**Kent State University**

Logo

Description automatically generated

**MIS-64018: Quantitative Management Modeling**

**Fall 2021**

**Supply Chain Management**

**BioPharma Case Study**

**Submitted By:**

**Yanxi Li**

**Jiahao Chen**

**Jayasri Maditati**

**Khushboo Yadav**

**(Group 4)**

**Table of Content**

[**Abstract** 3](#_Toc90460781)

[**Introduction** 3](#_Toc90460782)

[**Problem statement** 5](#_Toc90460783)

[**Assumptions** 5](#_Toc90460784)

[**Cost Structure** 7](#_Toc90460785)

[**Fixed Cost** 7](#_Toc90460786)

[**Variable Cost** 7](#_Toc90460787)

[**Solution** 9](#_Toc90460788)

[**Inputs** 9](#_Toc90460789)

[**Decision Variables** 10](#_Toc90460790)

[**Model Formulation** 10](#_Toc90460791)

[**Variable Cost** 11](#_Toc90460792)

[**Constraints** 11](#_Toc90460793)

[**Results** 13](#_Toc90460794)

[**Conclusion** 20](#_Toc90460795)

[**References** 22](#_Toc90460796)

[**Appendix** 23](#_Toc90460797)

# **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](https://www.investopedia.com/terms/d/distribution-management.asp). 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.

**Table

Description automatically generated**

**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.

**Table

Description automatically generated**

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

**Table

Description automatically generated**

**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**

**Diagram

Description automatically generated**

**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;

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

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

FAi: Annualized fixed cost related to idled for Produce A at factory I;

FBi: Annualized fixed cost related to idled for Produce B at factory I;

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

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

DAj: Annual demand of product A from market j (in million Kg);

DBj: Annual demand of product B from market j (in million Kg);

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

## **Decision Variables**

XAij: Quantity of product of A shipped from plant i to market j (in million Kg);

XBij: Quantity of product of B shipped from plant i to market j (in million Kg);

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

YAi: 1 if plant i is idled to produce product A, 0 otherwise ;

YBi: 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:

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

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

Description automatically generated with medium confidence

### **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:Shape

Description automatically generated with medium confidence

Objective Function is sum of fixed cost and variable cost:

Shape

Description automatically generated with medium confidence

### **Constraints**

1）Plant Capacity Constraint**:**

**Shape

Description automatically generated with medium confidence**

2）Demand Constraint:

**Shape

Description automatically generated with medium confidence**

**Shape

Description automatically generated with medium confidence**

3) For secure XAij to be 0 when YAi=0, and secure XBij to be 0 when YBi=0





4) Other Constraints:

**Shape

Description automatically generated with medium confidence**

**Table

Description automatically generated**

**Table 4 : Sales by region and production**

5) With Given Production the model

**PAi**: Production of A at plants I

**PBi**: Production of B at plants I

Shape

Description automatically generated with medium confidence

# 

# **Results**

There are 90 variables and 120 constraints.

1. **Result in RStudio**

A picture containing text

Description automatically generated

The total cost of production

Graphical user interface, application

Description automatically generated

**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.

Table

Description automatically generated

**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.

Table

Description automatically generated

**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

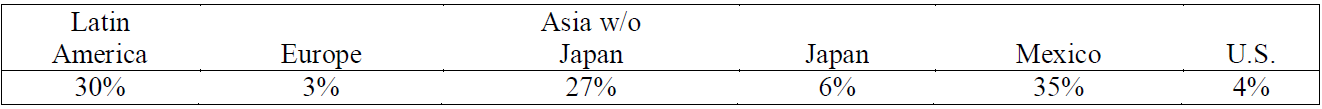
Table

Description automatically generated

**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.

****

**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.

**Table

Description automatically generated with medium confidence**

**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.

**Table

Description automatically generated**

**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.

Diagram

Description automatically generated

**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.

# **References**

Dr. S. Rick Fernandezand & Dr. J. Pablo Betancur (Aug,2013). Production Capabilities Decision Making: Biopharama, Inc, StudyCase.

<http://www.ijhssnet.com/journals/Vol_3_No_16_Special_Issue_August_2013/29.pdf>

<https://www.cnbc.com/2021/10/18/supply-chain-chaos-is-hitting-global-growth-and-could-get-worse.html>

<https://financesonline.com/supply-chain-trends/>

<https://www.hollingsworthllc.com/facts-about-supply-chain-and-logistics-2/>

<https://www.cips.org/knowledge/procurement-topics-and-skills/supply-chain-management/what-is-a-supply-chain/>

<https://supplychaindigital.com/supply-chain-2/what-supply-chain-definitive-guide>

# **Appendix**

Here, is the snapshot of LP file:

Text

Description automatically generated

Table

Description automatically generated

Table

Description automatically generated

Table

Description automatically generated

Table

Description automatically generated