Because it ‘s very complex to read in RStudio, we created a table in Excel to clearly express the results of the optimal solution.
```

A	Latin American	Europe	Asia w/o Japan	Japan	Brazil	U.S.	Production	Y	YA
Brazil	7	0	0	0	0	4	11	1	1
Germany	0	15	0	0	0	0	15	1	1
India	0	0	5	5	0	0	10	1	1
Japan	0	0	0	2	0	0	2	1	1
Mexico	0	0	0	0	3	9	12	1	1
U.S.	0	0	0	0	0	5	5	1	1
Demand	7	15	5	7	3	18	55		
B	**Latin American**	**Europe**	**Asia w/o Japan**	**Japan**	**Brazil**	**U.S.**	**Production**	**Y**	**YB**
Brazil	7	0	0	0	0	0	7	1	1
Germany	0	0	0	0	0	0	0	1	0
India	0	0	3	5	0	0	8	1	1
Japan	0	0	0	0	0	0	0	1	0
Mexico	0	12	0	3	3	0	18	1	1
U.S.	0	0	0	0	0	17	17	1	1
Demand	7	12	3	8	3	17	50		

Table 5: Production Network

It can be seen from the table that the markets with high import tariffs are basically self-produced and sold, and the markets with low import tariffs adopt a combination of import and local production due to higher production costs.

Discussion

When the production for each plant is given in the model formulation, the result shows that the German plant is limited to only Product A and the Japan plant is also limited to Product A. Our solution for the minimal total cost is 1314.193 million dollars.

Our original model converts the paper model using R and gets the same result with it. In the following discussion part, we will show 3 plans. Plan 1 is suggested in the paper but without further explanation or calculation and we continue to work on that. Plans 2 and 3 are both proposed and calculated by ourselves.

Plan 1

We try to remove the production limitation in model formulation, and the result shows that there is no production done in the Japan plant and German plant is also limited to producing only product A. We made this decision as our Plan 1 which is exactly corresponds to the paper's suggestion (Shutting down the Japan plant and limiting the German plant to a single chemical). The paper mentioned in the Capacity Table that surplus capacity is noted only in Japan and German these 2 plants (Table), their extra room is 80% and 67%, respectively. Japan plant has many production abilities that is not used. So the paper has the above suggestion.

Plant	Capacity	Extra	Product A	Product B
Brazil	18	0	11	7
Germany	45	30	15	0
India	18	0	10	8
Japan	10	8	2	0
Mexico	30	0	12	18
U.S.	22	0	5	17
Total	143	38	55	50

Table 6: Plant Capacity

Our original model result shows Japan plant received supplies from India for both product A and product B, but the India plant has low capacity and cannot supply the Japanese market. For plan

1, Japan plant supplier is transferred mostly to German market because Japan plant is shut down and German plant still has much extra capacity.

After removing the production limitation, which is our plan 1, the total cost is 1287.455 million dollars which can save 2% compared to the original model formulation. This result table is shown in Table

A	Latin American	Europe	Asia w/o Japan	Japan	Brazil	U.S.	Production	Y	YA
Brazil	7	0	0	4	0	0	11	1	1
Germany	0	15	0	1	0	1	17	1	1
India	0	0	5	2	0	0	7	1	1
Japan	0	0	0	0	0	0	0	1	0
Mexico	0	0	0	0	3	17	20	1	1
U.S.	0	0	0	0	0	0	0	1	0
Demand	7	15	5	7	3	18	55		
B	Latin American	Europe	Asia w/o Japan	Japan	Brazil	U.S.	Production	Y	YB
Brazil	7	0	0	0	0	0	7	1	1
Germany	0	0	0	0	0	0	0	1	0
India	0	0	3	8	0	0	11	1	1
Japan	0	0	0	0	0	0	0	1	0
Mexico	0	7	0	0	3	0	10	1	1
U.S.	0	5	0	0	0	17	22	1	1
Demand	7	12	3	8	3	17	50		

Table7. Plan 1 Result

Table 3 summarizes the variable cost which includes raw materials, production and transportation costs for each plant, we notice that India plant looks the most cost effective for the Bio Pharma company.

Japan and German plant have high costs while low duties, as we can conclude from the 2 tables. At the beginning of the paper, it said Japan plant is a technology leader with the ability to handle regulatory and environmental issues. German plant is a leader for its production ability, and it had the highest yield within the global network. While India plant is technology outdated and needs an update. If some money can be invested in India plant, it can provide better output to feed other markets.

Latin America	Europe	Asia w/o Japan	Japan	Mexico	U.S.
30%	3%	27%	6%	35%	4%

Table 8: Import Tariffs

Plan 2

So, we are considering shutting down both Japan and German plants, at the same time transferring both Japan plant advanced technology and German plant production ability to India plant. In this way, India plant will have the updated technology and increase the production ability from 18 to 35 million kilograms. After modifying the model formulation, total cost is 1183.625 million dollars which can save 10% compared to the paper original model.

Plan 2 result is shown in Table. From the table, we can see that India can have a better output to regions in Europe, Asia and Japan.

A	Latin American	Europe	Asia w/o Japan	Japan	Brazil	U.S.	Production	Y	YA
Brazil	7	4	0	0	0	0	11	1	1
Germany	0	0	0	0	0	0	0	0	0
India	0	5	5	7	0	0	17	1	1
Japan	0	0	0	0	0	0	0	0	0
Mexico	0	6	0	0	3	18	27	1	1
U.S.	0	0	0	0	0	0	0	1	0
Demand	7	14	5	7	3	18	55		
B	**Latin American**	**Europe**	**Asia w/o Japan**	**Japan**	**Brazil**	**U.S.**	**Production**	**Y**	**YB**
Brazil	7	0	0	0	0	0	7	1	1
Germany	0	0	0	0	0	0	0	0	0
India	0	7	3	8	0	0	18	1	1
Japan	0	0	0	0	0	0	0	0	0
Mexico	0	0	0	0	3	0	3	1	1
U.S.	0	5	0	0	0	17	22	1	1
Demand	7	12	3	8	3	17	50		

Table 9. Plan 2 Result

Plan 3

Paper also mentioned the market is stable, only Asian region expects to grow in sales by 10% annually in the next 5 years. We changed a little to grow sales percentage because our model decision variables are integer. Product A grow 20% and production from 5 to 6(million kilograms). For product B grow 33%, production from 3 to 4(million kilograms). India plant's capacity will need to increase extra 2 capacity to meet the demand which is from 35 to 37 million kilograms. This time our plan 3 total cost is 1208.666 million dollars.

Plan 3 result is shown in Table. This time Asian market's total demand is from 8 to 10 million kilograms.

A	Latin American	Europe	Asia w/o Japan	Japan	Brazil	U.S.	Production	Y	YA
Brazil	7	3	1	0	0	0	11	1	1
Germany	0	0	0	0	0	0	0	0	0
India	0	6	5	7	0	0	18	1	1
Japan	0	0	0	0	0	0	0	0	0
Mexico	0	6	0	0	3	18	27	1	1
U.S.	0	0	0	0	0	0	0	1	0
Demand	7	15	6	7	3	18	56		
B	**Latin American**	**Europe**	**Asia w/o Japan**	**Japan**	**Brazil**	**U.S.**	**Production**	**Y**	**YB**
Brazil	7	0	0	0	0	0	7	1	1
Germany	0	0	0	0	0	0	0	0	0
India	0	8	3	8	0	0	19	1	1
Japan	0	0	0	0	0	0	0	0	0
Mexico	0	0	0	0	3	0	3	1	1
U.S.	0	4	1	0	0	17	22	1	1
Demand	7	12	4	8	3	17	51		

Table 10. Plan 3 Result

When it comes to recommending a solution to the company, we need to consider below major factors:

- Individual country's economic growth and government schemes.
- Mutual trade and business environment within countries and continents.
- Industrial growth in individual countries and plant location.
- Job opportunities, Labor law and wages all around plant locations
- Crude and non-conventional raw material prices and changing demands in the regions.
- Sales and marketing team and their analysis for future scope.

Conclusion

The report has outlined a transportation model and the mathematical model according to the paper that can be applied to minimize transportation total cost for the BioPharma Company. The mathematical model is linear programming formulated which we have learned in the Quantitative Management class to solve a transport problem.

After solving the paper's model formulation with R, the total cost is 1314.193 million dollars. We found the company needs to do some adjustments to save cost. Therefore, 3 plans were made in our discussion.

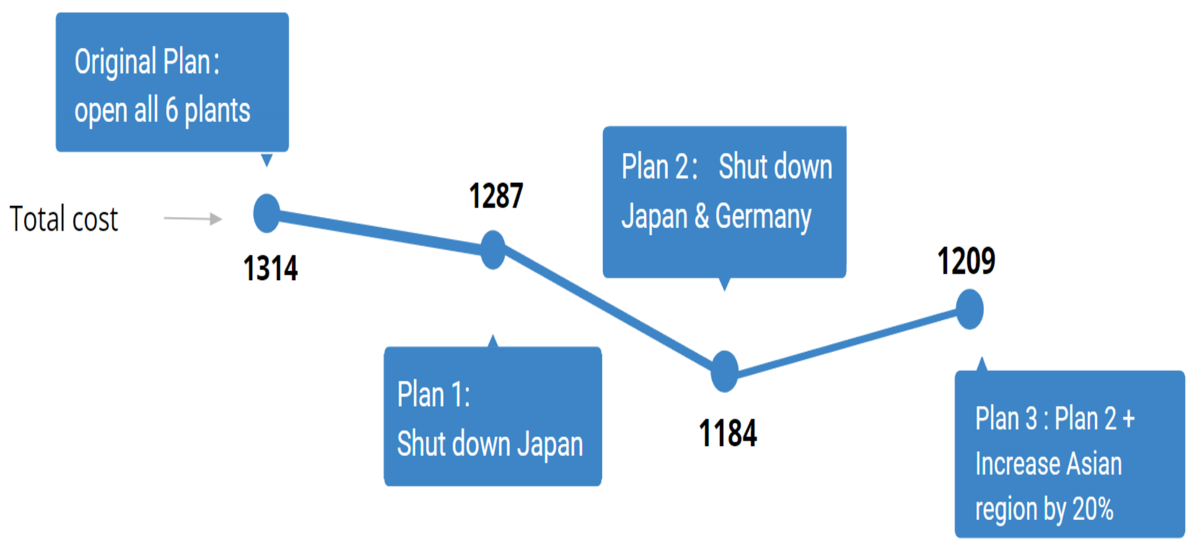

Figure 3. Plans Total Cost Comparison.

Total Cost	1314	1287	1184	1209
Total Production	105	105	105	107
India Capacity	18	18	35	37
Open Plants	6	5	4	4

Table 11 : Summary for various parameters.

The figure and table can show our main discussion results clearly. Including the paper's model formulation, we have 4 situations. First three productions are all 105, we transfer Japan's advanced technology and Germany's production ability to the India plant, which can help the company save 10% cost compared to the original plan.

When it comes to sales increasing for Asian market, we improve extra 2 capacities to the India plant to meet the demand. Total cost is estimated to be 1209 million dollars this time and compared to the original model, the total production has increased while total cost is declining.

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Appendix

Here, is the snapshot of LP file:

```
/* Objective function */
min: +18000000 Y1 +4000000 YA1 +4000000 YB1 +41400000 Y2 +10400000 YA2 +11200000 YB2 +16000000 Y3 +3200000 YA3
 +3200000 YB3 +16000000 Y4 +4800000 YA4 +4800000 YB4 +26400000 Y5 +4800000 YA5 +4800000 YB5 +18800000 Y6
 +4000000 YA6 +4000000 YB6 +8.9 XA11 +11.4 XB11 +9.4245 XA12 +11.9995 XB12 +11.684 XA13 +14.859 XB13
 +9.72 XA14 +12.402 XB14 +12.285 XA15 +15.66 XB15 +9.516 XA16 +12.116 XB16 +17.55 XA21 +18.135 XB21 +11.1 XA22
 +13.7 XB22 +14.2875 XA23 +17.5875 XB23 +11.978 XA24 +14.734 XB24 +15.12 XA25 +18.63 XB25 +11.648 XA26
 +14.352 XB26 +11.18 XA31 +14.3 XB31 +8.7035 XA32 +11.1755 XB32 +8.3 XA33 +10.7 XB33 +8.904 XA34 +11.448 XB34
 +11.61 XA35 +14.85 XB35 +8.944 XA36 +11.388 XB36 +15.47 XA41 +18.98 XB41 +12.154 XA42 +14.935 XB42 +14.859 XA43
 +18.288 XB43 +11.5 XA44 +14.2 XB44 +15.9925 XA45 +19.6425 XB45 +12.324 XA46 +15.132 XB46 +11.7 XA51
 +14.95 XB51 +9.167 XA52 +11.742 XB52 +11.557 XA53 +14.732 XB53 +9.593 XA54 +12.243 XB54 +8.8 XA55 +11.3 XB55
 +9.204 XA56 +11.804 XB56 +11.765 XA61 +14.885 XB61 +9.167 XA62 +11.639 XB62 +11.4935 XA63 +14.5415 XB63
 +9.593 XA64 +12.137 XB64 +11.9473 XA65 +15.1875 XB65 +8.8 XA66 +11.2 XB66;

/* Constraints */
U1: -18000000 Y1 +XA11 +XB11 +XA12 +XB12 +XA13 +XB13 +XA14 +XB14 +XA15 +XB15 +XA16 +XB16 <= 0;
U2: -45000000 Y2 +XA21 +XB21 +XA22 +XB22 +XA23 +XB23 +XA24 +XB24 +XA25 +XB25 +XA26 +XB26 <= 0;
U3: -18000000 Y3 +XA31 +XB31 +XA32 +XB32 +XA33 +XB33 +XA34 +XB34 +XA35 +XB35 +XA36 +XB36 <= 0;
U4: -10000000 Y4 +XA41 +XB41 +XA42 +XB42 +XA43 +XB43 +XA44 +XB44 +XA45 +XB45 +XA46 +XB46 <= 0;
U5: -30000000 Y5 +XA51 +XB51 +XA52 +XB52 +XA53 +XB53 +XA54 +XB54 +XA55 +XB55 +XA56 +XB56 <= 0;
U6: -22000000 Y6 +XA61 +XB61 +XA62 +XB62 +XA63 +XB63 +XA64 +XB64 +XA65 +XB65 +XA66 +XB66 <= 0;
U7: +XA11 +XA21 +XA31 +XA41 +XA51 +XA61 = 7000000;
U8: +XB11 +XB21 +XB31 +XB41 +XB51 +XB61 = 7000000;
U9: +XA12 +XA22 +XA32 +XA42 +XA52 +XA62 = 15000000;
U10: +XB12 +XB22 +XB32 +XB42 +XB52 +XB62 = 12000000;
U11: +XA13 +XA23 +XA33 +XA43 +XA53 +XA63 = 5000000;
U12: +XB13 +XB23 +XB33 +XB43 +XB53 +XB63 = 3000000;
+XA14 +XA24 +XA34 +XA44 +XA54 +XA64 = 7000000;
+XB14 +XB24 +XB34 +XB44 +XB54 +XB64 = 8000000;
+XA15 +XA25 +XA35 +XA45 +XA55 +XA65 = 3000000;
+XB15 +XB25 +XB35 +XB45 +XB55 +XB65 = 3000000;
+XA16 +XA26 +XA36 +XA46 +XA56 +XA66 = 18000000;
+XB16 +XB26 +XB36 +XB46 +XB56 +XB66 = 17000000;
-7000000 YA1 +XA11 <= 0;
-7000000 YB1 +XB11 <= 0;
-15000000 YA1 +XA12 <= 0;
-12000000 YB1 +XB12 <= 0;
-5000000 YA1 +XA13 <= 0;
-3000000 YB1 +XB13 <= 0;
-7000000 YA1 +XA14 <= 0;
-8000000 YB1 +XB14 <= 0;
-3000000 YA1 +XA15 <= 0;
-3000000 YB1 +XB15 <= 0;
-18000000 YA1 +XA16 <= 0;
-17000000 YB1 +XB16 <= 0;
-7000000 YA2 +XA21 <= 0;
-7000000 YB2 +XB21 <= 0;
-15000000 YA2 +XA22 <= 0;
-12000000 YB2 +XB22 <= 0;
-5000000 YA2 +XA23 <= 0;
-3000000 YB2 +XB23 <= 0;
-7000000 YA2 +XA24 <= 0;
-8000000 YB2 +XB24 <= 0;
-3000000 YA2 +XA25 <= 0;
-3000000 YB2 +XB25 <= 0;
-18000000 YA2 +XA26 <= 0;
-17000000 YB2 +XB26 <= 0;
-7000000 YA3 +XA31 <= 0;
```

Plants	XA_ij, Production Network(in million kg)						Production	Yi	YA_i
	Latin America	Europe	Asia W/O Japan	Japan	Mexico	US			
Brazil	7	0	0	0	0	4	11	1	1
Germany	0	15	0	0	0	0	15	1	1
India	0	0	5	5	0	0	10	1	1
Japan	0	0	0	2	0	0	2	1	1
Mexico	0	0	0	0	3	9	12	1	1
U.S	0	0	0	0	0	5	5	1	1
Demand(DA_j)	**7**	**15**	**5**	**7**	**3**	**18**	55		

Plants	XB_ij, Production Network(in million kg)						Production	Yi	YB_i
	Latin America	Europe	Asia W/O Japan	Japan	Mexico	US			
Brazil	7	0	0	0	0	0	7	1	1
Germany	0	0	0	0	0	0	0	1	0
India	0	0	3	5	0	0	8	1	1
Japan	0	0	0	0	0	0	0	1	0
Mexico	0	12	0	3	3	0	18	1	1
U.S	0	0	0	0	0	17	17	1	1
Demand(DB_j)	**7**	**12**	**3**	**8**	**3**	**17**	50	1	1

Fixed and Variable Production cost at each Biopharma Plant (US$)

	Plant	Highcal	Relax	Highcal		Relax	
	Fixed Cost (milliions $)	Fixed Cost (milliions $)	Fixed Cost (milliions $)	Raw Material ($/Kg)	Production cost ($/Kg)	Raw Material ($/Kg)	Production cost ($/Kg)
Brazil	20	5	5	3.6	5.1	4.6	6.6
Germany	45	13	14	3.9	7	5	8.5
India	18	4	4	3.6	4.5	4.5	6
Japan	17	6	6	3.9	7.5	5.1	9
Mexico	30	6	6	3.6	5	4.6	6.5
U.S.	21	5	5	3.6	5	4.5	6.5

Transportation Costs from plants to markets (US$/Kg)

	Latin America	Europe	Asia w/o Japan	Japan	Mexico	U.S.
Brazil	0.2	0.45	0.5	0.5	0.4	0.45
Germany	0.45	0.2	0.35	0.4	0.3	0.3
India	0.5	0.35	0.2	0.3	0.5	0.45
Japan	0.5	0.4	0.3	0.1	0.45	0.45
Mexico	0.4	0.3	0.5	0.45	0.2	0.25
U.S.	0.45	0.3	0.45	0.45	0.25	0.2

Import Tariffs (Percent of Values of Product Imported, Including Transportation)

Latin America	Europe	Asia w/o Japan	Japan	Mexico	U.S.
30%	3%	27%	6%	35%	4%

History of Exchange Rates in Currency/US$1(at the Beginning of each year)

	Brazilian real	Euro	Indian Rupee	Japanese Yen	Mexican Peso	U.S, Dollar
2005	2.7	0.74	43.47	103.11	11.21	1
2004	2.9	0.8	45.6	107	11.22	1
2003	3.5	0.96	48	119.25	10.38	1
2002	2.3	1.11	48.27	131.76	9.12	1
2001	1.95	1.06	46.75	114.76	9.72	1
2000	1.81	0.99	43.55	102.33	9.48	1