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THE DESIGN OF CEMENT DISTRIBUTION NETWORK IN MYANMAR: A CASE STUDY OF “X” CEMENT INDUSTRY

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Declare that both partial and entire contents of my thesis entitled:

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Are a complete independent work of mine, completed without using any illegal information, nor the work of others that I recognize as my own work.

All cited and referred references are listed in the bibliography.

If it turns out that this statement is not true, I am willing to accept the penalties as provided by the law.

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Sincerely yours,

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ABSTRACT

The network design problem is one of the most comprehensive strategic decision issues that need to be optimized for the long-term efficient operation of whole supply chain. The problem treated in this thesis is a capacitated location allocation planning of distribution centers for the distribution network design. The distribution network in this research is considered from plants to distribution centers and distribution centers to demand points. The research will explore the optimal number and locations of cement distribution center of “X” cement industry in Myanmar. The Mixed Integer Linear Programming (MILP) was developed as a tool to solve optimization problem which involves 3 manufacturing plants, 6 distribution centers and 6 m arket regions. The data collection was done by the company. The (MILP) model provides useful information for the Company about which distribution centers should be opened and what would be the best distribution network in order to maximize profit while still satisfies the customers’ demand. In this study, we proposed three scenarios which are scenario two, six and eight. In all scenarios, the solution was to have only two distribution centers from Mandalay and Meikhtila markets are recommended to open in the distribution network.

Keywords: distribution network design, mixed integer linear programming, optimization problem, Supply chain

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CHAPTER 1

INTRODUCTION

1.1 Background

Supply chain is a process of obtaining raw materials, producing a product from raw materials to finish goods and then delivering them to end-user. A supply chain network is divided into three stages including supplier stage, plant stage and distribution stage (Erenguc, Simpson & Vakharia, 1999). Supplier stage is related to acquiring raw materials and other related materials from different sources supplying to the plants. Plant stage transformed raw materials to finish goods. Distributing finished products to the customer is the final stage in the supply chain. Distribution stage will be the area of concern in this research.

Chopra (2001) explained about distribution in his paper. Distribution refers to the steps taken to move and store a product from the supplier stage to a customer stage in the supply chain. Distribution is a key driver of the overall profitability of a company because it directly impacts both the supply chain cost and the customer experience. Good distribution can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness. As a result, companies in the same industry often select very different distribution networks.

Logistics Management council defined logistics management is the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements (Simchi-Levi, 2004). Because of growing interest in supply chain management, recently logistics has acquired great significance in industry (Syam, 2002). Logistics involves in stages of supply chain since logistics integrates and manipulates procedures in placing of the right products into the right places at the right time with enhancing of information technology (Pitaksringkarn & Taylor, 2004). Generally costs are automatically taken into account in every logistic component when processes and services occurred. The effective integration of logistics cost components such as transport costs with facility location models could affect the entire supply chain because the two are highly interrelated in practice (Syam, 2002). The quality of logistics processes can be affected from locations of facilities and allocation of demand/supply in the supply chain configuration.

The concept of facility location and capacity allocation models can be obtained from the book (Chopra & Meindl, 2007). The book e xplained that locating facilities and allocating capacity should be to maximize the overall profitability of the resulting supply chain network while providing customers with the appropriate responsiveness. Establishing many facilities to serve local markets reduce transportation cost and provides a fast response time, but it increases the facility and inventory costs incurred by the firm. These models are used to decide on locations and capacities of each facility by considering a time horizon (typically in years) and to assign current demand to the available facilities and identify lanes along which product will be transported.

Daskin (2003) proposed in his research paper facility location in supply chain design. Location decisions may be the most critical and most difficult of the decisions needed to realize an efficient supply chain. Transportation and inventory decisions can often be changed on relatively short notice in response to changes in the availability of raw materials, labor costs, component prices, transportation costs, inventory holding costs, exchange rates and tax codes. Of course, facility location decisions are fixed and difficult to change in intermediate term. Establishing distribution centers with handling equipments are very expensive and impossible to shut down in short term. In a competitive facility location model, in order to maximize market share, facilities attempt to serve as many customers as possible. Therefore, the main objective of any industrial site location–allocation analysis is to select a certain number of optimum locations to place facilities, and then allocate customers to each of them (Sule, 2001).

1.2 Research Gap

The research goal is to determine the optimal number and location of distribution centers. Distribution network design is a strategic decision that has a long-lasting effect on the firm. The objective of network design is to minimize annual system wide cost, including production and purchasing costs, inventory holding costs, distribution center storage costs and fixed costs, and transportation costs (Simchi-Levi, 2004).

In the case of distribution network design, it has been discovered that most studies considering on single period. For example, Yao (2010) proposed multi-source facility location–allocation and inventory problem. The problem is to determine number and locations of warehouses, allocation of customers demand and inventory levels of warehouses. The problem is formulated as a mixed integer nonlinear programming problem. Eskigun et al. presented the design of a SC distribution network considering lead time, location of distribution facilities and choice of transportation mode. These two papers are considered on single period that based on annual basis. However, in reality demands and inventory can change weekly, monthly or seasonally. It depends on the types of product and condition of market. So, considering single period is not enough for the network design problem.

Golmohammadi (2010) presented a heuristic approach for designing a distribution network in a supply chain system. The aim of this research is to determine the location of production plants and distribution warehouses**.** Inventory is not considered in that research. Most of researches have to consider inventory only in the plant site. In reality, we need to consider inventory the whole distribution network.

In this research, we will consider for distribution network design of cement industry. Cement demands in our research area depends on construction projects. There are three seasons in our research area in a year. In the rainy season, construction projects have to stop. So, the demand in the rainy season is lower than summer and winter seasons. The research will be considered three periods in a year. Inventories also are considered in all plants, distribution centers and demand points. Thus, the research will be more perfect than pervious researches.

1.3 The Company

"X" cement industry is situated in the central Myanmar near Kyaukse Township, 37 miles from Mandalay, the second largest city in Myanmar. The first production line was a 400tpd wet-process plant; the second production unit was a 700tpd dry-process line. These two plants began its operation in 2002. Cement demand was increased year by year in last decade. So, The Company constructed plant (3) in the same region in 2014. It has the capacity to make 1,200 tones of cement a day.

The company has four market regions which have six demand points as shown in Figure 1.1.There are seven competitors in the same market regions. According to supply and estimated demand balance of market regions in 2016 as shown in Table 1.1 and Table 1.2, the product will be shortage in the markets. The company sends the product directly to the demand points from the warehouse in the plants. The company has to face high transportation costs, long lead times and low customer service. So, the current distribution system of the company is not good. The company also has a plan to increase production capacity and establish distribution centers. So, the company needs to design for distribution network in order to reduce transportation costs and provide customers with a fast response time.

1.4 Statement of the Problem

Supply chain network design is a strategic decision. It has a long-term impact on the supply chain's performance especially manufacturing company.

The important decision in distribution network is the location of distribution centers in relation to a plant or supplier and the customer. A good distribution network is related to the location of distribution centers and how to connect the manufacturing plant or supplier and respective downstream customers. In a good quality distribution network, the location of distribution centers are directly impacts the productivity and profitability of the supply chain. Location-allocation model determines how many distribution centers to locate, where to locate the opened distribution centers, what capacity level to consider for each of them, and how to allocate customers to them. The problem treated in this thesis is capacitated location allocation planning of distribution centers for the distribution network design. This involves location planning of distribution centers and customer allocations considering facility opening costs, inventory costs and distribution costs to customers under given capacity constraints of distribution centers and customer demands.

1.5 Research Questions

The research will solve the following questions.

1. How many cement distribution centers should be established in “X” cement industry?
2. Where are the locations of cement distribution centers in research area?
3. Which demand points are covered by which distribution centers?

1.6 Research Objectives

The main objective is to get the maximum profit by considering distribution network design. The research will also have the following objectives to succeed main objective.

- To determine the optimal number of cement distribution centers of “X” cement industry.

- To determine where to locate the cement distribution centers of “X” cement industry.
- To determine which demand points are covered by which distribution centers.

1.7 Research Significance

The cement distribution centers in Myanmar had not yet designed seriously. First and foremost this study adds a well understanding of the distribution network design in the supply chain concepts and how to design cement distribution in Myanmar cement market. The research will provide a better situation of distribution network design for the company to improve the development and get ready for competitive market. If the research is successful, the other manufacturing companies can use this concept for their distribution network design. Transportation costs, lead time and product prices will be reduced. So, not only the company but also the customers will get benefit from this research.

1.8 Outline of Thesis

The research will be organized into six chapters. Chapter 1 introduces the reader to the research background, statement of the problem and objective of research. Chapter 2 is dedicated to literature review of previous literature on the topic in question. Data collection and model development will be explained in Chapter 3 and chapter 4. Chapter 5 will analyze the results and compare scenarios. Finally, Chapter 6 will give result suggestions and opportunities for further research.

Figure1. 1 Market Regions of “X” cement Industry

Table1.1 Cement Supply of "X" Cement Market Regions in 2016

Cement Supply	
Cement plant	Capacity (tpd)
MCI (Kyaukse)	500
Elephant	600
Sin Minn	1600
YCDC	500
Htoo Group	1250
NCDC	500
Max	500
Thayet	1200
Total Capacity	6650

Table1.2 Cement Supply-Demand Balance in “X” Cement Market Regions (2016)

Supply- Demand Balance (2016)	
Estimated demand	2757800 (tpy)
Supply	1965000 (tpy)
Shortage	792800 (tpy)

CHAPTER 2

LITERATURE REVIEW

2.1 Facility Location and Supply Chain Management

In this section, we will make review relationship between facility location and supply chain management. Facility location models play an important role in supply chain planning. Typically, three planning levels are distinguished depending on the time horizon: strategic, tactical and operational (Bender, 2002). Simchi-Levi et al. (2004) state that "the strategic level deals with decisions that have a long-lasting effect on the firm; these include decisions regarding the number, location and capacities of warehouses and manufacturing plants, or the flow of material through the logistics network". This statement establishes a clear link between location models and strategic supply chain management.

The rapid developments of information technologies and economic activities have led to shorter product life cycles, smaller lot sizes and dynamic customer behavior in terms of preferences. These aspects have contributed to growing demand uncertainty and supply chain network design has become more important. According to Teo and Shu (2004), "in today's competitive market, a company's distribution network must meet service goals at the lowest possible cost. In some instances, a co mpany may be able to save millions of dollars in logistics costs and simultaneously improve service levels by redesigning its distribution network. To achieve this, an ideal network must have the optimum number, size, and location of warehouses to support the inventory replenishment activities of its retailers". This statement calls for sophisticated facility location models to determine the best supply chain configuration.

Facility location and supply chain aspects could be taken into account in an iterative manner. The approach followed by Talluri and Baker (2002) is such an example of non-integrated decision-making in supply chain network design:

first, the candidate locations are selected and next, the corresponding transportation problem is solved. Since the two problems are solved separately, they do not fulfill the requirements of supply chain management to find a global optimal network configuration.

2.2 Distribution Network Design in the Supply Chain

Simchi-Levi (2004) clarified that network design is a strategic decision that has a long-lasting effect on the firm. It involves decisions relating to plant and warehouse location as well as distribution and sourcing. The objective of network design is to minimize annual system wide cost, including production and purchasing costs, inventory holding costs, distribution center storage costs and fixed costs, and transportation costs, ex posed t o a v ariety of service-level requirements. There are many trade-offs during network design. For example establishing many distribution centers to close local markets reduce transportation costs and provide high customer services in terms of fast response time but it increases facility and inventory holding costs. The company must balance the advantage of being closer to customer and high customer services, and the costs of establishing new distribution center. Thus, distribution center location decision is an essential component of supply chain strategy.

Chopra (2001) explained a framework for designing the distribution network in a supply chain. Changing the distribution network design affects on inventories, transportation, facilities and handling costs. As the number of facilities in supply chain increases, the inventory and resulting inventory costs also increases. As long as inbound transportation economies of scale are maintained, increasing the number of facilities decreases total transportation costs. If the number of facilities is increased to a point where there is a significant loss of economies of scale in inbound transportation, increasing the number of facilities increases total transportation cost. Total logistics costs are the sum of inventory, transportation, and facility costs for a supply chain network. The company should have at least the number of facilities that minimize total logistics costs. As the company wants to reduce the response time to its customers, it may have to increase the number of facilities beyond the point that minimizes logistics costs. The company should establish new facilities beyond the cost- minimizing point only if managers are confident that the increase in revenues because of better responsiveness is greater than the increase in costs because of opening the new facilities.

Network design belongs to the strategic planning level and involves decision concerning the number, location; capacity and technology of facilities (see Ghiani, Miller, Shapiro, Santoso). Network design models are used to decide on locations where facilities will be established and the capacity to be assigned to each facility. Supply chain network design deals with a variety of decisions such as determining number, size and location of facilities in a supply chain and may include tactical decisions (such as distribution, transportation and inventory management policies) as well as operational decisions (such as fulfilling customers demand) (Farahani, 2014).

After mentioning some important reviews on SC network design problem, we present a review of the several relevant papers in the following. In our review, we focus especially on the papers that develop or consider linear deterministic SC network design models. . Geoffrion and Graves (1974) present a new method for the solution of the problem addresses the optimal location of distribution centers between plants and customers. Jayaraman (1998) studies the capacitated warehouse location problem that involves locating a given number of warehouses to satisfy customer demands for different products. They applied to the model a primal decomposition technique similar to Geoffrion and Graves'. Pirkul and Jayaraman (1998) extend the previous problem by considering locating also a given number of plants. They present a model for multi commodity, multi-plant, capacitated facility location problem, and develop a Lagrangean-based heuristic solution procedure.

Tragntalerngsak (2000) considers a two echelon facility location problem in which the facilities in the first echelon are incapacitated and the facilities in the second echelon are capacitated. The goal in their model is to determine the number and locations of facilities in both echelons in order to satisfy customer demand of the product. They develop a Lagrangian relaxation-based branch and bound algorithm to solve the problem. Lee (2000) develops a multi-product mixed integer nonlinear programming model to develop a capacity expansion of an integrated production and distribution system. The system comprises the multi-site batch plants and warehouses. Melachrinodis and Min (2000) design a multi-objective, multi-period mixed integer programming model that determine the optimal relocation site and phase out schedule of a combined manufacturing and distribution facility from supply chain perspectives.

Eskigun et al. (2005) deals with the design of a supply chain distribution network considering lead time, location of distribution facilities and choice of transportation mode. They present a Lagrangian heuristic that gives good solution quality in reasonable computational time. In a recent paper, Amiri (2006) addresses the distribution network design problem in a supply chain system. His research develops a mixed integer programming model and provides a heuristic solution procedure.

Selim (2008) presents in his paper supply chain distribution network design model. The model is to provide a more realistic model structure, decision makers' imprecise aspiration levels for the goals, and demand uncertainties are incorporated into the model through fuzzy modeling approach. The goal is to select the optimum numbers, locations and capacity levels of plants and warehouses to deliver the products to the retailers at the least cost while satisfying the desired service level to the retailers.

Park et al. (2010) propose a mathematical model for single-sourcing a network design problem with a three-level supply chain that consists of multiple suppliers, distribution centers and retailers. The proposed integer nonlinear programming model is solved using a two-phase heuristic solution algorithm based on the Lagrangian relaxation approach. Yao (2010) considers multi-source facility location–allocation and inventory problem. The problem is to determine number and locations of warehouses, allocation of customers demand and inventory levels of warehouses. The objective is to minimize the expected total cost with the satisfaction of desired demand weighted average customer lead time and desired cycle service level. The problem is formulated as a mixed integer nonlinear programming problem.

Shu et al. (2012) presents profit-maximization location-inventory problems with demand flexibility. The problem is studied for two cases: un-capacitated and capacitated distribution centers. Badri (2013) describes a new mathematical model for multiple echelon, multiple commodities Supply Chain Network Design and considers different time resolutions for tactical and strategic decisions. Minimum number of facilities, public warehouses and potential sites for the establishment of private warehouses, are considered. To solve the model, an approach based on a Lagrangian Relaxation method has been developed, and some numerical analyses have been conducted to evaluate the performance of the designed approach.

Hosseininezhad (2014) also proposes a continuous capacitated location-allocation model with fixed cost as a risk management model. The model is solved by a fuzzy algorithm based on a-cut method. After solving the model based on different a-values, the zones with the largest possibilities are determined for locating new facilities and the best locations are calculated based on the obtained possibilities. Ahmadi-Javid and Ghandali (2014) present a capacitated profit-maximization location allocation problem with price sensitive demands. Ahmadi-Javid (2015) studies a profit-maximization location-inventory problem in a multi commodity supply chain distribution network with price-sensitive demands. The problem determines location, allocation, price and order-size decisions in order to maximize the total profit of serving the customers. Marcos (2015) proposes a hybrid method for the Probabilistic Maximal Covering Location– Allocation Problem. The Maximal Covering Location Problem is a facility location problem which aims to select some location candidates to install facilities, in order to maximize the total demand of clients that are located within a covering distance from an existing facility.

The contribution of our research to the literature consists of two parts. First, a capacitated facility location model has been developed for supply chain distribution network design problem. Second, Mixed Integer Linear Programming based solution approach is proposed to determine the compromise solution.

Table2.1 Gaps of Research with Previous Researches.

No	Year	Title	Name	Source	Model consideration			Objective
					Single period	Multi period	Inventory	
1	2000	A two echelon facility location problem	Tragntalererngsak	Eur J Oper Res	v			To determine the number and location of facilities in both echelons
2	2000	A multi objective, multi period mixed integer programming model	Melachrinodis and Min	Eur J Oper Res		V		To determine the optimal relocation site and phase out schedule of a combined manufacturing and distribution facility
3	2005	The design of a supply chain distribution network considering lead time	Eskigun Et al	Eur J Oper Res	v			To determine location of distribution facilities and choice of transportation mode
4	2010	Multi source facility location-allocation and inventory problem	Yao	Eur J Oper Res	v		v	To determine the number and locations of warehouses
5	2010	Heurustic approach for designing a distribution network in a supply chain system	Golmohammadi	African journal of business management	v			To determine the location of production plants and distribution warehouses
6	2014	Capacitated location allocation model with fixed cost as a risk management model	Hosseininezhad	Applied mathematical modelling		V		To determine new facilities best location based on obtained possibilities
7	2015	The design of cement distribution center in Myanmar: A case study of Sin Minn cement industry	My research			V	v	To determine the number and location of distribution center and which distribution center covered by which market

2.3 Strategic Planning Models

Strategic planning at the firm level typically involves the highest level of management and requires large capital investments over long horizons. Strategic decisions determine general development policies and broadly shape the operating strategies of the system. Several such decisions affect the design of the physical infrastructure network: where to locate facilities, what capacity level to consider for each of them. Location models are strategic planning models.

2.3.1. Location Models

Location problems involve the sitting of one or several facilities, usually at vertices of a network, in order to facilitate the movement of goods or the provision of services along the network. The main location models are often classified as follows.

Covering Models

Locate facilities at the vertices of a network so that the remaining vertices are covered by a facility, i.e., they lie within a given distance of a facility. The problem can be to minimize the cost of locating facilities, subject to a constraint stating that all remaining vertices are covered. If one operates within a fixed budget, then an objective can be to maximize the demand covered by the facilities.

Center Models

Locate p facilities at vertices of a network in order to minimize the maximal distance between a vertex and a facility.

Median Models

Locate p facilities at vertices on the network and allocate demands to these facilities in order to minimize the total weighted distance between facilities and demand points. If facilities are uncapacitated and p is fixed, one obtains the so-called p-median problem. In such a case, each vertex is associated to its closest facility. If p is a variable and facilities are uncapacitated, this defines the Uncapacitated Plant Location Problem (UPLP). If p is a decision variable and facilities are capacitated, one obtains the Capacitated Plant Location Problem (CPLP). Covering problems are typically associated with the location of public facilities such as health clinics, post offices, libraries, schools, etc. Center problems often arise in the location of emergency facilities such as fire or ambulance stations. Median problems are directly relevant to freight distribution. Daskin (1995) described the Capacitated Plant Location Problem. The CPLP can be formulated as follows. Assume there are n points in the plane called vertices and define.

f_j = the cost of locating a facility at vertex v_j

d_i = the demand at vertex vi

c_{ij} = the travel cost per unit of demand between vertices v_i and v_j

u_j = the capacity of a facility located at vertex v_j

y_j = 0, 1 variable equal to 1 if and only if a facility is located at vertex v_j

x_{ij} = the fraction of the demand of vertex v_i served by a facility located at a vertex v_j

The model is then

Minimize

$$\sum_j f_j \ y_j + \sum_i \sum_j d_i \, c_{ij} \, x_{ij} \qquad (2.1)$$

Subject to

$$x_{ij} \le y_j \qquad \text{for all } i \text{ and } j, \qquad (2.2)$$

$$\sum_j x_{ij} = 1 \qquad \text{for all } i, \qquad (2.3)$$

$$\sum_i d_i \, x_{ij} \le u_j \, y_j \qquad \text{for all } j, \qquad (2.4)$$

$$y_j = 0 \text{ or } 1 \qquad \text{for all } i \qquad (2.5)$$

$$x_{ij} \ge 0 \qquad \text{for all } i \text{ and } j \qquad (2.6)$$

In this model, the objective function represents the sum of fixed facility costs and transportation costs. It is assumed these costs are scaled over the same planning horizon. Constraints (2.2) express the condition that vertex v_i can only be served by vertex v_j if a facility is located at v_j. Constraints (2.3) state that the entire demand of each vertex must be allocated to facilities. Constraints (2.4) ensure that the capacity of a facility is never exceeded by its assigned demand.

The p-median problem is the one of the most studied facility location models. Basically, the p-median problem seeks the location of a given number of facilities so as to minimize some measure of transportation costs, such as distance or travel time. Therefore, demand is assigned to the closest facility. The P-median problem, first introduced by Hakimi (1964), is to find P facility locations which will minimize the sum of weighted distances between demand points (customers) and their respective nearest facilities. Such a model would be useful in the cases where the service provided by the facilities is demanded on a regular, steady basis. ReVelle and Swain (1970) proposed an optimal procedure for the P-median, based on linear programming and branch and bound. Their formulation is now well known and used profusely, in a slightly different form:

P-Median:

$$\text{Min} \sum_{i,j} h_i \, d_{ij} \, x_{ij} \qquad (2.7)$$

Subject to

$$\sum_j x_{ij} = 1 \qquad i = 1, 2 \ldots n \qquad (2.8)$$

$$x_{ij} - y_{ij} \leq 0 \qquad i,j = 1, 2 \ldots n \qquad (2.9)$$

$$\sum_j y_j = \text{P} \qquad (2.10)$$

$$x_{ij},\, y_j \in \{0, 1\} \qquad i,j = 1, 2 \ldots n \qquad (2.11)$$

Where:

i = Index of demand points.

m = Total number of demand points in the space of interest.

j = Index of potential facility sites.

n = Total number of potential facility locations.

h_i = Weight associated to each demand point.

d_{ij} = Distance between demand area i and potential facility at j.

x_{ij} = Variable that is equal to 1 if demand area i is assigned to a facility at j and 0 otherwise

y_j = Variable that is equal to 1 if there is an open facility at j, and 0 otherwise

The first set of constraints forces each demand point to be assigned to only one facility. The second set of constraints allows demand point i to assign to a point j only if there is an open facility in this location. Finally, the last constraint sets the number of facilities to be located.

Chopra and Meidl (2007) explained in their book about locating plants and warehouses simultaneously. A much more general form of the plant location model needs to be considered if the entire supply chain network from the supplier to the customer is to be designed. Location and capacity allocation decisions have to be made for both factories and warehouses. Multiple warehouses may be used to satisfy demand at a market and multiple factories may be used to replenish warehouses. It is also assumed that units have been appropriately adjusted such that one unit of input from a supply source produces one unit of the finished product. The model requires the following inputs:

m = number of markets or demand points

n = number of potential factory locations

l = number of suppliers

t = number of potential warehouse locations

D_j = annual demand from customer j

k_i = potential capacity of factory at site *i*

S_h = supply capacity at supplier *h*

w_e = potential warehouse capacity at site *e*

F_i = fixed cost of locating a plant at site *i*

f_e = fixed cost of locating a warehouse at site *e*

C_{hi} = cost of shipping one unit from supply source *h* to factory *i*

C_{ie} = cost of producing and shipping one unit from factory i to warehouse *e*

C_{ej} = cost of shipping one unit from warehouse *e* to customer *j*

The goal is to identify plant and warehouse locations as well as quantities shipped between various points that minimize the total fixed and variable costs. Define the following decision variables:

y_i = 1 if factory is located at site *i,* 0 otherwise

y_e = 1 if warehouse is located at site *e,* 0 otherwise

x_{ej} = quantity shipped from warehouse *e* to market *j*

x_{ie} = quantity shipped from factory at site *i* to warehouse *e*

x_{hi} = quantity shipped from supplier *h* to factory at site *i*

The problem is formulated as the following integer program:

$$\text{Min} \sum_{i=1}^{n} F_i\, y_i + \sum_{i=1}^{n} F_e\, y_e + \sum_{n=1}^{l} \sum_{i=1}^{n} c_{hi}\, x_{hi} + \sum_{i=1}^{n} \sum_{e=1}^{t} c_{ie}\, x_{ie} + \sum_{e=1}^{t} \sum_{j=1}^{m} c_{ej}\, x_{ej} \quad (2.12)$$

Subject to

$\sum_{i=1}^{n} x_{hi} \leq S_h$	for	$h = 1,\ldots,l$	(2.13)
$\sum_{h=1}^{l} x_{hi} - \sum_{e=1}^{t} x_{ie} \geq 0$	for	$i = 1,\ldots,n$	(2.14)
$\sum_{e=1}^{t} x_{ie} \leq k_i\, y_i$	for	$i = 1,\ldots,n$	(2.15)
$\sum_{i=1}^{n} x_{ie} - \sum_{j=1}^{m} x_{ij} \geq 0$	for	$e = 1,\ldots,t$	(2.16)

$\sum_{j=1}^{m} x_{ej} \leq w_e \, y_e$ for $e = 1,\ldots,t$ (2.17)

$\sum_{e=1}^{t} x_{ej} \leq D_j$ for $j = 1,\ldots,m$ (2.18)

$y_i, y_e \in \{0, 1\}, x_{ej}, x_{ie}, x_{hi} \geq 0$ (2.19)

The objective function minimizes the total fixed and variable costs of the supply chain network. The constraints (2.13) specify that the total amount shipped from a supplier cannot exceed the supplier's capacity. The constraints (2.14) state that the amount shipped out of a factory cannot exceed the quantity of raw material received. The constraints (2.15) enforce that the amount produced in the factory cannot exceed its capacity. The constraints (2.16) specify that the amount shipped out of a warehouse cannot exceed the quantity received from the factories. The constraints (2.17) specify that the amount shipped through a warehouse cannot exceed its capacity. The constraints (2.18) specify that the amount shipped to a customer must cover the demand. The constraints (2.19) enforce that each factory or warehouse is either open or closed. All the models discussed previously can also be modified to accommodate economies of scale in production, transportation, and inventory costs. However, these requirements make the models more difficult to solve. These models are based on to develop our distribution network design model for this research.

CHAPTER 3

DATA COLLECTION

This part explains the data needed to input into the Mixed Integer Linear Programming model and how to collect and aggregate all of these data. Most of the data used are provided by the company and some missing data are calculated based on formulated assumptions.

All the data needed includes.

1. Location of demand points, distribution centers and manufacturing plants.
2. Distance between all manufacturing plants and all distribution centers, all distribution centers and all demand points.
3. Period
4. Period demand by demand points location.
5. Transportation costs.
6. Distribution centers fixed cost.
7. Plants capacity and Distribution centers capacity
8. Production plan in the plants
9. Inventory cost for manufacturing plants, distribution centers and demand points.
10. The price in demand points

3.1 Location of Demand Points, Distribution Centers and Manufacturing Plants

In this research, the study area is limited in the central, western and north western parts of Myanmar. There are four destination regions in the study area as shown in the Figure 3.1, and which have six cities. Demand points in each city are aggregated and assumed to be located at the center of each city, so there are also six demand points in this study. Distribution centers will be assumed to locate each demand points. So, six distribution centers are considered in this study area. There are three manufacturing plants in the same place which have its own warehouse attached to it. So, any manufacturing plant and its attached warehouses are located in the same location. Location of demand points, distribution centers and plants are shown in Figure 3.2.

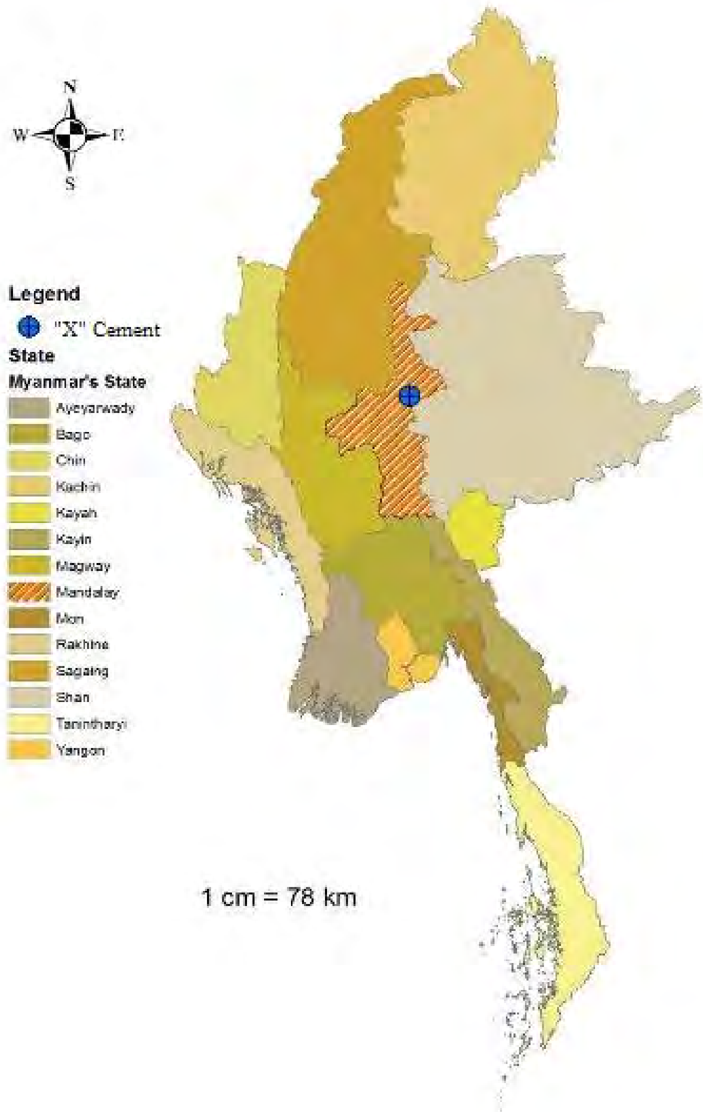

Figure3.1The Location of “X” Cement Industry

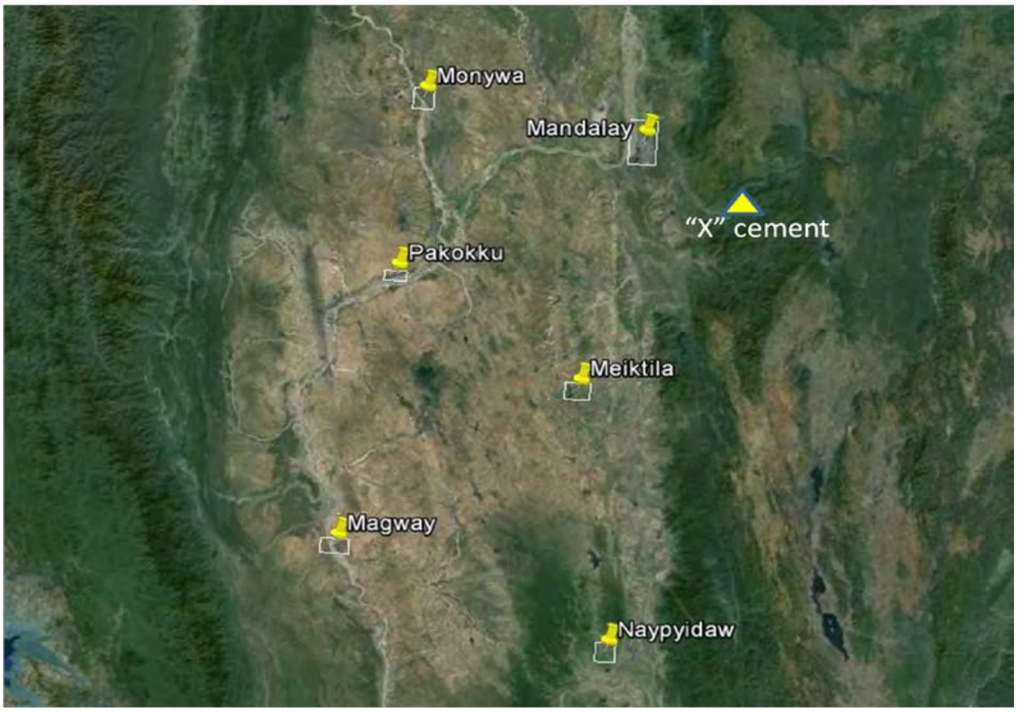

Figure3.2 Demand Point Location of “X” Cement Industry

3.2 Distance Data

Distance data are the distance between all manufacturing plants and distribution centers, all distribution centers and all demand points as shown in Table 3.1 and Table 3.2, which are collected to calculate transportation costs. All of the distances are considered the shortest ways.

Table3.1 Distance between Plants and Distribution Centers

Distance (km)						
	Mandalay	Monywa	Magway	Naypyidaw	Meikhtila	Pakokku
plant1	60	189	313	279	118	221
plant2	60	189	313	279	118	221
plant3	60	189	313	279	118	221

Table3.2 Distance between Distribution Centers and Demand Points

Distance (km)						
	Mandalay	Monywa	Magway	Naypyidaw	Meikhtila	Pakokku
Mandalay	0	129	317	309	148	161
Monywa	129	0	282	438	258	113
Magway	317	282	0	165	169	169
Naypyidaw	309	438	165	0	161	306
Meikhtila	148	258	195	161	0	145
Pakokku	161	113	169	306	145	0

3.3 Period

Three periods are divided in a year. First period starts from March to June. Second period is July to October and third period is November to February.

3.4 Demands in the Demand Points

Period demands data of product by destination input in the model is forecast demand in (2016) as shown in Table 3.3. We will consider our model based on annual basis and divide three periods in a year according to condition of the study area (described in Chapter one). Demand is converted into unit of ton per period.

Table3.3 Estimated Demands in the Demand Points in (2016)

Demand (Ton)				
No	Demand point	Period 1	Period 2	Period 3
1	Mandalay	48991	30619	42867
2	Monywa	14874	9296	13015
3	Magway	11552	7220	10108
4	Naypyidaw	46321	28950	40531
5	Meikhtila	12375	7734	10828
6	Pakokku	11583	7239	10135

3.5 Transportation Costs

Transportation costs from all manufacturing plants to all distribution centers; from all distribution centers to all demand points are the products of distances and transportation rate, which is the unit of Kyat per ton per kilometer. We will not consider transportation costs from manufacturing plants to its warehouses. We will assume that there is no transportation cost if the distribution center and market are located in the same market regions. Transportation costs are shown in Table 3.4 and 3.5.

Transportation cost rate = 87 Kyat per km

Table3.4 Transportation Cost from Plants to Distribution Centers

Transportation costs (Kyat)						
	Mandalay	Monywa	Magway	Naypyidaw	Meikhtila	Pakokku
plant1	5220	16443	27231	24273	10266	19227
plant2	5220	16443	27231	24273	10266	19227
plant3	5220	16443	27231	24273	10266	19227

Table3.5 Transportation Cost from Distribution Center to Demand Points

Transportation costs (Kyat)						
	Mandalay	Monywa	Magway	Naypyidaw	Meikhtila	Pakokku
Mandalay	0	11223	27579	26883	12876	14007
Monywa	11223	0	24534	38106	22446	9831
Magway	27579	24534	0	14355	14703	14703
Naypyidaw	26883	38106	14355	0	14007	26622
Meikhtila	12876	22446	14703	14007	0	12615
Pakokku	14007	9831	14703	26622	12615	0

3.6 Distribution Center Fixed Cost

Distribution center fixed cost is the unit of Kyat per year. Distribution center fixed cost depends on the storage area in square meters. So, we divided actual fixed cost for the distribution centers for which the data was available by its storage area to get rate of fixed cost per square meters. We can use this rate to calculate fixed cost of other distribution centers. So, fixed cost depends on the capacity of distribution center. For example, capacity is increased, fixed cost will be increased. Distribution center's capacities and their fixed costs are shown in the in Table 3.6.

Distribution center fixed cost rate = 428.57 Kyat per square meter

Table3.6 Distribution Center Fixed Costs

Capacity(Ton)	Fixed Cost(Kyat)
100000	30000000
200000	60000000
300000	90000000

3.7 Plants Capacities and Distribution Center Capacities

Plant capacity is the maximum production quantity in a year as shown in Table 3.7. Distribution center capacity is the maximum through capacity of a distribution center. Both plant capacity and distribution center capacity is the unit of Ton per year.

Table3.7 Capacity of Plants

Plant	Capacity(Ton per Year)
1	120000
2	210000
3	360000

3.8 Production Plan in the Plants

Production plan in each plant must be less than the each plant capacity. We divided production plan for three periods in a year. Production plan is the unit of ton per period as shown in Table 3.8.

Table3.8 Production Plan in the plants

Production plan (Ton)			
	Period 1	Period 2	Period 3
Plant 1	40000	20000	30400
Plant 2	51500	30400	40900
Plant 3	71900	51500	61500

3.9 Inventory Cost in Manufacturing Plants, Distribution Centers and Demand Points

Inventory cost is the unit of Kyat per period as shown in Table 3.9. It will be provided by the company. Initial inventory in plants, distribution center and demand points are assumed 500 Ton. Inventory cost in plants, distribution centers and demand points can be calculated the products of the amount of inventory and unit inventory cost.

Table3.9 Inventory Cost in Plants, Distribution Centers and Markets

Unit Inventory cost	Kyat per period
Plants	7000
Distribution centers	8000
Markets	9000

3.10 Price in the Demand Points

We will use the current prices in this study. The price is the unit of Kyat per Ton. Price depends on the location of demand points and market conditions. All demand points are different prices as shown in Table 3.10. We will consider only average price for each period in this study.

Table3.10 Prices in the Demand Points

No	Demand point	One unit Price(Kyat)
1	Mandalay	90000
2	Monywa	96000
3	Magway	110000
4	Naypyidaw	102000
5	Meikhtila	112000
6	Pakokku	94000

CHAPTER 4

MODEL DEVELOPMENT

In order to solve the distribution center optimization problem, a capacitated facility location problem is implemented. To find the best possible solution, Mixed Integer Linear Programming (MILP) model is used to optimize the distribution network design problem in this study as shown in Figure 4.1. The MILP model address following issues.

- How many distribution centers should be established for research areas?
- Where are the locations of distribution centers?
- Which demand points are to be served by which distribution centers?

In order to run the MILP model, Lingo 11 is used as a tool.

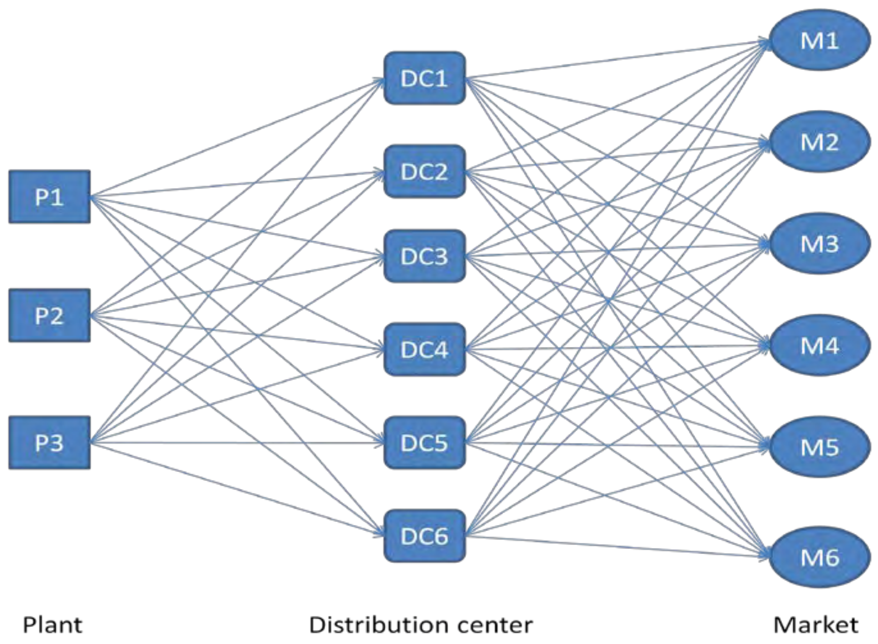

Figure4.1 Structure of the Supply Chain Distribution Network

4.1 Model Formulation

The following mathematical formulations are used to develop the MILP model.

4.1.1 Indices and Sets

i = index for manufacturing plants; i ϵ A

j = index for distribution centers; j ϵ J

k = index for market regions; k ϵ K

t = index for periods; t ϵ T

4.1.2 Model Parameters

c_{ij} = unit transportation cost from plant i to distribution center j (Kyat/Ton)

s_{jk} = unit transportation cost from distribution center j to demand points k (Kyat/Ton)

Q_i = production capacity of plant i (Ton/Year)

f_j = fixed cost of opening distribution center j (Kyat/Year)

w_j = capacity of distribution center j (Ton/Year)

r_k = revenue from selling one unit in demand points k (Kyat)

p_{it} = production quantity from plant i in period t (Ton/Period)

d_{kt} = demand from demand points k in period t (Ton/Period)

$I_{i(t-1)}$ = initial inventory in plant i in period one (t=1) (Ton)

$I_{j(t-1)}$ = initial inventory in distribution center j in period one (t=1) (Ton)

$I_{k(t-1)}$ = initial inventory in demand point k in period one (t=1) (Ton)

I_{it} = Inventory in plant i in period t (Ton)

I_{jt} = Inventory in distribution center j in period t (Ton)

I_{kt} = Inventory in demand point k in period t (Ton)

Co_i = unit inventory cost in plant i (Kyat/Ton/Period)

Co_j = unit inventory cost in distribution center j (Kyat/Ton/Period)

Co_k = unit inventory cost in demand point k (Kyat/Ton/Period)

4.1.3 Decision Variables

y_{ijt} = quantity shipment of product from plants i to distribution center j in period t (Ton)

z_{jkt} = quantity shipment of product from distribution center j to demand point k in period t (Ton)

x_j = {1, 0}, if distribution center j is opened 1, otherwise 0

4.1.4 Objective Function

Maximize Profit

$$\sum_{k\in K} (r_k \sum_{t\in T} d_{kt}) - \sum_{j\in J} f_j x_j - \sum_{i\in A}\sum_{j\in J} (c_{ij} \sum_{t\in T} y_{ijt}) \\ - \sum_{j\in J}\sum_{k\in K} (s_{jk} \sum_{t\in T} z_{jkt}) - \sum_{i\in A}\sum_{t\in T} I_{it}\, Co_i - \sum_{j\in J}\sum_{t\in T} I_{jt}\, Co_j \\ - \sum_{k\in K}\sum_{t\in T} I_{kt}\, Co_k \qquad (4.1)$$

The objective function of the model is to maximize the profit for a year, including total revenue, total distribution center fixed costs, inbound transportation costs from plants to distribution centers, outbound transportation costs from distribution centers to demand points and inventory costs in plants, distribution centers and demand points.

4.1.5 Constraints

$$\sum_{t\in T} p_{it} \leq Q_i \quad \forall i \in A \quad (4.2)$$

The amount produced in the plants for all period can not exceed its capacities.

$$\sum_{j=J} y_{ijt} \leq 0.98\, P_{it} \quad \forall\, i \in A,\ t \in T \quad (4.3)$$

The amount shipped to distribution center from the plants for all period must be less than or equal to 98% of production plan of the plants for each period.

$$\sum_{k=K} z_{jkt} \leq 0.98 \sum_{i=A} y_{ijt} \quad \forall\, j \in J,\ t \in T \quad (4.4)$$

The amount shipped out of the distribution centers for all period must not exceed 98% of the quantity received from the plants for all period.

$$\sum_{k=K} \sum_{t=T} z_{jkt} \leq w_j\ x_j \quad \forall\, j \in J \quad (4.5)$$

The amount shipped through the distribution centers for all period can not exceed its capacities.

$$\sum_{j=J} z_{jkt} \geq d_{kt} \quad \forall\, k \in K,\ t \in T \quad (4.6)$$

The amount shipped to the demand points for all period must be covered each demand in the demand points for all period.

$$(I_{i(t-1)} + p_{it} - \sum_{j\in J} y_{ijt}) = I_{it} \quad \forall\, i \in A, \mathrm{t} \in T \quad (4.7)$$

The total inventory in plants must equal to the sum of initial inventory in plants and production plan in plants for all period to abstract of the quantity shipment from the plants for all periods.

$$(I_{j\,(t-1)} + \sum_{i\in A} y_{ijt} - \sum_{k\in K} z_{jkt}) = I_{jt} \quad \forall\, j \in J, \mathrm{t} \in T \quad (4.8)$$

The total inventory in distribution centers must equal to the sum of initial inventory in distribution centers and the quantity shipment from the plants for all period to abstract of the quantity shipment from distribution centers for all period.

$$(I_{k(t-1)} + \sum_{j \in J} z_{jkt} \ - d_{kt}) \qquad = I_{kt} \qquad \forall k \ \in K, \mathrm{t} \in T \qquad (4.9)$$

The total inventory in market regions must equal to the sum of initial inventory in market regions and the quantity shipment from distribution centers for all period to abstract the demands in demand points for all period.

$$I_{kt} \quad \geq \ 0.05 \ \sum_{j=J} z_{jkt} \qquad \forall k \ \in K, \mathrm{t} \in T \qquad (4.10)$$

Inventory in demand points for each period must be at least the 5% of the quantity shipment from the warehouse for each period.

$$x_j \quad = \quad \{0, 1\} \qquad \forall \, j \in J \qquad (4.11)$$

Each distribution centers is either opened or closed

$$y_{ijt} \ \geq \quad 0 \qquad \forall \, i \in A, j \in J, t \in T \qquad (4.12)$$

The amount shipped to the distribution center from the plant must be greater than or equal to zero.

$$z_{jkt} \ \geq \quad 0 \qquad \forall \, j \in J, k \in K, t \in T \qquad (4.13)$$

The amount shipped to the market from the distribution center must be greater than or equal to zero.

4.2 Scenarios

The MILP model was run by changing distribution center capacity to see the sensitivity of distribution center selection due to the variability of distribution center fixed cost and capacity. Scenario one will be assumed each distribution center's capacity 100000 Ton per year and the fixed cost 30000000 Kyat per year. Scenario two, two times of distribution centers' capacity are considered. Three times of distribution centers' capacity are considered scenario three. Increased twenty percent demands and scenario one's distribution centers' capacity were considered for scenario four. The equal amount of demands and increased two times and three times distribution capacity were considered by scenario five and six. Decreased twenty percent demands and scenario one's distribution centers' capacity were considered for scenario seven. The equal amount of demands and increased two times and three times distribution centers' capacity were considered by scenario eight and nine.

The objective of these nine scenarios is to determine the sensitivity of distribution center selection due to the increase of distribution center capacity fixed cost, increase demand and decrease demand. It can be seen from these nine scenarios that if all the distribution centers' capacity were increased, which distribution centers will be neglected by the model. According to these scenarios, we can compare the results. The distribution centers that will still be selected in all scenarios, it can be assumed that they are located right locations.

In order to use the model to determine the optimal locations and number of distribution centers, we conducted and experiment. In the experiment, we increased the capacity of each distribution center to be 2x and 3x their first assumed capacity. If the distribution centers' capacity were increased, the number of distribution centers selected by model will decrease. This is due to the fact that the distribution centers located at the appropriate locations can handle more products volume, thus the products that were stored at other distribution centers will be stored at these appropriate distribution centers instead. If we continue to increase distribution centers' capacity, the number of distribution centers selected by model will continue to decrease. The number of distribution center selected will decrease until the total distribution cost can not go down further. We can determine the optimal number of distribution centers for all sources by continuing to increase the distribution center' capacity until the point that the model will not suggest using fewer distribution centers. The fewest number of distribution center selected by model can be assumed to be the optimal number of distribution center. We have to consider the profit because our objective is to get the maximum profit by designing distribution network.

CHAPTER 5

RESULT ANALYSIS

This chapter analyzes the results of running the MILP model in the nine scenarios mentioned in the previous chapter. The reasons why some distribution centers were selected and other were not selected in each scenario are explained. We will compare the results of each scenario and we will select the best distribution network from these scenarios suggested by model.

5.1 Optimization Results

The results from running the model in nine scenarios are analyzed in this chapter. The analysis of the optimization results of each scenario is as following.

Scenario One

Forecasted demand, initial production plan and initial distribution center capacity are considered for scenario one. Each distribution center is assumed to open in each market in the model. Optimization results and distribution network of scenario one are as shown in table 5.1 and figure 5.1. Distribution center DC3 is not selected to open by the model. So, the total number of distribution centers used in this scenario is 5 out of 6 distribution centers. The market M3 which was assumed to open distribution center DC3 is lower demands than other markets and higher transportation cost from the plants. It may affect on the profit. So, other selected distribution centers will be used to distribute the market M3.

Table5.1 Optimization Results of Scenario One

Objective value = 0.2845499 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	11628.2	20611.9	23326.2
Production		163400	101900	132800
Shipment out		153272	92916.3	130086

Distribution Centers				
Period	0	1	2	3
Inventory	2500	5565.45	7423.78	10025.5
Shipment in		153271.8	92916.33	130085.7
Shipment out		150206	91058	127484

Markets				
Period	0	1	2	3
Inventory	3000	7511.89	7510.87	7512.25
Shipment in		150206	91058	127484
Demand		145694	91059	127483

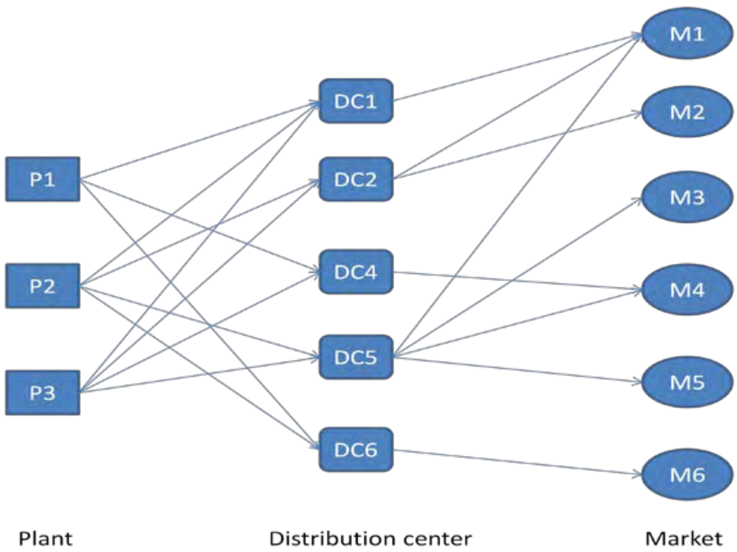

Figure5.1 Structure of Distribution Network for Scenario One

Scenario Two

Forecasted demand, initial production plan and increased two times of distribution center capacity are considered for scenario two. Optimization results and distribution network of scenario two are as shown in table 5.2 and figure 5.2. Distribution centers DC2, DC3, DC4 and DC6 are not selected to open by the model. So, the total number of distribution centers used in this scenario is 2 out of 6 distribution centers. Objective value of scenario two is greater than scenario one because the model opens two distribution centers. So, it can reduce fixed costs and the profit will be high.

Table5.2 Optimization Results of Scenario Two

Objective value = 0.2912741 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	11628.3	20611.9	23326.2
Production		163400	101900	132800
Shipment out		153272	92916.3	130086

Distribution Centers				
Period	0	1	2	3
Inventory	1000	4065.43	5923.76	8525.47
Shipment in		153271.8	92916.33	130085.7
Shipment out		150206	91058	127484

Markets				
Period	0	1	2	3
Inventory	3000	7511.9	7510.88	7512.26
Shipment in		150206	91058	127484
Demand		145694	91059	127483

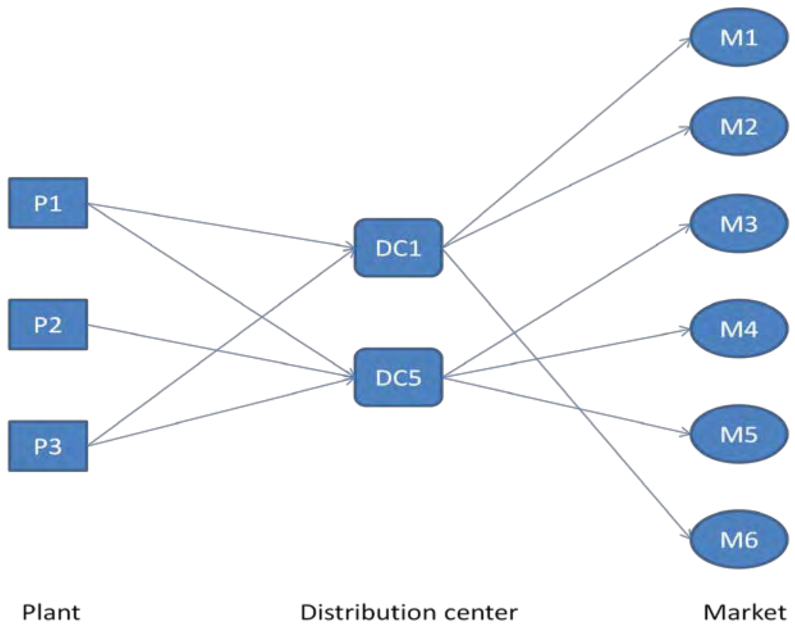

Figure5.2 Structure of Distribution Network for Scenario Two

Scenario Three

Forecasted demand, initial production plan and increased three times of distribution center capacity are considered for scenario three. Optimization results and distribution network of scenario three are as shown in table 5.3 and figure 5.3. Distribution centers DC2, DC3, DC4 and DC6 are not selected to open by the model. So, the total number of distribution centers used in this scenario is 2 out of 6 distribution centers. The number of opening distribution centers are the same with scenario two. Distribution centers' capacity is higher than scenario two. So, fixed cost will be high and it affect on the profit. Objective value of this scenario is lower than scenario two.

Table5.3 Optimization Results of Scenario Three

Objective value = 0.2906741 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	11628.3	20611.9	23326.2
Production		163400	101900	132800
Shipment out		153272	92916.3	130086

Distribution Centers				
Period	0	1	2	3
Inventory	1000	4065.43	5923.76	8525.47
Shipment in		153271.8	92916.33	130085.7
Shipment out		150206	91058	127484

Markets				
Period	0	1	2	3
Inventory	3000	7511.9	7510.88	7512.26
Shipment in		150206	91058	127484
Demand		145694	91059	127483

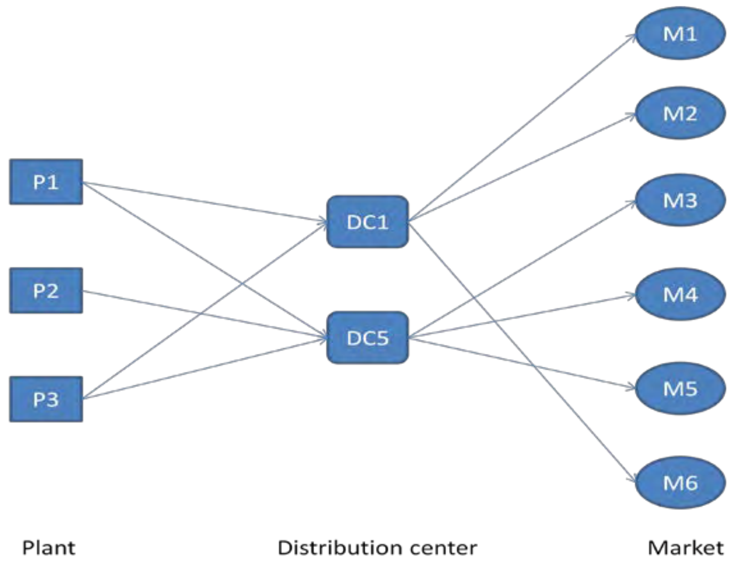

Figure5.3 Structure of Distribution Network for Scenario Three

Scenario Four

Twenty percent increased demand and production plan, and initial distribution center capacity are considered for scenario four. Optimization results and distribution network of scenario four are as shown in table 5.4 and figure 5.4. Each distribution center was assumed to open each in each market in the model. All Distribution centers were selected to open by the model because the demand in each market is increased and the distribution center' capacity are not increased. Objective value increases because increased demand affect on the profit.

Table5.4 Optimization Results of Scenario Four

Objective value = 0.3358713 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	13010.7	23788.7	27046.7
Production		196080	122280	159360
Shipment out		184569	111502	156102

Distribution Centers				
Period	0	1	2	3
Inventory	3000	6691.38	8921.42	12043.4
Shipment in		184569.3	111502	156102
Shipment out		180878	109272	152980

Markets				
Period	0	1	2	3
Inventory	3000	9044.57	9045.75	9046.6
Shipment in		180878	109272	152980
Demand		174833	109271	152979

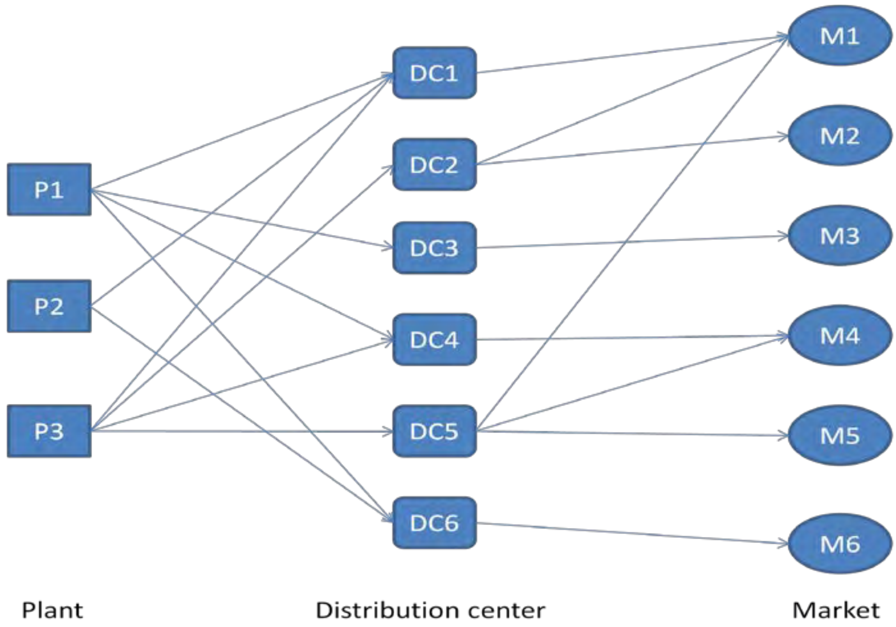

Figure5.4 Structure of Distribution Network for Scenario Four

Scenario Five

Twenty percent increased demand and production plan, and two times of increased distribution center capacity are considered for scenario five. Optimization results and distribution network of scenario five are as shown in table 5.5 and figure 5.5. Distribution center DC3 and DC6 are not selected to open by the model. So, the total number of distribution centers used in this scenario is 4 out of 6 distribution centers. Objective value is higher than scenario four because of fixed cost reducing for distribution center DC3.

Table5.5 Optimization Results of Scenario Five

Objective value = 0.3483508 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	13010.7	23788.7	27046.7
Production		196080	122280	159360
Shipment out		184569	111502	156102

Distribution Centers				
Period	0	1	2	3
Inventory	2000	5691.38	7921.42	11043.4
Shipment in		184569.3	111502	156102
Shipment out		180878	109272	152980

Markets				
Period	0	1	2	3
Inventory	3000	9044.57	9045.75	9046.6
Shipment in		180878	109272	152980
Demand		174833	109271	152979

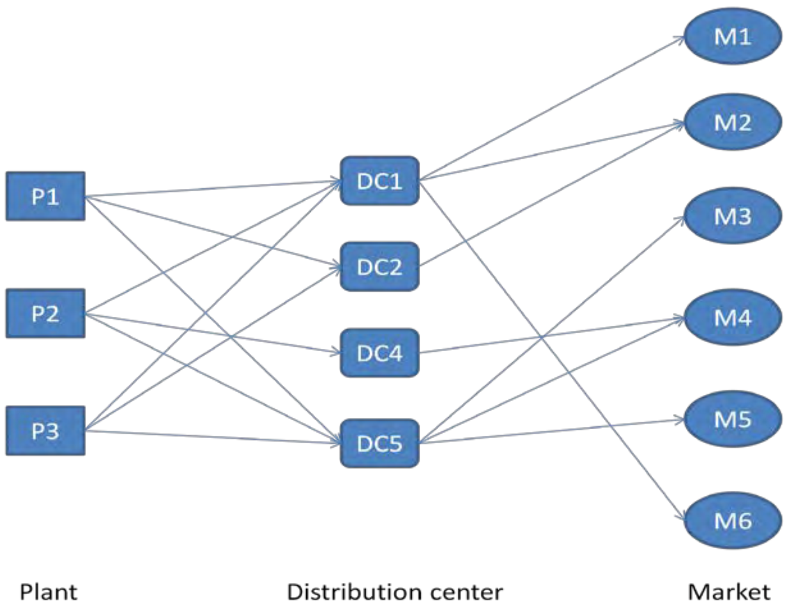

Figure5.5 Structure of Distribution Network for Scenario Five

Scenario Six

Twenty percent increased demand and production plan, and three times of increased distribution center capacity are considered for scenario six. Optimization results and distribution network of scenario six are as shown in table 5.6 and figure 5.6. Distribution centers DC2, DC3, DC4 and DC6 are not selected to open by model. So, the total number of distribution centers used in this scenario is 2 out of 6 distribution centers. As two distribution centers are opened, fixed costs are low. So, the objective value is higher than scenario five.

Table5.6 Optimization Results of Scenario Six

Objective value = 0.3492974 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	13010.7	23788.7	27046.7
Production		196080	122280	159360
Shipment out		184569	111502	156102

Distribution Centers				
Period	0	1	2	3
Inventory	1000	4691.38	6921.42	10043.4
Shipment in		184569.3	111502	156102
Shipment out		180878	109272	152980

Markets				
Period	0	1	2	3
Inventory	3000	9044.57	9045.75	9046.6
Shipment in		180878	109272	152980
Demand		174833	109271	152979

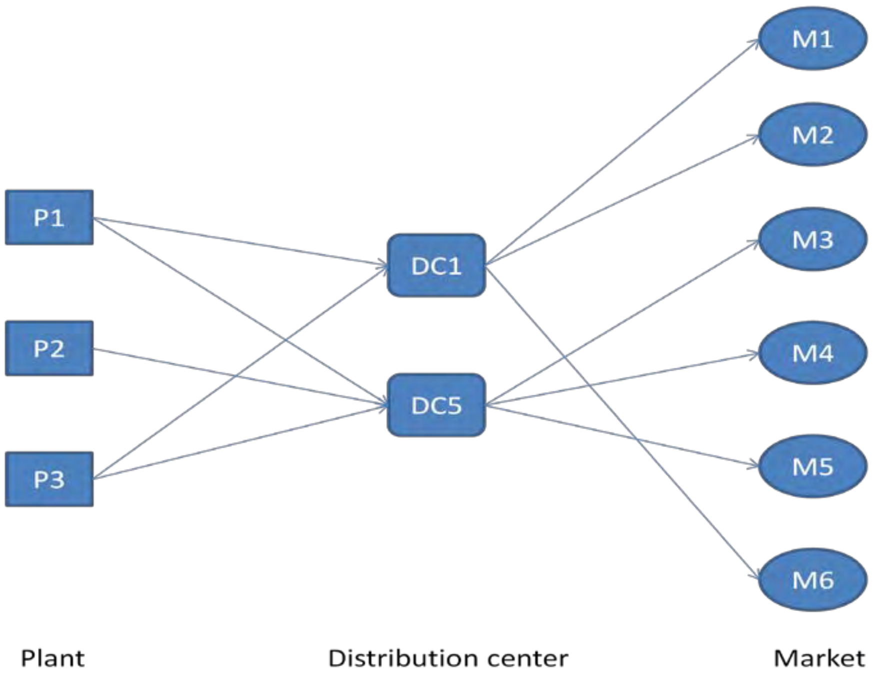

Figure5.6 Structure of Distribution Network for Scenario Six

Scenario Seven

Twenty percent decreased demand and production plan, and initial distribution center capacity are considered for scenario seven. Optimization results and distribution network of scenario seven are shown in table 5.7 and figure 5.7. Each distribution center is assumed to open in each market. Distribution centers DC3 and DC6 are not selected to open by model. So, the total number of distribution centers used in this scenario is 4 o ut of 6 d istribution centers. Objective value is lower than scenario six because of demand reducing.

Table5.7 Optimization Results of Scenario Seven

Objective value = 0.2312786 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	10163.5	17350.8	19524.5
Production		130720	81520	106240
Shipment out		122057	74332.7	104066

Distribution Centers				
Period	0	1	2	3
Inventory	2000	4441.1	5927.75	8009.07
Shipment in		122056.5	74332.65	104066.3
Shipment out		119615	72846	101985

Markets				
Period	0	1	2	3
Inventory	3000	6059.88	6058.66	6057.57
Shipment in		119615	72846	101985
Demand		116556	72847.2	101986

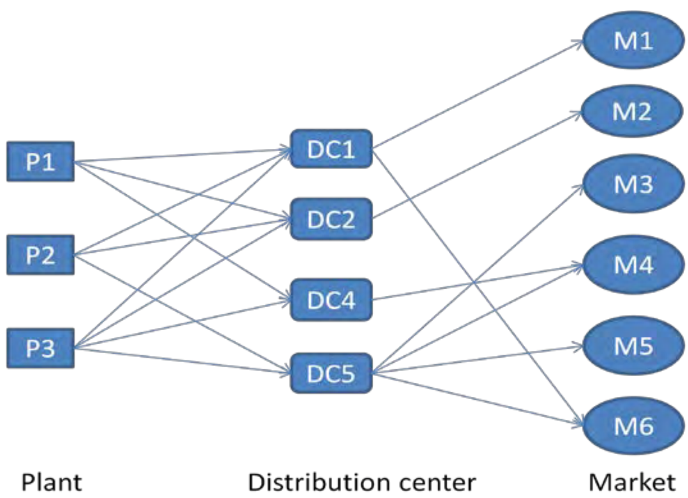

Figure5.7 Structure of Distribution Network for Scenario Seven

Scenario Eight

Twenty percent decreased demand and production plan, and increased two times of distribution center capacity are considered for scenario eight. Optimization results and distribution network of scenario eight are as shown in table 5.8 and figure 5.8. Distribution center DC2, DC3, DC4 and DC6 are not selected to open by model. So, total number of distribution centers used in this scenario is 2 out of 6 distribution centers. Objective value increases because fixed costs are reduced.

Table5.8 Optimization Results of Scenario Eight

Objective value = 0.2326238 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	10163.5	17350.8	19524.5
Production		130720	81520	106240
Shipment out		122057	74332.7	104066

Distribution Centers				
Period	0	1	2	3
Inventory	1000	3441.18	4927.83	7009.16
Shipment in		122056.6	74332.65	104066.3
Shipment out		119615	72846	101985

Markets				
Period	0	1	2	3
Inventory	3000	6059.88	6058.66	6057.57
Shipment in		119615	72846	101985
Demand		116556	72847.2	101986

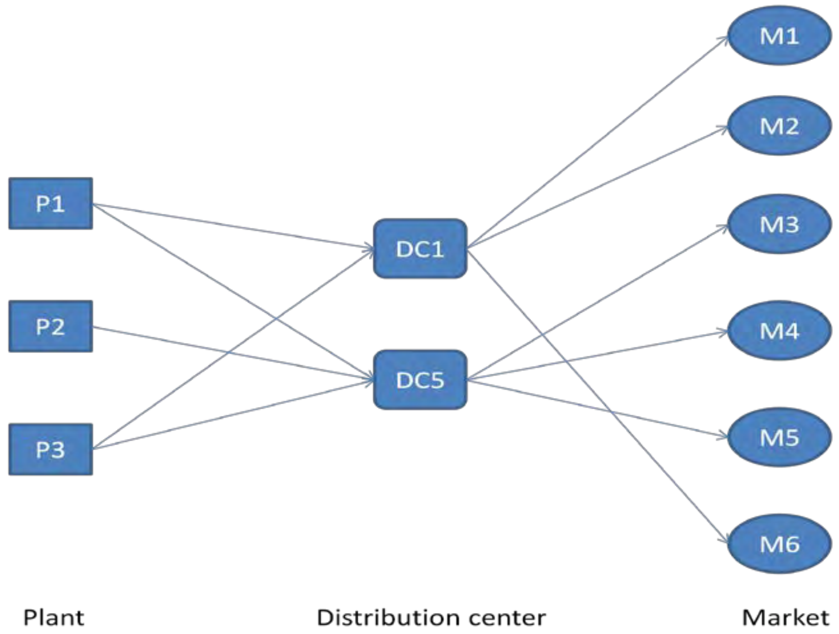

Figure5.8 Structure of Distribution Network for Scenario Eight

Scenario Nine

Twenty percent decreased demand and production plan, and increased three times of distribution center capacity are considered for scenario nine. Optimization results and distribution network of scenario nine are as shown in table 5.9 and figure 5.9. The selected distribution centers by model are the same number with scenario eight. Objective value is lower than scenario eight. When the distribution centers' capacity is increased, fixed costs also are increased. It affects on the profit.

According to the comparison of results as shown in table 5.10, the objective value is the highest if distribution center DC1 and DC5 are selected to open by model. So, these two distribution centers are the best locations.

Table5.9 Optimization Results of Scenario Nine

Objective value = 0.2314238 E+11				
Plants				
Period	0	1	2	3
Inventory	1500	10163.5	17350.8	19524.5
Production		130720	81520	106240
Shipment out		122057	74332.7	104066

Distribution Centers				
Period	0	1	2	3
Inventory	1000	3441.18	4927.83	7009.16
Shipment in		122056.6	74332.65	104066.3
Shipment out		119615	72846	101985

Markets				
Period	0	1	2	3
Inventory	3000	6059.88	6058.66	6057.57
Shipment in		119615	72846	101985
Demand		116556	72847.2	101986

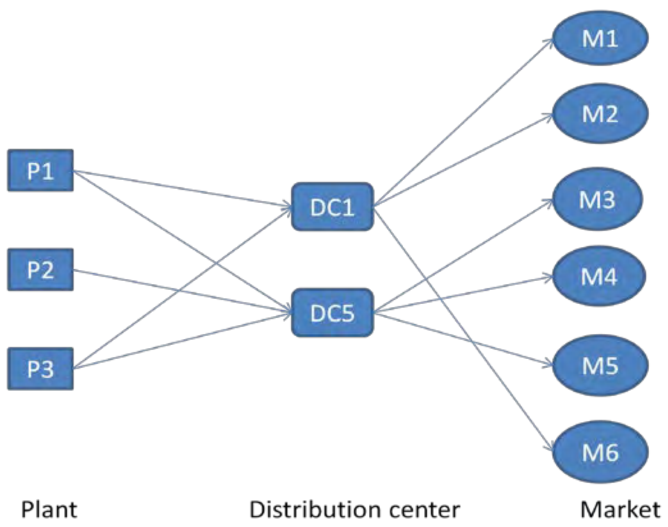

Figure5.9 Structure of Distribution Network for Scenario Nine

Table5.10 Comparison of Scenarios

Scenario	Demand	DC Capacity	Opened DC	Objective Value(billion Kyat)
1	Initial Forecasted Demand	100000	1,2,4,5,6	28.45499
2	Initial Forecasted Demand	200000	1,5	29.12741
3	Initial Forecasted Demand	300000	1,5	29.06741
4	20% Increased Demand	100000	1,2,3,4,5,6	33.58713
5	20% Increased Demand	200000	1,2,4,5	34.83508
6	20% Increased Demand	300000	1,5	34.92974
7	20% Decreased Demand	100000	1,2,4,5	23.12786
8	20% Decreased Demand	200000	1,5	23.26238
9	20% Decreased Demand	300000	1,5	23.14238

CHAPTER 6

RESULT SUGGESTION

6.1 Summary of the Thesis

This thesis focuses on developing an optimization model to design distribution networks for “X” cement industry in Myanmar, the model which is trying to maximize profit by reducing distribution costs, distribution center fixed costs and inventory costs to increase its competitiveness in the market. The current distribution network is direct shipment to the market regions from the warehouses in the plants. It is high transportation costs, long lead time and low customer service. The company has three manufacturing plants and six market regions which are located in the central, western and north western parts of Myanmar. The results suggest opening two distribution centers with suitable capacities. The locations are Mandalay and Meikhtila market. These markets are the best location to serve all market.

The objective of this thesis is to determine the number and location of distribution centers. Data collection was primarily done by the company. Those data included the location of manufacturing plants and demand points, distance between these facilities, inbound and outbound transportation costs, distribution center fixed cost and finally the customer demand and price in each market regions.

Mixed Integer Linear Programming (MILP) is used to solve the optimization of this complex problem. The real data was input to the model with some estimated and calculated data based on assumption provided by all distribution networks. The model was run in nine scenarios to examine the sensitivity of distribution centers selection due to the variability of distribution center capacity and fixed cost. We found that two distribution centers were selected by the model every scenario, one distribution center was selected only one time and other three distribution centers were selected in some scenario. Supply chain manager can use these distribution centers' data as a guide to make decision on distribution center opening in the future.

6.2 Keys Learning

There are seven competitors in the same market regions. So, the company has to design supply chain distribution network from current distribution network to maximize profit while still satisfying customer service level. Design of distribution network is a strategic decision that has long term effects on the company' performance, so it requires collaboration from related organization inside and outside of the company including supplier and customer.

In doing the network optimization problem using the model, the data input to the model is a key factor to obtain the reliable result. A company has to pay great attention in data collection process to obtain the correct information from all related parties such as sales, operation and financial departments. Wrong data can lead to unreliable results which may loss the profit for the company.

Finally, before making distribution network design decision, the manager must consider many trade-offs during network design. For example opening many distribution centers to serve local markets to reduce transportation cost and provides a fast response time, but it increases the distribution center fixed costs and inventory costs incurred by the company. This model is used to decide on locations where distribution centers will be established.

6.3 Opportunities for Further Research

This thesis developed MILP model to optimize the distribution network for plants, distribution centers and markets. However, some of the data input to the model is not actual data because we can not obtain actual data for all, so these data were calculated based on the assumptions. Distribution centers fixed costs were calculated based on the rate of fixed cost per square meter of warehouse in the plants. We assumed distribution center capacity and fixed cost were increased linearly. In real condition, it will not be linear. Model accuracy can be greatly improved by having the real data input into the model. It is important to coordinate people from other related parties to get the real data. Not only distribution center fixed costs but also transportation costs are important as they are keys determinants in the model selection. All sources really need to invest the effort to obtain the real data to input the model. This will make the model results more reliable and the company can apply it to make decision confidently.

In this thesis, transportation cost assumptions are based on truck load rates. In reality, rate of transportation costs are not the same. It depends on the condition of high way. So, to obtain the more accurate result, we need to calculate transportation cost by dividing the paths which is different transportation rates for the whole high way network.

Another area to conduct further research is to use multi mode transportation network. In our research area, train, truck and ship can use for transportation. Combined transportation system will be cheaper transportation costs than truck load transportation. For example, we can transport by train first and carry by truck from the station to the destination places. We can transport by ship first and carry by truck from the port to the destination places. It will be more beneficial for making decision for distribution network.

In this research, we assumed that all distribution centers in each market are the same capacity. Further research can consider different distribution center capacity in different market and more than one distribution center in the market. Each market has many retail stores. Further research can expand distribution network design in detail.

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APPENDICES

Appendix: A Lingo Model

Sets:

Time/1..3/;

Plant/1..3/:capacityp;

Warehouse/1..6/:capacityw,X,fixed;

Market/1..6/:price;

Links(plant,warehouse):Cij;

Links1(plant,warehouse,time):Yijt;

Links2(warehouse,market):Sjk;

Links3(warehouse,market,time):Zjkt;

Links4(market,time):demand,Initialinvm,inventorym;

Links5(warehouse,time):Initialinvw,inventoryw;

Links6(plant,time):production,initialinvp,inventoryp;

Endsets

Data:

capacityp=120000 210000 360000;

production=

40000 20000 30400

51500 30400 40900

71900 51500 61500;

capacityw=200000 200000 200000 200000 200000 200000;

price=90000 96000 110000 102000 112000 94000;

demand=

48991	30619	42867
14874	9296	13015
11552	7220	10108
46321	28950	40531
12375	7734	10828
11583	7239	10135

;

Cij=

5220	16443	27231	24273	10266	22881
5220	16443	27231	24273	10266	22881
5220	16443	27231	24273	10266	22881

;

Sjk=

0	11223	27579	26883	12876	14007
11223	0	24534	38106	22446	9831
27579	24534	0	14355	14703	14703
26883	38106	14355	0	14007	26622
12876	22446	14703	14007	0	12615
14007	9831	14703	26622	12615	0

```
;
Fixed=60000000 60000000 60000000  60000000  60000000  60000000;
ip=7000;
iw=8000;
im=9000;
Enddata
! The objective function;
Max=@sum(links4(k,t):demand(k,t)*price(k))-@sum(warehouse(j):fixed(j)*X(j))
-@sum(links1(i,j,t):Cij(i,j)*Yijt)-@sum(links3(j,k,t):Sjk(j,k)*Zjkt(j,k,t))
-@sum(links6(i,t):Inventoryp(i,t))*ip-@sum(links5(j,t):Inventoryw(j,t))*iw-
@sum(links4(k,t):Inventorym(k,t))*im;
! The plants capacity constraints;
@for(plant(i):
@sum(time(t):production(i,t))<=capacityp(i));
@for(links6(i,t):
@sum(warehouse(j):Yijt(i,j,t))<=0.98*production(i,t));
@for(links5(j,t):
@sum(plant(i):Yijt(i,j,t))*0.98>=@sum(market(k):Zjkt(j,k,t)));
@for(warehouse(j):
@sum(links4(k,t):Zjkt(j,k,t))<=Capacityw(j)*X(j));
@for(links4(k,t):
@sum(warehouse(j):Zjkt(j,k,t))>=demand(k,t));
!For time period 1;
@for(plant(i):
@for(time(t)|t#EQ#1:
Initialinvp(i,t)=500));
@for(plant(i):
@for(time(t)|t#EQ#1:
Initialinvp(i,t)+Production(i,t)-@sum(warehouse(j):Yijt(i,j,t))=Inventoryp(i,t)));
!Subsequesnt periods;
@for(plant(i):
```

```
@for(time(t)|t#GT#1:
Inventoryp(i,t-1)+Production(i,t)-@sum(warehouse(j):Yijt(i,j,t))=Inventoryp(i,t)));
!For time period 1;
@for(warehouse(j):
@for(time(t)|t#EQ#1:
Initialinvw(j,t)=500*x(j)));
@for(warehouse(j):
@for(time(t)|t#EQ#1:
Initialinvw(j,t)+@sum(plant(i):Yijt(i,j,t))-@sum(market(k):Zjkt(j,k,t))=Inventoryw(j,t)));
!Subsequest periods;
@for(warehouse(j):
@for(time(t)|t#GT#1:
Inventoryw(j,t-1)+@sum(plant(i):Yijt(i,j,t)) -@sum(market(k):Zjkt(j,k,t))=Inventoryw(j,t)));
!For time period 1;
@for(market(k):
@for(time(t)|t#EQ#1:
Initialinvm(k,t)=500));
@for(market(k):
@for(time(t)|t#EQ#1:
Initialinvm(k,t)+@sum(warehouse(j):Zjkt(j,k,t))-demand(k,t)=Inventorym(k,t)));
!Subsequence periods;
@for(market(k):
@for(time(t)|t#GT#1:
Inventorym(k,t-1)+@sum(warehouse(j):Zjkt(j,k,t))-demand(k,t)=Inventorym(k,t)));
@for(warehouse(j):
@bin(X(j)));
@for(market(k):
@for(time(t):
Inventorym(k,t)>=0.05*@sum(warehouse(j):Zjkt(j,k,t))));
End
```

Appendix: B Lingo Model Equation

MODEL:

[_1] MAX= - 8000 * INVENTORYW_1_1 - 8000 * INVENTORYW_1_2 - 8000 * INVENTORYW_1_3 - 8000 * INVENTORYW_2_1 - 8000 * INVENTORYW_2_2 - 8000 * INVENTORYW_2_3 - 8000 * INVENTORYW_3_1 - 8000 * INVENTORYW_3_2 - 8000 * INVENTORYW_3_3 - 8000 * INVENTORYW_4_1 - 8000 * INVENTORYW_4_2 - 8000 * INVENTORYW_4_3 - 8000 * INVENTORYW_5_1 - 8000 * INVENTORYW_5_2 - 8000 * INVENTORYW_5_3 - 8000 * INVENTORYW_6_1 - 8000 * INVENTORYW_6_2 - 8000 * INVENTORYW_6_3 - 11223 * ZJKT_1_2_1 - 11223 * ZJKT_1_2_2 - 11223 * ZJKT_1_2_3 - 27579 * ZJKT_1_3_1 - 27579 * ZJKT_1_3_2 - 27579 * ZJKT_1_3_3 - 26883 * ZJKT_1_4_1 - 26883 * ZJKT_1_4_2 - 26883 * ZJKT_1_4_3 - 12876 * ZJKT_1_5_1 - 12876 * ZJKT_1_5_2 - 12876 * ZJKT_1_5_3 - 14007 * ZJKT_1_6_1 - 14007 * ZJKT_1_6_2 - 14007 * ZJKT_1_6_3 - 11223 * ZJKT_2_1_1 - 11223 * ZJKT_2_1_2 - 11223 * ZJKT_2_1_3 - 24534 * ZJKT_2_3_1 - 24534 * ZJKT_2_3_2 - 24534 * ZJKT_2_3_3 - 38106 * ZJKT_2_4_1 - 38106 * ZJKT_2_4_2 - 38106 * ZJKT_2_4_3 - 22446 * ZJKT_2_5_1 - 22446 * ZJKT_2_5_2 - 22446 * ZJKT_2_5_3 - 9831 * ZJKT_2_6_1 - 9831 * ZJKT_2_6_2 - 9831 * ZJKT_2_6_3 - 27579 * ZJKT_3_1_1 - 27579 * ZJKT_3_1_2 - 27579 * ZJKT_3_1_3 - 24534 * ZJKT_3_2_1 - 24534 * ZJKT_3_2_2 - 24534 * ZJKT_3_2_3 - 14355 * ZJKT_3_4_1 - 14355 * ZJKT_3_4_2 - 14355 * ZJKT_3_4_3 - 14703 * ZJKT_3_5_1 - 14703 * ZJKT_3_5_2 - 14703 * ZJKT_3_5_3 - 14703 * ZJKT_3_6_1 - 14703 * ZJKT_3_6_2 - 14703 * ZJKT_3_6_3 - 26883 * ZJKT_4_1_1 - 26883 * ZJKT_4_1_2 - 26883 * ZJKT_4_1_3 - 38106 * ZJKT_4_2_1 - 38106 * ZJKT_4_2_2 - 38106 * ZJKT_4_2_3 - 14355 * ZJKT_4_3_1 - 14355 * ZJKT_4_3_2 - 14355 * ZJKT_4_3_3 - 14007 * ZJKT_4_5_1 - 14007 * ZJKT_4_5_2 - 14007 * ZJKT_4_5_3 - 26622 * ZJKT_4_6_1 - 26622 * ZJKT_4_6_2 - 26622 * ZJKT_4_6_3 - 12876 * ZJKT_5_1_1 - 12876 * ZJKT_5_1_2 - 12876 * ZJKT_5_1_3 - 22446 * ZJKT_5_2_1 - 22446 * ZJKT_5_2_2 - 22446 * ZJKT_5_2_3 - 14703 * ZJKT_5_3_1 - 14703 * ZJKT_5_3_2 - 14703 * ZJKT_5_3_3 - 14007 * ZJKT_5_4_1 - 14007 * ZJKT_5_4_2 - 14007 * ZJKT_5_4_3 - 12615 * ZJKT_5_6_1 - 12615 * ZJKT_5_6_2 - 12615 * ZJKT_5_6_3 - 14007 * ZJKT_6_1_1 - 14007 * ZJKT_6_1_2 - 14007 * ZJKT_6_1_3 - 9831 * ZJKT_6_2_1 - 9831 * ZJKT_6_2_2 - 9831 * ZJKT_6_2_3 - 14703 * ZJKT_6_3_1 - 14703 * ZJKT_6_3_2 - 14703 * ZJKT_6_3_3 - 26622 * ZJKT_6_4_1 - 26622 * ZJKT_6_4_2 - 26622 * ZJKT_6_4_3 - 12615 * ZJKT_6_5_1 - 12615 * ZJKT_6_5_2 - 12615 * ZJKT_6_5_3 - 5220 * YIJT_1_1_1 - 5220 * YIJT_1_1_2

- 5220 * YIJT_1_1_3 - 16443 * YIJT_1_2_1 - 16443 * YIJT_1_2_2 - 16443 * YIJT_1_2_3 - 27231 * YIJT_1_3_1 - 27231 * YIJT_1_3_2 - 27231 * YIJT_1_3_3 - 24273 * YIJT_1_4_1 - 24273 * YIJT_1_4_2 - 24273 * YIJT_1_4_3 - 10266 * YIJT_1_5_1 - 10266 * YIJT_1_5_2 - 10266 * YIJT_1_5_3 - 22881 * YIJT_1_6_1 - 22881 * YIJT_1_6_2 - 22881 * YIJT_1_6_3 - 5220 * YIJT_2_1_1 - 5220 * YIJT_2_1_2 - 5220 * YIJT_2_1_3 - 16443 * YIJT_2_2_1 - 16443 * YIJT_2_2_2 - 16443 * YIJT_2_2_3 - 27231 * YIJT_2_3_1 - 27231 * YIJT_2_3_2 - 27231 * YIJT_2_3_3 - 24273 * YIJT_2_4_1 - 24273 * YIJT_2_4_2 - 24273 * YIJT_2_4_3 - 10266 * YIJT_2_5_1 - 10266 * YIJT_2_5_2 - 10266 * YIJT_2_5_3 - 22881 * YIJT_2_6_1 - 22881 * YIJT_2_6_2 - 22881 * YIJT_2_6_3 - 5220 * YIJT_3_1_1 - 5220 * YIJT_3_1_2 - 5220 * YIJT_3_1_3 - 16443 * YIJT_3_2_1 - 16443 * YIJT_3_2_2 - 16443 * YIJT_3_2_3 - 27231 * YIJT_3_3_1 - 27231 * YIJT_3_3_2 - 27231 * YIJT_3_3_3 - 24273 * YIJT_3_4_1 - 24273 * YIJT_3_4_2 - 24273 * YIJT_3_4_3 - 10266 * YIJT_3_5_1 - 10266 * YIJT_3_5_2 - 10266 * YIJT_3_5_3 - 22881 * YIJT_3_6_1 - 22881 * YIJT_3_6_2 - 22881 * YIJT_3_6_3 - 9000 * INVENTORYM_1_1 - 9000 * INVENTORYM_1_2 - 9000 * INVENTORYM_1_3 - 9000 * INVENTORYM_2_1 - 9000 * INVENTORYM_2_2 - 9000 * INVENTORYM_2_3 - 9000 * INVENTORYM_3_1 - 9000 * INVENTORYM_3_2 - 9000 * INVENTORYM_3_3 - 9000 * INVENTORYM_4_1 - 9000 * INVENTORYM_4_2 - 9000 * INVENTORYM_4_3 - 9000 * INVENTORYM_5_1 - 9000 * INVENTORYM_5_2 - 9000 * INVENTORYM_5_3 - 9000 * INVENTORYM_6_1 - 9000 * INVENTORYM_6_2 - 9000 * INVENTORYM_6_3 - 7000 * INVENTORYP_1_1 - 7000 * INVENTORYP_1_2 - 7000 * INVENTORYP_1_3 - 7000 * INVENTORYP_2_1 - 7000 * INVENTORYP_2_2 - 7000 * INVENTORYP_2_3 - 7000 * INVENTORYP_3_1 - 7000 * INVENTORYP_3_2 - 7000 * INVENTORYP_3_3 - 60000000 * X_1 - 60000000 * X_2 - 60000000 * X_3 - 60000000 * X_4 - 60000000 * X_5 - 60000000 * X_6 + 35768196000 ;

[_2] 0 <= 29600 ;

[_3] 0 <= 87200 ;

[_4] 0 <= 175100 ;

[_5] YIJT_1_1_1 + YIJT_1_2_1 + YIJT_1_3_1 + YIJT_1_4_1 + YIJT_1_5_1 + YIJT_1_6_1 <= 39200 ;

[_6] YIJT_1_1_2 + YIJT_1_2_2 + YIJT_1_3_2 + YIJT_1_4_2 + YIJT_1_5_2 + YIJT_1_6_2 <= 19600 ;

[_7] YIJT_1_1_3 + YIJT_1_2_3 + YIJT_1_3_3 + YIJT_1_4_3 + YIJT_1_5_3 + YIJT_1_6_3 <= 29792 ;

[_8] YIJT_2_1_1 + YIJT_2_2_1 + YIJT_2_3_1 + YIJT_2_4_1 + YIJT_2_5_1 +

YIJT_2_6_1 <= 50470 ;

[_9] YIJT_2_1_2 + YIJT_2_2_2 + YIJT_2_3_2 + YIJT_2_4_2 + YIJT_2_5_2 + YIJT_2_6_2 <= 29792 ;

[_10] YIJT_2_1_3 + YIJT_2_2_3 + YIJT_2_3_3 + YIJT_2_4_3 + YIJT_2_5_3 + YIJT_2_6_3 <= 40082 ;

[_11] YIJT_3_1_1 + YIJT_3_2_1 + YIJT_3_3_1 + YIJT_3_4_1 + YIJT_3_5_1 + YIJT_3_6_1 <= 70462 ;

[_12] YIJT_3_1_2 + YIJT_3_2_2 + YIJT_3_3_2 + YIJT_3_4_2 + YIJT_3_5_2 + YIJT_3_6_2 <= 50470 ;

[_13] YIJT_3_1_3 + YIJT_3_2_3 + YIJT_3_3_3 + YIJT_3_4_3 + YIJT_3_5_3 + YIJT_3_6_3 <= 60270 ;

[_14] - ZJKT_1_1_1 - ZJKT_1_2_1 - ZJKT_1_3_1 - ZJKT_1_4_1 - ZJKT_1_5_1 - ZJKT_1_6_1 + 0.98 * YIJT_1_1_1 + 0.98 * YIJT_2_1_1 + 0.98 * YIJT_3_1_1 >= 0 ;

[_15] - ZJKT_1_1_2 - ZJKT_1_2_2 - ZJKT_1_3_2 - ZJKT_1_4_2 - ZJKT_1_5_2 - ZJKT_1_6_2 + 0.98 * YIJT_1_1_2 + 0.98 * YIJT_2_1_2 + 0.98 * YIJT_3_1_2 >= 0 ;

[_16] - ZJKT_1_1_3 - ZJKT_1_2_3 - ZJKT_1_3_3 - ZJKT_1_4_3 - ZJKT_1_5_3 - ZJKT_1_6_3 + 0.98 * YIJT_1_1_3 + 0.98 * YIJT_2_1_3 + 0.98 * YIJT_3_1_3 >= 0 ;

[_17] - ZJKT_2_1_1 - ZJKT_2_2_1 - ZJKT_2_3_1 - ZJKT_2_4_1 - ZJKT_2_5_1 - ZJKT_2_6_1 + 0.98 * YIJT_1_2_1 + 0.98 * YIJT_2_2_1 + 0.98 * YIJT_3_2_1 >= 0 ;

[_18] - ZJKT_2_1_2 - ZJKT_2_2_2 - ZJKT_2_3_2 - ZJKT_2_4_2 - ZJKT_2_5_2 - ZJKT_2_6_2 + 0.98 * YIJT_1_2_2 + 0.98 * YIJT_2_2_2 + 0.98 * YIJT_3_2_2 >= 0 ;

[_19] - ZJKT_2_1_3 - ZJKT_2_2_3 - ZJKT_2_3_3 - ZJKT_2_4_3 - ZJKT_2_5_3 - ZJKT_2_6_3 + 0.98 * YIJT_1_2_3 + 0.98 * YIJT_2_2_3 + 0.98 * YIJT_3_2_3 >= 0 ;

[_20] - ZJKT_3_1_1 - ZJKT_3_2_1 - ZJKT_3_3_1 - ZJKT_3_4_1 - ZJKT_3_5_1 - ZJKT_3_6_1 + 0.98 * YIJT_1_3_1 + 0.98 * YIJT_2_3_1 + 0.98 * YIJT_3_3_1 >= 0 ;

[_21] - ZJKT_3_1_2 - ZJKT_3_2_2 - ZJKT_3_3_2 - ZJKT_3_4_2 - ZJKT_3_5_2 - ZJKT_3_6_2 + 0.98 * YIJT_1_3_2 + 0.98 * YIJT_2_3_2 + 0.98 * YIJT_3_3_2 >= 0 ;

[_22] - ZJKT_3_1_3 - ZJKT_3_2_3 - ZJKT_3_3_3 - ZJKT_3_4_3 - ZJKT_3_5_3 - ZJKT_3_6_3 + 0.98 * YIJT_1_3_3 + 0.98 * YIJT_2_3_3 + 0.98 * YIJT_3_3_3 >= 0 ;

[_23] - ZJKT_4_1_1 - ZJKT_4_2_1 - ZJKT_4_3_1 - ZJKT_4_4_1 - ZJKT_4_5_1 - ZJKT_4_6_1 + 0.98 * YIJT_1_4_1 + 0.98 * YIJT_2_4_1 + 0.98 * YIJT_3_4_1 >= 0 ;

[_24] - ZJKT_4_1_2 - ZJKT_4_2_2 - ZJKT_4_3_2 - ZJKT_4_4_2 - ZJKT_4_5_2 - ZJKT_4_6_2 + 0.98 * YIJT_1_4_2 + 0.98 * YIJT_2_4_2 + 0.98 * YIJT_3_4_2 >= 0 ;

[_25] - ZJKT_4_1_3 - ZJKT_4_2_3 - ZJKT_4_3_3 - ZJKT_4_4_3 - ZJKT_4_5_3 - ZJKT_4_6_3 + 0.98 * YIJT_1_4_3 + 0.98 * YIJT_2_4_3 + 0.98 * YIJT_3_4_3 >= 0 ;

[_26] - ZJKT_5_1_1 - ZJKT_5_2_1 - ZJKT_5_3_1 - ZJKT_5_4_1 - ZJKT_5_5_1 - ZJKT_5_6_1 + 0.98 * YIJT_1_5_1 + 0.98 * YIJT_2_5_1 + 0.98 * YIJT_3_5_1 >= 0 ;

[_27] - ZJKT_5_1_2 - ZJKT_5_2_2 - ZJKT_5_3_2 - ZJKT_5_4_2 - ZJKT_5_5_2 -

ZJKT_5_6_2 + 0.98 * YIJT_1_5_2 + 0.98 * YIJT_2_5_2 + 0.98 * YIJT_3_5_2 >= 0 ;
[_28] - ZJKT_5_1_3 - ZJKT_5_2_3 - ZJKT_5_3_3 - ZJKT_5_4_3 - ZJKT_5_5_3 - ZJKT_5_6_3 + 0.98 * YIJT_1_5_3 + 0.98 * YIJT_2_5_3 + 0.98 * YIJT_3_5_3 >= 0 ;
[_29] - ZJKT_6_1_1 - ZJKT_6_2_1 - ZJKT_6_3_1 - ZJKT_6_4_1 - ZJKT_6_5_1 - ZJKT_6_6_1 + 0.98 * YIJT_1_6_1 + 0.98 * YIJT_2_6_1 + 0.98 * YIJT_3_6_1 >= 0 ;
[_30] - ZJKT_6_1_2 - ZJKT_6_2_2 - ZJKT_6_3_2 - ZJKT_6_4_2 - ZJKT_6_5_2 - ZJKT_6_6_2 + 0.98 * YIJT_1_6_2 + 0.98 * YIJT_2_6_2 + 0.98 * YIJT_3_6_2 >= 0 ;
[_31] - ZJKT_6_1_3 - ZJKT_6_2_3 - ZJKT_6_3_3 - ZJKT_6_4_3 - ZJKT_6_5_3 - ZJKT_6_6_3 + 0.98 * YIJT_1_6_3 + 0.98 * YIJT_2_6_3 + 0.98 * YIJT_3_6_3 >= 0 ;
[_32] ZJKT_1_1_1 + ZJKT_1_1_2 + ZJKT_1_1_3 + ZJKT_1_2_1 + ZJKT_1_2_2 + ZJKT_1_2_3 + ZJKT_1_3_1 + ZJKT_1_3_2 + ZJKT_1_3_3 + ZJKT_1_4_1 + ZJKT_1_4_2 + ZJKT_1_4_3 + ZJKT_1_5_1 + ZJKT_1_5_2 + ZJKT_1_5_3 + ZJKT_1_6_1 + ZJKT_1_6_2 + ZJKT_1_6_3 - 200000 * X_1 <= 0 ;
[_33] ZJKT_2_1_1 + ZJKT_2_1_2 + ZJKT_2_1_3 + ZJKT_2_2_1 + ZJKT_2_2_2 + ZJKT_2_2_3 + ZJKT_2_3_1 + ZJKT_2_3_2 + ZJKT_2_3_3 + ZJKT_2_4_1 + ZJKT_2_4_2 + ZJKT_2_4_3 + ZJKT_2_5_1 + ZJKT_2_5_2 + ZJKT_2_5_3 + ZJKT_2_6_1 + ZJKT_2_6_2 + ZJKT_2_6_3 - 200000 * X_2 <= 0 ;
[_34] ZJKT_3_1_1 + ZJKT_3_1_2 + ZJKT_3_1_3 + ZJKT_3_2_1 + ZJKT_3_2_2 + ZJKT_3_2_3 + ZJKT_3_3_1 + ZJKT_3_3_2 + ZJKT_3_3_3 + ZJKT_3_4_1 + ZJKT_3_4_2 + ZJKT_3_4_3 + ZJKT_3_5_1 + ZJKT_3_5_2 + ZJKT_3_5_3 + ZJKT_3_6_1 + ZJKT_3_6_2 + ZJKT_3_6_3 - 200000 * X_3 <= 0 ;
[_35] ZJKT_4_1_1 + ZJKT_4_1_2 + ZJKT_4_1_3 + ZJKT_4_2_1 + ZJKT_4_2_2 + ZJKT_4_2_3 + ZJKT_4_3_1 + ZJKT_4_3_2 + ZJKT_4_3_3 + ZJKT_4_4_1 + ZJKT_4_4_2 + ZJKT_4_4_3 + ZJKT_4_5_1 + ZJKT_4_5_2 + ZJKT_4_5_3 + ZJKT_4_6_1 + ZJKT_4_6_2 + ZJKT_4_6_3 - 200000 * X_4 <= 0 ;
[_36] ZJKT_5_1_1 + ZJKT_5_1_2 + ZJKT_5_1_3 + ZJKT_5_2_1 + ZJKT_5_2_2 + ZJKT_5_2_3 + ZJKT_5_3_1 + ZJKT_5_3_2 + ZJKT_5_3_3 + ZJKT_5_4_1 + ZJKT_5_4_2 + ZJKT_5_4_3 + ZJKT_5_5_1 + ZJKT_5_5_2 + ZJKT_5_5_3 + ZJKT_5_6_1 + ZJKT_5_6_2 + ZJKT_5_6_3 - 200000 * X_5 <= 0 ;
[_37] ZJKT_6_1_1 + ZJKT_6_1_2 + ZJKT_6_1_3 + ZJKT_6_2_1 + ZJKT_6_2_2 + ZJKT_6_2_3 + ZJKT_6_3_1 + ZJKT_6_3_2 + ZJKT_6_3_3 + ZJKT_6_4_1 + ZJKT_6_4_2 + ZJKT_6_4_3 + ZJKT_6_5_1 + ZJKT_6_5_2 + ZJKT_6_5_3 + ZJKT_6_6_1 + ZJKT_6_6_2 + ZJKT_6_6_3 - 200000 * X_6 <= 0 ;
[_38] ZJKT_1_1_1 + ZJKT_2_1_1 + ZJKT_3_1_1 + ZJKT_4_1_1 + ZJKT_5_1_1 + ZJKT_6_1_1 >= 48991 ;
[_39] ZJKT_1_1_2 + ZJKT_2_1_2 + ZJKT_3_1_2 + ZJKT_4_1_2 + ZJKT_5_1_2 + ZJKT_6_1_2 >= 30619 ;
[_40] ZJKT_1_1_3 + ZJKT_2_1_3 + ZJKT_3_1_3 + ZJKT_4_1_3 + ZJKT_5_1_3 +

ZJKT_6_1_3 >= 42867 ;

[_41] ZJKT_1_2_1 + ZJKT_2_2_1 + ZJKT_3_2_1 + ZJKT_4_2_1 + ZJKT_5_2_1 + ZJKT_6_2_1 >= 14874 ;

[_42] ZJKT_1_2_2 + ZJKT_2_2_2 + ZJKT_3_2_2 + ZJKT_4_2_2 + ZJKT_5_2_2 + ZJKT_6_2_2 >= 9296 ;

[_43] ZJKT_1_2_3 + ZJKT_2_2_3 + ZJKT_3_2_3 + ZJKT_4_2_3 + ZJKT_5_2_3 + ZJKT_6_2_3 >= 13015 ;

[_44] ZJKT_1_3_1 + ZJKT_2_3_1 + ZJKT_3_3_1 + ZJKT_4_3_1 + ZJKT_5_3_1 + ZJKT_6_3_1 >= 11552 ;

[_45] ZJKT_1_3_2 + ZJKT_2_3_2 + ZJKT_3_3_2 + ZJKT_4_3_2 + ZJKT_5_3_2 + ZJKT_6_3_2 >= 7220 ;

[_46] ZJKT_1_3_3 + ZJKT_2_3_3 + ZJKT_3_3_3 + ZJKT_4_3_3 + ZJKT_5_3_3 + ZJKT_6_3_3 >= 10108 ;

[_47] ZJKT_1_4_1 + ZJKT_2_4_1 + ZJKT_3_4_1 + ZJKT_4_4_1 + ZJKT_5_4_1 + ZJKT_6_4_1 >= 46321 ;

[_48] ZJKT_1_4_2 + ZJKT_2_4_2 + ZJKT_3_4_2 + ZJKT_4_4_2 + ZJKT_5_4_2 + ZJKT_6_4_2 >= 28950 ;

[_49] ZJKT_1_4_3 + ZJKT_2_4_3 + ZJKT_3_4_3 + ZJKT_4_4_3 + ZJKT_5_4_3 + ZJKT_6_4_3 >= 40531 ;

[_50] ZJKT_1_5_1 + ZJKT_2_5_1 + ZJKT_3_5_1 + ZJKT_4_5_1 + ZJKT_5_5_1 + ZJKT_6_5_1 >= 12375 ;

[_51] ZJKT_1_5_2 + ZJKT_2_5_2 + ZJKT_3_5_2 + ZJKT_4_5_2 + ZJKT_5_5_2 + ZJKT_6_5_2 >= 7734 ;

[_52] ZJKT_1_5_3 + ZJKT_2_5_3 + ZJKT_3_5_3 + ZJKT_4_5_3 + ZJKT_5_5_3 + ZJKT_6_5_3 >= 10828 ;

[_53] ZJKT_1_6_1 + ZJKT_2_6_1 + ZJKT_3_6_1 + ZJKT_4_6_1 + ZJKT_5_6_1 + ZJKT_6_6_1 >= 11583 ;

[_54] ZJKT_1_6_2 + ZJKT_2_6_2 + ZJKT_3_6_2 + ZJKT_4_6_2 + ZJKT_5_6_2 + ZJKT_6_6_2 >= 7239 ;

[_55] ZJKT_1_6_3 + ZJKT_2_6_3 + ZJKT_3_6_3 + ZJKT_4_6_3 + ZJKT_5_6_3 + ZJKT_6_6_3 >= 10135 ;

[_59] - YIJT_1_1_1 - YIJT_1_2_1 - YIJT_1_3_1 - YIJT_1_4_1 - YIJT_1_5_1 - YIJT_1_6_1 - INVENTORYP_1_1 = - 40500 ;

[_60] - YIJT_2_1_1 - YIJT_2_2_1 - YIJT_2_3_1 - YIJT_2_4_1 - YIJT_2_5_1 - YIJT_2_6_1 - INVENTORYP_2_1 = - 52000 ;

[_61] - YIJT_3_1_1 - YIJT_3_2_1 - YIJT_3_3_1 - YIJT_3_4_1 - YIJT_3_5_1 - YIJT_3_6_1 - INVENTORYP_3_1 = - 72400 ;

[_62] - YIJT_1_1_2 - YIJT_1_2_2 - YIJT_1_3_2 - YIJT_1_4_2 - YIJT_1_5_2 -

YIJT_1_6_2 + INVENTORYP_1_1 - INVENTORYP_1_2 = - 20000 ;
[_63] - YIJT_1_1_3 - YIJT_1_2_3 - YIJT_1_3_3 - YIJT_1_4_3 - YIJT_1_5_3 -
YIJT_1_6_3 + INVENTORYP_1_2 - INVENTORYP_1_3 = - 30400 ;
[_64] - YIJT_2_1_2 - YIJT_2_2_2 - YIJT_2_3_2 - YIJT_2_4_2 - YIJT_2_5_2 -
YIJT_2_6_2 + INVENTORYP_2_1 - INVENTORYP_2_2 = - 30400 ;
[_65] - YIJT_2_1_3 - YIJT_2_2_3 - YIJT_2_3_3 - YIJT_2_4_3 - YIJT_2_5_3 -
YIJT_2_6_3 + INVENTORYP_2_2 - INVENTORYP_2_3 = - 40900 ;
[_66] - YIJT_3_1_2 - YIJT_3_2_2 - YIJT_3_3_2 - YIJT_3_4_2 - YIJT_3_5_2 -
YIJT_3_6_2 + INVENTORYP_3_1 - INVENTORYP_3_2 = - 51500 ;
[_67] - YIJT_3_1_3 - YIJT_3_2_3 - YIJT_3_3_3 - YIJT_3_4_3 - YIJT_3_5_3 -
YIJT_3_6_3 + INVENTORYP_3_2 - INVENTORYP_3_3 = - 61500 ;
[_68] INITIALINVW_1_1 - 500 * X_1 = 0 ;
[_69] INITIALINVW_2_1 - 500 * X_2 = 0 ;
[_70] INITIALINVW_3_1 - 500 * X_3 = 0 ;
[_71] INITIALINVW_4_1 - 500 * X_4 = 0 ;
[_72] INITIALINVW_5_1 - 500 * X_5 = 0 ;
[_73] INITIALINVW_6_1 - 500 * X_6 = 0 ;
[_74] INITIALINVW_1_1 - INVENTORYW_1_1 - ZJKT_1_1_1 - ZJKT_1_2_1 -
ZJKT_1_3_1 - ZJKT_1_4_1 - ZJKT_1_5_1 - ZJKT_1_6_1 + YIJT_1_1_1 +
YIJT_2_1_1 + YIJT_3_1_1 = 0 ;
[_75] INITIALINVW_2_1 - INVENTORYW_2_1 - ZJKT_2_1_1 - ZJKT_2_2_1 -
ZJKT_2_3_1 - ZJKT_2_4_1 - ZJKT_2_5_1 - ZJKT_2_6_1 + YIJT_1_2_1 +
YIJT_2_2_1 + YIJT_3_2_1 = 0 ;
[_76] INITIALINVW_3_1 - INVENTORYW_3_1 - ZJKT_3_1_1 - ZJKT_3_2_1 -
ZJKT_3_3_1 - ZJKT_3_4_1 - ZJKT_3_5_1 - ZJKT_3_6_1 + YIJT_1_3_1 +
YIJT_2_3_1 + YIJT_3_3_1 = 0 ;
[_77] INITIALINVW_4_1 - INVENTORYW_4_1 - ZJKT_4_1_1 - ZJKT_4_2_1 -
ZJKT_4_3_1 - ZJKT_4_4_1 - ZJKT_4_5_1 - ZJKT_4_6_1 + YIJT_1_4_1 +
YIJT_2_4_1 + YIJT_3_4_1 = 0 ;
[_78] INITIALINVW_5_1 - INVENTORYW_5_1 - ZJKT_5_1_1 - ZJKT_5_2_1 -
ZJKT_5_3_1 - ZJKT_5_4_1 - ZJKT_5_5_1 - ZJKT_5_6_1 + YIJT_1_5_1 +
YIJT_2_5_1 + YIJT_3_5_1 = 0 ;
[_79] INITIALINVW_6_1 - INVENTORYW_6_1 - ZJKT_6_1_1 - ZJKT_6_2_1 -
ZJKT_6_3_1 - ZJKT_6_4_1 - ZJKT_6_5_1 - ZJKT_6_6_1 + YIJT_1_6_1 +
YIJT_2_6_1 + YIJT_3_6_1 = 0 ;
[_80] INVENTORYW_1_1 - INVENTORYW_1_2 - ZJKT_1_1_2 - ZJKT_1_2_2 -
ZJKT_1_3_2 - ZJKT_1_4_2 - ZJKT_1_5_2 - ZJKT_1_6_2 + YIJT_1_1_2 +
YIJT_2_1_2 + YIJT_3_1_2 = 0 ;

[_81] INVENTORYW_1_2 - INVENTORYW_1_3 - ZJKT_1_1_3 - ZJKT_1_2_3 - ZJKT_1_3_3 - ZJKT_1_4_3 - ZJKT_1_5_3 - ZJKT_1_6_3 + YIJT_1_1_3 + YIJT_2_1_3 + YIJT_3_1_3 = 0 ;
[_82] INVENTORYW_2_1 - INVENTORYW_2_2 - ZJKT_2_1_2 - ZJKT_2_2_2 - ZJKT_2_3_2 - ZJKT_2_4_2 - ZJKT_2_5_2 - ZJKT_2_6_2 + YIJT_1_2_2 + YIJT_2_2_2 + YIJT_3_2_2 = 0 ;
[_83] INVENTORYW_2_2 - INVENTORYW_2_3 - ZJKT_2_1_3 - ZJKT_2_2_3 - ZJKT_2_3_3 - ZJKT_2_4_3 - ZJKT_2_5_3 - ZJKT_2_6_3 + YIJT_1_2_3 + YIJT_2_2_3 + YIJT_3_2_3 = 0 ;
[_84] INVENTORYW_3_1 - INVENTORYW_3_2 - ZJKT_3_1_2 - ZJKT_3_2_2 - ZJKT_3_3_2 - ZJKT_3_4_2 - ZJKT_3_5_2 - ZJKT_3_6_2 + YIJT_1_3_2 + YIJT_2_3_2 + YIJT_3_3_2 = 0 ;
[_85] INVENTORYW_3_2 - INVENTORYW_3_3 - ZJKT_3_1_3 - ZJKT_3_2_3 - ZJKT_3_3_3 - ZJKT_3_4_3 - ZJKT_3_5_3 - ZJKT_3_6_3 + YIJT_1_3_3 + YIJT_2_3_3 + YIJT_3_3_3 = 0 ;
[_86] INVENTORYW_4_1 - INVENTORYW_4_2 - ZJKT_4_1_2 - ZJKT_4_2_2 - ZJKT_4_3_2 - ZJKT_4_4_2 - ZJKT_4_5_2 - ZJKT_4_6_2 + YIJT_1_4_2 + YIJT_2_4_2 + YIJT_3_4_2 = 0 ;
[_87] INVENTORYW_4_2 - INVENTORYW_4_3 - ZJKT_4_1_3 - ZJKT_4_2_3 - ZJKT_4_3_3 - ZJKT_4_4_3 - ZJKT_4_5_3 - ZJKT_4_6_3 + YIJT_1_4_3 + YIJT_2_4_3 + YIJT_3_4_3 = 0 ;
[_88] INVENTORYW_5_1 - INVENTORYW_5_2 - ZJKT_5_1_2 - ZJKT_5_2_2 - ZJKT_5_3_2 - ZJKT_5_4_2 - ZJKT_5_5_2 - ZJKT_5_6_2 + YIJT_1_5_2 + YIJT_2_5_2 + YIJT_3_5_2 = 0 ;
[_89] INVENTORYW_5_2 - INVENTORYW_5_3 - ZJKT_5_1_3 - ZJKT_5_2_3 - ZJKT_5_3_3 - ZJKT_5_4_3 - ZJKT_5_5_3 - ZJKT_5_6_3 + YIJT_1_5_3 + YIJT_2_5_3 + YIJT_3_5_3 = 0 ;
[_90] INVENTORYW_6_1 - INVENTORYW_6_2 - ZJKT_6_1_2 - ZJKT_6_2_2 - ZJKT_6_3_2 - ZJKT_6_4_2 - ZJKT_6_5_2 - ZJKT_6_6_2 + YIJT_1_6_2 + YIJT_2_6_2 + YIJT_3_6_2 = 0 ;
[_91] INVENTORYW_6_2 - INVENTORYW_6_3 - ZJKT_6_1_3 - ZJKT_6_2_3 - ZJKT_6_3_3 - ZJKT_6_4_3 - ZJKT_6_5_3 - ZJKT_6_6_3 + YIJT_1_6_3 + YIJT_2_6_3 + YIJT_3_6_3 = 0 ;
[_98] ZJKT_1_1_1 + ZJKT_2_1_1 + ZJKT_3_1_1 + ZJKT_4_1_1 + ZJKT_5_1_1 + ZJKT_6_1_1 - INVENTORYM_1_1 = 48491 ;
[_99] ZJKT_1_2_1 + ZJKT_2_2_1 + ZJKT_3_2_1 + ZJKT_4_2_1 + ZJKT_5_2_1 + ZJKT_6_2_1 - INVENTORYM_2_1 = 14374 ;
[_100] ZJKT_1_3_1 + ZJKT_2_3_1 + ZJKT_3_3_1 + ZJKT_4_3_1 + ZJKT_5_3_1 +

ZJKT_6_3_1 - INVENTORYM_3_1 = 11052 ;
[_101] ZJKT_1_4_1 + ZJKT_2_4_1 + ZJKT_3_4_1 + ZJKT_4_4_1 + ZJKT_5_4_1 + ZJKT_6_4_1 - INVENTORYM_4_1 = 45821 ;
[_102] ZJKT_1_5_1 + ZJKT_2_5_1 + ZJKT_3_5_1 + ZJKT_4_5_1 + ZJKT_5_5_1 + ZJKT_6_5_1 - INVENTORYM_5_1 = 11875 ;
[_103] ZJKT_1_6_1 + ZJKT_2_6_1 + ZJKT_3_6_1 + ZJKT_4_6_1 + ZJKT_5_6_1 + ZJKT_6_6_1 - INVENTORYM_6_1 = 11083 ;
[_104] ZJKT_1_1_2 + ZJKT_2_1_2 + ZJKT_3_1_2 + ZJKT_4_1_2 + ZJKT_5_1_2 + ZJKT_6_1_2 + INVENTORYM_1_1 - INVENTORYM_1_2 = 30619 ;
[_105] ZJKT_1_1_3 + ZJKT_2_1_3 + ZJKT_3_1_3 + ZJKT_4_1_3 + ZJKT_5_1_3 + ZJKT_6_1_3 + INVENTORYM_1_2 - INVENTORYM_1_3 = 42867 ;
[_106] ZJKT_1_2_2 + ZJKT_2_2_2 + ZJKT_3_2_2 + ZJKT_4_2_2 + ZJKT_5_2_2 + ZJKT_6_2_2 + INVENTORYM_2_1 - INVENTORYM_2_2 = 9296 ;
[_107] ZJKT_1_2_3 + ZJKT_2_2_3 + ZJKT_3_2_3 + ZJKT_4_2_3 + ZJKT_5_2_3 + ZJKT_6_2_3 + INVENTORYM_2_2 - INVENTORYM_2_3 = 13015 ;
[_108] ZJKT_1_3_2 + ZJKT_2_3_2 + ZJKT_3_3_2 + ZJKT_4_3_2 + ZJKT_5_3_2 + ZJKT_6_3_2 + INVENTORYM_3_1 - INVENTORYM_3_2 = 7220 ;
[_109] ZJKT_1_3_3 + ZJKT_2_3_3 + ZJKT_3_3_3 + ZJKT_4_3_3 + ZJKT_5_3_3 + ZJKT_6_3_3 + INVENTORYM_3_2 - INVENTORYM_3_3 = 10108 ;
[_110] ZJKT_1_4_2 + ZJKT_2_4_2 + ZJKT_3_4_2 + ZJKT_4_4_2 + ZJKT_5_4_2 + ZJKT_6_4_2 + INVENTORYM_4_1 - INVENTORYM_4_2 = 28950 ;
[_111] ZJKT_1_4_3 + ZJKT_2_4_3 + ZJKT_3_4_3 + ZJKT_4_4_3 + ZJKT_5_4_3 + ZJKT_6_4_3 + INVENTORYM_4_2 - INVENTORYM_4_3 = 40531 ;
[_112] ZJKT_1_5_2 + ZJKT_2_5_2 + ZJKT_3_5_2 + ZJKT_4_5_2 + ZJKT_5_5_2 + ZJKT_6_5_2 + INVENTORYM_5_1 - INVENTORYM_5_2 = 7734 ;
[_113] ZJKT_1_5_3 + ZJKT_2_5_3 + ZJKT_3_5_3 + ZJKT_4_5_3 + ZJKT_5_5_3 + ZJKT_6_5_3 + INVENTORYM_5_2 - INVENTORYM_5_3 = 10828 ;
[_114] ZJKT_1_6_2 + ZJKT_2_6_2 + ZJKT_3_6_2 + ZJKT_4_6_2 + ZJKT_5_6_2 + ZJKT_6_6_2 + INVENTORYM_6_1 - INVENTORYM_6_2 = 7239 ;
[_115] ZJKT_1_6_3 + ZJKT_2_6_3 + ZJKT_3_6_3 + ZJKT_4_6_3 + ZJKT_5_6_3 + ZJKT_6_6_3 + INVENTORYM_6_2 - INVENTORYM_6_3 = 10135 ;
[_116] - 0.05 * ZJKT_1_1_1 - 0.05 * ZJKT_2_1_1 - 0.05 * ZJKT_3_1_1 - 0.05 * ZJKT_4_1_1 - 0.05 * ZJKT_5_1_1 - 0.05 * ZJKT_6_1_1 + INVENTORYM_1_1 >= 0 ;
[_117] - 0.05 * ZJKT_1_1_2 - 0.05 * ZJKT_2_1_2 - 0.05 * ZJKT_3_1_2 - 0.05 * ZJKT_4_1_2 - 0.05 * ZJKT_5_1_2 - 0.05 * ZJKT_6_1_2 + INVENTORYM_1_2 >= 0 ;
[_118] - 0.05 * ZJKT_1_1_3 - 0.05 * ZJKT_2_1_3 - 0.05 * ZJKT_3_1_3 - 0.05 * ZJKT_4_1_3 - 0.05 * ZJKT_5_1_3 - 0.05 * ZJKT_6_1_3 + INVENTORYM_1_3 >= 0 ;

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[_119] - 0.05 * ZJKT_1_2_1 - 0.05 * ZJKT_2_2_1 - 0.05 * ZJKT_3_2_1 -
0.05 * ZJKT_4_2_1 - 0.05 * ZJKT_5_2_1 - 0.05 * ZJKT_6_2_1 + INVENTORYM_2_1 >= 0 ;
[_120] - 0.05 * ZJKT_1_2_2 - 0.05 * ZJKT_2_2_2 - 0.05 * ZJKT_3_2_2 -
0.05 * ZJKT_4_2_2 - 0.05 * ZJKT_5_2_2 - 0.05 * ZJKT_6_2_2 + INVENTORYM_2_2 >= 0 ;
[_121] - 0.05 * ZJKT_1_2_3 - 0.05 * ZJKT_2_2_3 - 0.05 * ZJKT_3_2_3 -
0.05 * ZJKT_4_2_3 - 0.05 * ZJKT_5_2_3 - 0.05 * ZJKT_6_2_3 + INVENTORYM_2_3 >= 0 ;
[_122] - 0.05 * ZJKT_1_3_1 - 0.05 * ZJKT_2_3_1 - 0.05 * ZJKT_3_3_1 -
0.05 * ZJKT_4_3_1 - 0.05 * ZJKT_5_3_1 - 0.05 * ZJKT_6_3_1 +INVENTORYM_3_1 >= 0 ;
[_123] - 0.05 * ZJKT_1_3_2 - 0.05 * ZJKT_2_3_2 - 0.05 * ZJKT_3_3_2 -
0.05 * ZJKT_4_3_2 - 0.05 * ZJKT_5_3_2 - 0.05 * ZJKT_6_3_2 +INVENTORYM_3_2 >= 0 ;
[_124] - 0.05 * ZJKT_1_3_3 - 0.05 * ZJKT_2_3_3 - 0.05 * ZJKT_3_3_3 -
0.05 * ZJKT_4_3_3 - 0.05 * ZJKT_5_3_3 - 0.05 * ZJKT_6_3_3 +INVENTORYM_3_3 >= 0 ;
[_125] - 0.05 * ZJKT_1_4_1 - 0.05 * ZJKT_2_4_1 - 0.05 * ZJKT_3_4_1 -
0.05 * ZJKT_4_4_1 - 0.05 * ZJKT_5_4_1 - 0.05 * ZJKT_6_4_1 +INVENTORYM_4_1 >= 0 ;
[_126] - 0.05 * ZJKT_1_4_2 - 0.05 * ZJKT_2_4_2 - 0.05 * ZJKT_3_4_2 -
0.05 * ZJKT_4_4_2 - 0.05 * ZJKT_5_4_2 - 0.05 * ZJKT_6_4_2 +INVENTORYM_4_2 >= 0 ;
[_127] - 0.05 * ZJKT_1_4_3 - 0.05 * ZJKT_2_4_3 - 0.05 * ZJKT_3_4_3 -
0.05 * ZJKT_4_4_3 - 0.05 * ZJKT_5_4_3 - 0.05 * ZJKT_6_4_3 +INVENTORYM_4_3 >= 0 ;
[_128] - 0.05 * ZJKT_1_5_1 - 0.05 * ZJKT_2_5_1 - 0.05 * ZJKT_3_5_1 -
0.05 * ZJKT_4_5_1 - 0.05 * ZJKT_5_5_1 - 0.05 * ZJKT_6_5_1 + INVENTORYM_5_1 >= 0 ;
[_129] - 0.05 * ZJKT_1_5_2 - 0.05 * ZJKT_2_5_2 - 0.05 * ZJKT_3_5_2 -
0.05 * ZJKT_4_5_2 - 0.05 * ZJKT_5_5_2 - 0.05 * ZJKT_6_5_2 + INVENTORYM_5_2 >= 0 ;
[_130] - 0.05 * ZJKT_1_5_3 - 0.05 * ZJKT_2_5_3 - 0.05 * ZJKT_3_5_3 -
0.05 * ZJKT_4_5_3 - 0.05 * ZJKT_5_5_3 - 0.05 * ZJKT_6_5_3 + INVENTORYM_5_3 >= 0 ;
[_131] - 0.05 * ZJKT_1_6_1 - 0.05 * ZJKT_2_6_1 - 0.05 * ZJKT_3_6_1 -
0.05 * ZJKT_4_6_1 - 0.05 * ZJKT_5_6_1 - 0.05 * ZJKT_6_6_1 +INVENTORYM_6_1 >= 0 ;
[_132] - 0.05 * ZJKT_1_6_2 - 0.05 * ZJKT_2_6_2 - 0.05 * ZJKT_3_6_2 -
0.05 * ZJKT_4_6_2 - 0.05 * ZJKT_5_6_2 - 0.05 * ZJKT_6_6_2 + INVENTORYM_6_2 >= 0 ;
[_133] - 0.05 * ZJKT_1_6_3 - 0.05 * ZJKT_2_6_3 - 0.05 * ZJKT_3_6_3 -
0.05 * ZJKT_4_6_3 - 0.05 * ZJKT_5_6_3 - 0.05 * ZJKT_6_6_3 + INVENTORYM_6_3 >= 0 ;
@BIN( X_1); @BIN( X_2); @BIN( X_3); @BIN( X_4); @BIN( X_5); @BIN( X_6);
END
```

Appendix: C Optimization Results

Scenario One

Objective value = 0.2845499 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	8160.25	15505.9	16113.9
Production		40000	20000	30400
Shipment out		32339.8	12654.3	29792

Plant 2				
Period	0	1	2	3
Inventory	500	1530	2138	3014.28
Production		51500	30400	40900
Shipment out		50470	29792	40023.7

Plant 3				
Period	0	1	2	3
Inventory	500	1938	2968	4198.01
Production		71900	51500	61500
Shipment out		70462	50470	60270

Distribution Center 1				
Period	0	1	2	3
Inventory	500	1087.36	1665.98	2540.81
Shipment in		29367.8	28931.2	43741.8
Shipment out		28780.5	28352.5	42867

Distribution Center 2				
Period	0	1	2	3
Inventory	500	808.78	1044.75	1310.36
Shipment in		15439.3	11798.4	13280.6
Shipment out		15130.5	11562.5	13015

Distribution Center 4				
Period	0	1	2	3
Inventory	500	1421.81	1713.66	2540.82
Shipment in		46090.2	14592.5	41358.2
Shipment out		45168.4	14300.6	40531

Distribution Center 5				
Period	0	1	2	3
Inventory	500	1509.41	2113.56	2540.83
Shipment in		50470	30207.6	21363.3
Shipment out		49460.6	29603.4	20936

Distribution Center 6				
Period	0	1	2	3
Inventory	500	738.08	885.815	1092.66
Shipment in		11904.4	7386.74	10341.8
Shipment out		11666.3	7239	10135

Market 1				
Period	0	1	2	3
Inventory	500	2552.15	2552.15	2552.15
Shipment in		51043.2	30619	42867
Demand		48991	30619	42867

Market 2				
Period	0	1	2	3
Inventory	500	756.53	756.53	756.53
Shipment in		15130.5	9296	13015
Demand		14874	9296	13015

Market 3				
Period	0	1	2	3
Inventory	500	581.68	581.68	581.68
Shipment in		11633.7	7220	10108
Demand		11552	7220	10108

Market 4				
Period	0	1	2	3
Inventory	500	2411.63	2411.63	2411.63
Shipment in		48232.6	28950	40531
Demand		46321	28950	40531

Market 5				
Period	0	1	2	3
Inventory	500	625	625	625
Shipment in		12500	7734	10828
Demand		12375	7734	10828

Market 6				
Period	0	1	2	3
Inventory	500	583.32	583.32	583.32
Shipment in		11666.3	7239	10135
Demand		11583	7239	10135

Scenario Two

Objective value = 0.2912741 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	8160.25	15505.9	16113.9
Production		40000	20000	30400
Shipment out		32339.8	12654.3	29792

Plant 2				
Period	0	1	2	3
Inventory	500	1530	2138	2956
Production		51500	30400	40900
Shipment out		50470	29792	40082

Plant 3				
Period	0	1	2	3
Inventory	500	1938	2968	4256.28
Production		71900	51500	61500
Shipment out		70462	50470	60211.7

Distribution Center 1				
Period	0	1	2	3
Inventory	500	2088.56	3050.89	4398.17
Shipment in		79428.6	48116.3	67364.3
Shipment out		77840	47154	66017

Distribution Center 5				
Period	0	1	2	3
Inventory	500	1976.87	2872.87	4127.3
Shipment in		73843.2	44800	62721.4
Shipment out		72366.3	43904	61467

Market 1				
Period	0	1	2	3
Inventory	500	2552.16	2552.16	2552.16
Shipment in		51043.2	30619	42867
Demand		48991	30619	42867

Market 2				
Period	0	1	2	3
Inventory	500	756.53	756.53	756.53
Shipment in		15130.5	9296	13015
Demand		14874	9296	13015

Market 3				
Period	0	1	2	3
Inventory	500	581.68	581.68	581.68
Shipment in		11633.7	7220	10108
Demand		11552	7220	10108

Market 4				
Period	0	1	2	3
Inventory	500	2411.63	2411.63	2411.63
Shipment in		48232.6	28950	40531
Demand		46321	28950	40531

Market 5				
Period	0	1	2	3
Inventory	500	625	625	625
Shipment in		12500	7734	10828
Demand		12375	7734	10828

Market 6				
Period	0	1	2	3
Inventory	500	583.32	583.32	583.32
Shipment in		11666.3	7239	10135
Demand		11583	7239	10135

Scenario Three

Objective value = 0.2906741 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	8160.25	15505.9	16172.2
Production		40000	20000	30400
Shipment out		32339.8	12654.3	29733.7

Plant 2				
Period	0	1	2	3
Inventory	500	1530	2138	2956
Production		51500	30400	40900
Shipment out		50470	29792	40082

Plant 3				
Period	0	1	2	3
Inventory	500	1938	2968	4198
Production		71900	51500	61500
Shipment out		70462	50470	60270

Distribution Center 1				
Period	0	1	2	3
Inventory	500	2088.56	3050.89	4398.17
Shipment in		79428.6	48116.3	67364.3
Shipment out		77840	47154	66017

Distribution Center 5				
Period	0	1	2	3
Inventory	500	1976.87	2872.87	4127.3
Shipment in		73843.2	44800	62721.4
Shipment out		72366.3	43904	61467

Market 1				
Period	0	1	2	3
Inventory	500	2552.16	2552.16	2552.16
Shipment in		51043.2	30619	42867
Demand		48991	30619	42867

Market 2				
Period	0	1	2	3
Inventory	500	756.53	756.53	756.53
Shipment in		15130.5	9296	13015
Demand		14874	9296	13015

Market 3				
Period	0	1	2	3
Inventory	500	581.68	581.68	581.68
Shipment in		11633.7	7220	10108
Demand		11552	7220	10108

Market 4				
Period	0	1	2	3
Inventory	500	2411.63	2411.63	2411.63
Shipment in		48232.6	28950	40531
Demand		46321	28950	40531

Market 5				
Period	0	1	2	3
Inventory	500	625	625	625
Shipment in		12500	7734	10828
Demand		12375	7734	10828

Market 6				
Period	0	1	2	3
Inventory	500	583.32	583.32	583.32
Shipment in		11666.3	7239	10135
Demand		11583	7239	10135

Scenario Four

Objective value = 0.3358713 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	9049.12	17861.5	18591.1
Production		48000	24000	36480
Shipment out		39450.9	15187.6	35750.4

Plant 2				
Period	0	1	2	3
Inventory	500	1736	2465.6	3517.96
Production		61800	36480	49080
Shipment out		60564	35750.4	48027.6

Plant 3				
Period	0	1	2	3
Inventory	500	2225.6	3461.6	4937.61
Production		86280	61800	73800
Shipment out		84554.4	60564	72324

Distribution Center 1				
Period	0	1	2	3
Inventory	500	844.09	1491.02	2540.79
Shipment in		17204.7	32346.4	52489.8
Shipment out		16860.6	31699.4	51440

Distribution Center 2				
Period	0	1	2	3
Inventory	500	1346.95	1677.55	1996.28
Shipment in		42347.8	16530.2	15936.7
Shipment out		41500.9	16199.6	15618

Distribution Center 3				
Period	0	1	2	3
Inventory	500	787.05	963.866	1211.4
Shipment in		14352.3	8840.82	12376.5
Shipment out		14065.3	8664	12129

Distribution Center 4				
Period	0	1	2	3
Inventory	500	1214.17	1548.23	2540.82
Shipment in		35708.5	16702.8	49629.6
Shipment out		34994.3	16368.7	48637

Distribution Center 5				
Period	0	1	2	3
Inventory	500	1711.28	2275.63	2540.81
Shipment in		60564	28217.6	13259.2
Shipment out		59352.7	27653.3	12994

Distribution Center 6				
Period	0	1	2	3
Inventory	500	787.84	965.126	1213.33
Shipment in		14392.1	8864.29	12410.2
Shipment out		14104.2	8687	12162

Market 1				
Period	0	1	2	3
Inventory	500	3067.83	3067.83	3067.83
Shipment in		61356.8	36743	51440
Demand		58789	36743	51440

Market 2				
Period	0	1	2	3
Inventory	500	913.11	913.11	913.11
Shipment in		18262.1	11156	15618
Demand		17849	11156	15618

Market 3				
Period	0	1	2	3
Inventory	500	703.26	703.26	703.26
Shipment in		14065.3	8664	12129
Demand		13862	8664	12129

Market 4				
Period	0	1	2	3
Inventory	500	2899.21	2899.21	2899.21
Shipment in		57984.2	34741	48637
Demand		55585	34741	48637

Market 5				
Period	0	1	2	3
Inventory	500	755.26	755.26	755.26
Shipment in		15105.3	9281	12994
Demand		14850	9281	12994

Market 6				
Period	0	1	2	3
Inventory	500	705.21	705.21	705.21
Shipment in		14104.2	8687	12162
Demand		13899	8687	12162

Scenario Five

Objective value = 0.3483508 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	9049.12	17861.5	18591.1
Production		48000	24000	36480
Shipment out		39450.9	15187.6	35750.4

Plant 2				
Period	0	1	2	3
Inventory	500	1736	2465.6	3517.96
Production		61800	36480	49080
Shipment out		60564	35750.4	48027.6

Plant 3				
Period	0	1	2	3
Inventory	500	2225.6	3461.6	4937.61
Production		86280	61800	73800
Shipment out		84554.4	60564	72324

Distribution Center 1				
Period	0	1	2	3
Inventory	500	2040.02	2967.17	4581.64
Shipment in		77001.1	46357.1	80723.4
Shipment out		75461.1	45430	79109

Distribution Center 2				
Period	0	1	2	3
Inventory	500	872.696	1100.37	1102.63
Shipment in		18634.8	11383.7	113.319
Shipment out		18262.1	11156	111.053

Distribution Center 4				
Period	0	1	2	3
Inventory	500	500	500	777.56
Shipment in		0	0	13878.3
Shipment out		0	0	13600.7

Distribution Center 5				
Period	0	1	2	3
Inventory	500	2278.67	3353.89	4581.63
Shipment in		88933.4	53761.2	61387
Shipment out		87154.7	52686	60159.3

Market 1				
Period	0	1	2	3
Inventory	500	3067.84	3067.84	3067.84
Shipment in		61356.8	36743	51440
Demand		58789	36743	51440

Market 2				
Period	0	1	2	3
Inventory	500	913.11	913.11	913.11
Shipment in		18262.1	11156	15618
Demand		17849	11156	15618

Market 3				
Period	0	1	2	3
Inventory	500	703.26	703.26	703.26
Shipment in		14065.3	8664	12129
Demand		13862	8664	12129

Market 4				
Period	0	1	2	3
Inventory	500	2899.21	2899.21	2899.21
Shipment in		57984.2	34741	48637
Demand		55585	34741	48637

Market 5				
Period	0	1	2	3
Inventory	500	755.26	755.26	755.26
Shipment in		15105.3	9281	12994
Demand		14850	9281	12994

Market 6				
Period	0	1	2	3
Inventory	500	705.21	705.21	705.21
Shipment in		14104.2	8687	12162
Demand		13899	8687	12162

Scenario Six

Objective value = 0.3492974 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	9049.12	17861.5	18661.8
Production		48000	24000	36480
Shipment out		39450.9	15187.6	35679.6

Plant 2				
Period	0	1	2	3
Inventory	500	1736	2465.6	3447.2
Production		61800	36480	49080
Shipment out		60564	35750.4	48098.4

Plant 3				
Period	0	1	2	3
Inventory	500	2225.6	3461.6	4937.61
Production		86280	61800	73800
Shipment out		84554.4	60564	72324

Distribution Center 1				
Period	0	1	2	3
Inventory	500	2412.72	3567.54	5184.27
Shipment in		95635.9	57740.8	80836.7
Shipment out		93723.2	56586	79220

Distribution Center 5				
Period	0	1	2	3
Inventory	500	2278.67	3353.89	4859.2
Shipment in		88933.4	53761.2	75265.3
Shipment out		87154.7	52686	73760

Market 1				
Period	0	1	2	3
Inventory	500	3067.84	3067.84	3067.84
Shipment in		61356.8	36743	51440
Demand		58789	36743	51440

Market 2				
Period	0	1	2	3
Inventory	500	913.11	913.11	913.11
Shipment in		18262.1	11156	15618
Demand		17849	11156	15618

Market 3				
Period	0	1	2	3
Inventory	500	703.26	703.26	703.26
Shipment in		14065.3	8664	12129
Demand		13862	8664	12129

Market 4				
Period	0	1	2	3
Inventory	500	2899.21	2899.21	2899.21
Shipment in		57984.2	34741	48637
Demand		55585	34741	48637

Market 5				
Period	0	1	2	3
Inventory	500	755.26	755.26	755.26
Shipment in		15105.3	9281	12994
Demand		14850	9281	12994

Market 6				
Period	0	1	2	3
Inventory	500	705.21	705.21	705.21
Shipment in		14104.2	8687	12162
Demand		13899	8687	12162

Scenario Seven

Objective value = 0.2312786 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	4622.89	10499.8	10986.2
Production		32000	16000	24320
Shipment out		27877.1	10123.1	23833.6

Plant 2				
Period	0	1	2	3
Inventory	500	1324	1810.4	2513.68
Production		41200	24320	32720
Shipment out		40376	23833.6	32016.7

Plant 3				
Period	0	1	2	3
Inventory	500	4216.57	5040.57	6024.57
Production		57520	41200	49200
Shipment out		53803.4	40376	48216

Distribution Center 1				
Period	0	1	2	3
Inventory	500	1331.19	1831.08	2540.82
Shipment in		41559.6	24994.9	35486.3
Shipment out		40728.4	24495	34776.6

Distribution Center 2				
Period	0	1	2	3
Inventory	500	744.87	896.646	1109.14
Shipment in		12243.8	7588.78	10624.5
Shipment out		11999	7437	10412

Distribution Center 4				
Period	0	1	2	3
Inventory	500	1057.54	1530.19	1818.33
Shipment in		27877.1	23632.7	14407
Shipment out		27319.6	23160	14118.9

Distribution Center 5				
Period	0	1	2	3
Inventory	500	1307.5	1669.83	20379.3
Shipment in		40376	18116.3	61387
Shipment out		39568.5	17754	42677.5

Market 1				
Period	0	1	2	3
Inventory	500	2036.42	2036.42	2036.42
Shipment in		40728.4	24495	34293
Demand		39192	24495	34293

Market 2				
Period	0	1	2	3
Inventory	500	599.95	599.95	599.95
Shipment in		11999	7437	10412
Demand		11899	7437	10412

Market 3				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9241	5776	8086
Demand		9241	5776	8086

Market 4				
Period	0	1	2	3
Inventory	500	1924.05	1924.05	1924.05
Shipment in		38481.1	23160	32424
Demand		37057	23160	32424

Market 5				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9900	6187	8662
Demand		9900	6187	8662

Market 6				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9266	5791	8108
Demand		9266	5791	8108

Scenario Eight

Objective value = 0.2326238 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	7189.05	13066	13552.4
Production		32000	16000	24320
Shipment out		25310.9	10123.1	23833.6

Plant 2				
Period	0	1	2	3
Inventory	500	1324	1810.4	2513.68
Production		41200	24320	32720
Shipment out		40376	23833.6	32016.7

Plant 3				
Period	0	1	2	3
Inventory	500	1650.4	2474.4	3458.4
Production		57520	41200	49200
Shipment out		56369.6	40376	48216

Distribution Center 1				
Period	0	1	2	3
Inventory	500	1765.17	2535.02	3612.83
Shipment in		63258.5	38492.9	53890.8
Shipment out		61993.4	37723	52813

Distribution Center 5				
Period	0	1	2	3
Inventory	500	1676.03	2392.83	3396.34
Shipment in		58798.1	35839.8	50175.5
Shipment out		57622.1	35123	49172

Market 1				
Period	0	1	2	3
Inventory	500	2036.42	2036.42	2036.42
Shipment in		40728.4	24495	34293
Demand		39192	24495	34293

Market 2				
Period	0	1	2	3
Inventory	500	599.95	599.95	599.95
Shipment in		11999	7437	10412
Demand		11899	7437	10412

Market 3				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9241	5776	8086
Demand		9241	5776	8086

Market 4				
Period	0	1	2	3
Inventory	500	1924.05	1924.05	1924.05
Shipment in		38481.1	23160	32424
Demand		37057	23160	32424

Market 5				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9900	6187	8662
Demand		9900	6187	8662

Market 6				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9266	5791	8108
Demand		9266	5791	8108

Scenario Nine

Objective value = 0.2320238 E+11

Plant 1				
Period	0	1	2	3
Inventory	500	7189.05	13066	13552.4
Production		32000	16000	24320
Shipment out		25310.9	10123.1	23833.6

Plant 2				
Period	0	1	2	3
Inventory	500	1324	1810.4	2513.68
Production		41200	24320	32720
Shipment out		40376	23833.6	32016.7

Plant 3				
Period	0	1	2	3
Inventory	500	1650.4	2474.4	3458.4
Production		57520	41200	49200
Shipment out		56369.6	40376	48216

Distribution Center 1				
Period	0	1	2	3
Inventory	500	1765.17	2535.02	3612.83
Shipment in		63258.5	38492.9	53890.8
Shipment out		61993.4	37723	52813

Distribution Center 5				
Period	0	1	2	3
Inventory	500	1676.03	2392.83	3396.34
Shipment in		58798.1	35839.8	50175.5
Shipment out		57622.1	35123	49172

Market 1				
Period	0	1	2	3
Inventory	500	2036.42	2036.42	2036.42
Shipment in		40728.4	24495	34293
Demand		39192	24495	34293

Market 2				
Period	0	1	2	3
Inventory	500	599.95	599.95	599.95
Shipment in		11999	7437	10412
Demand		11899	7437	10412

Market 3				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9241	5776	8086
Demand		9241	5776	8086

Market 4				
Period	0	1	2	3
Inventory	500	1924.05	1924.05	1924.05
Shipment in		38481.1	23160	32424
Demand		37057	23160	32424

Market 5				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9900	6187	8662
Demand		9900	6187	8662

Market 6				
Period	0	1	2	3
Inventory	500	500	500	500
Shipment in		9266	5791	8108
Demand		9266	5791	8108

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