MIT SCALE RESEARCH REPORT

The MIT Global Supply Chain and Logistics Excellence (SCALE) Network is an international alliance of leading-edge research and education centers, dedicated to the development and dissemination of global innovation in supply chain and logistics.

The Global SCALE Network allows faculty, researchers, students, and affiliated companies from all six centers around the world to pool their expertise and collaborate on projects that will create supply chain and logistics innovations with global applications.

This reprint is intended to communicate research results of innovative supply chain research completed by faculty, researchers, and students of the Global SCALE Network, thereby contributing to the greater public knowledge about supply chains.

For more information, contact
MIT Global SCALE Network

Postal Address:
Massachusetts Institute of Technology 77
Massachusetts Avenue, Cambridge, MA 02139 (USA)

Location:
Building E40, Room 267
1 Amherst St.

Access:
Tel: +1 617-253-5320
Fax: +1 617-253-4560

Email: *scale@mit.edu*
Website: *scale.mit.edu*

Research Report: ZLC-2005-12
Strategic Network Design in China Using a Hierarchical Decision Making Framework
Min Su

For Full Thesis Version Please Contact:
Marta Romero
ZLOG Director
Zaragoza Logistics Center (ZLC) Edificio
Náyade 5, C/Bari 55 – PLAZA 50197
Zaragoza, SPAIN
Email: mromero@zlc.edu.es
Telephone: +34 976 077 605

Strategic Network Design in China Using a Hierarchical Decision Making Framework

Executive Summary

Strategic network design decisions are of the most important supply chain management decisions due to their long-term planning horizon, large scale of capital investment and significant impact over other low-level supply chain management decisions. The thesis aims to develop a hierarchical decision-making framework for the strategic network design, and to apply for this framework to manufacturers in China. We specifically focus on the modeling part of this hierarchical decision making progress. Three types of network design decisions are discussed in this thesis, facility location decisions, capacity allocation decisions, and shipment allocation decisions.

This thesis assumes a Chinese PC manufacturer, which has five sales regions in China: East, South, West, North, and Middle. In each region the manufacturer can place two distribution centers or a central transportation center (CTC), and has four cities to serve. The manufacturer has three potential sites to locate its plants: Beijing, Shanghai, and Shenzhen. Considering the population distribution in China, we assume that North, East, and South regions have high demand and the other two have relatively low demand.

The first decision is to define the facility locations, which in this case are the plant locations. A Mixed Integer Programming (MIP) model is developed to solve this problem. When defining the facility locations, we focus on the plant's fixed costs and variable costs because these two costs exist over the entire decision horizon. We ignore the capacity cost at this stage because capacity cost normally is a smaller investment compared to fixed cost of building and maintaining a plant.

The second decision to be made is the long-term capacity decision. After defining the facility locations, the manufacturer can start to design the long term capacities for each plant. The planning horizon used here is 6 years. We introduce the concepts of expected net present value (ENPV) and ideal capacity. The ideal capacity represents the output of the plant when it has no capacity constraints. Using the MIP model employed previously, we can easily determine the ideal capacity for each plant.

The objective of the second decision is to find a set of capacities which can maximize the ENPV of the network over the 6 years. The manufacturer faces two possible scenarios in China: one is the demand disparity in regions; the other is the development of the 3PL industry in China.

The first scenario assumes that each region has its own demand increase rate. The region can have either a high demand increase or a low demand increase with certain probabilities. Both the demand increase rates and the probabilities are constant for the next five years.

We can use a "tree" structure to list all the possible demands and their probabilities for each year. Having the possible demands and their probabilities, we can calculate the expected demand for every year. The expected profit for each year can be

MIT ZA RAGOZA
International Logistics Program

determined by using the MIP model with the expected demand in those years, and the capacity available.

We can solve this problem by performing a simulation analysis. We start from the ideal capacity in Year 0, which is the minimum possible capacity, and end in the ideal capacity in Year 5, which is the maximum possible capacity. The result proves that the optimal capacity is between the ideal capacity in Year 0 and Year 5. The value of the optimal capacity depends on the value of the capacity cost and the discount rate.

Another scenario for the second decision is the development of 3PL industry in China. We assume that in Year 0 all the local cities can only be served by the local distribution center or center transportation centers. Every year, due to the development of 3PL industry, there exists the probability that one DC/CTC can serve the cities in other regions or one city can be served by DC/CTC in other regions. We investigate how to design the long-term capacity for our manufacturer taking this condition into account using the concept of ENPV. We split the ENPV of each plant into fixed ENPV and variable ENPV. The fixed ENPV is defined as the ENPV that the plant can get from certain cities, which will not be disrupted by 3PL industry in China. The variable ENPV is defined as the ENPV of the plant which will be disrupted by 3PL industry in China. Using this concept, the manufacturer can divide its capacity into fixed capacity and variable capacity. We employ a simulation analysis to solve this problem.

After defining the plant locations and long-term capacity, we address the short-term capacity decisions.

The short-term capacity is planned for one year or less to supplement the shortfalls of the long-term capacity decisions. In the long-term capacity decision, all the data used are aggregated, but in the short-term, these data need to be disaggregated and the uncertainty data has to be considered.

This thesis addresses two typical scenarios the manufacturer may face when it makes its short-term capacity decisions in China. One is the stochastic demand; the other is the energy shortage. The first scenario represents the stochastic factors of the market, which may cause either excess or shortage of long-term capacity. Short-term capacity can help manufacturers to capture the expected profit. The optimal levels of capacity are determined by employing simulation analysis

Besides capturing the expected profit, another function of short-term capacity is to mitigate the risk. Under the second scenario, we analyze how the excess capacity helps the manufacturer minimize the loss when it encounters the energy shortage problem. We assume that the Shanghai plant has an energy problem, thus it may not completely use its available capacity. We calculates the unit profits of all the markets served by Shanghai and examines the effects if these markets were served by the other two plants, and the resulting net loss.

After defining the plant location, long-term capacity and short-term capacity, we know exactly the capacity and location for each node on the network. Using the MIP model, we can easily solve the market allocation problem. Here the capacity is not

unlimited, but the sum of long-term capacity and short-term capacities at this point of time.

This thesis introduces a hierarchical decision-making framework for strategic network design and illustrates this framework of a realistic example from the Chinese PC manufacturer. Plant location is the most important decision. The long-term capacity decision is designed after the plant location decision is made. We simulate two typical scenarios in China, demand disparities, and the development of the 3PL industry. Scenario planning, dynamic analysis and expected net present value are implemented to solve the long-term capacity decisions. A short-term decision is subsequent to the long term decision. Excess capacity can be used to capture expected profit and mitigate risk, giving the manufacturer excess capacity to have additional operational flexibility.