

**A LOGISTICS OPTIMIZATION STUDY FOR
GARDEN CITY CO-OP, INC.**

by

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ABSTRACT

Garden City Co-op, Inc. is a farm cooperative in Southwest Kansas. It provides marketing and storage of grain, fertilizer, crop protection products, seed, and petroleum to both member and non-member accounts. The cooperative also operates a transportation company called Western Transport. Western Transport provides transportation of anhydrous ammonia (NH₃), liquid fertilizer (32-0-0 or 10-34-0), diesel, gasoline, and propane utilizing semi-tractors and trailers to Garden City Co-op, Inc. as well as to other agribusinesses in the region.

The purpose of this thesis is to integrate and optimize the supply chain strategies for the cooperative's fertilizer and petroleum products as it relates to storage and transportation of those commodities. Utilizing the framework of an aggregate production plan, a model is constructed to minimize costs associated with inventory holding, net storage asset depreciation after tax savings, net transportation asset depreciation after tax savings, labor, operations, and freight. By varying the quantities of petroleum and fertilizer the cooperative purchases, sells, and stores each month over a one-year period, an optimum mix of storage and transportation assets is determined.

Two different demand scenarios are evaluated that relate to demand during a drought year versus demand during a non-drought year. Also, different model scenarios include varying beginning period inventory and ending period inventory to stress transportation assets versus storage assets. The model is optimized using a genetic algorithm solver in the software program Evolver produced by Palisade Corporation.

Results of the optimization provided two feasible strategies for the cooperative. By continuing services to non-member accounts, there was a greater investment placed on transportation. Investments included additional trucks, NH₃ trailers, petroleum trailers, and drivers. The strategy favored a just-in-time inventory approach versus inventory smoothing with storage. When discontinuing services to non-member accounts, investment between storage and transportation assets were relatively equal. The model favored a reduction in NH₃ trailers, liquid fertilizer trailers, trucks, and drivers. However, additional storage was necessary as well as petroleum trailers. The scenario favored an inventory smoothing approach across the model year.

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CHAPTER I: INTRODUCTION

Garden City Co-op, Inc. is a farm cooperative established in 1919. Despite suffering through economic and climatic swings, the cooperative has grown into one of the largest cooperatives in Kansas, serving 2,052 member owners. The Board of Directors, which consists of seven Directors and four Associate Directors, guides the business and financial decisions. The cooperative employs approximately 120 employees who operate in various facets of the business. There are four divisions that focus on three commodity groups (grain, agronomy inputs, and petroleum), as well as an operations group.

The Grain Division offers grain storage and marketing. Stretching from Ulysses, Kansas, in the south to Shields, Kansas, in the north, the Grain Division has 18 elevators for local grain storage with a capacity of 20,434,000 bushels, (Figure 1.1). The Crop Production division, which is located in Lowe and Dighton, Kansas, offers seed, fertilizer, and crop protection products coupled with agronomic consultation and support. The division provides both delivery and pickup of all crop inputs, as well as custom application of pesticide, liquid fertilizer, and dry fertilizer. The Petroleum Division is one of the largest distributors of Cenex refined fuels in the U.S. and has become one of the largest distributors for Cenex lubricants. The Operations Division focuses on the everyday operations of elevators, warehouses, fertilizer plants, transportation, and maintenance. A Vice President who reports directly to the General Manager leads each group.

Figure 1.1: Garden City Co-op, Inc.'s Grain Elevator Locations

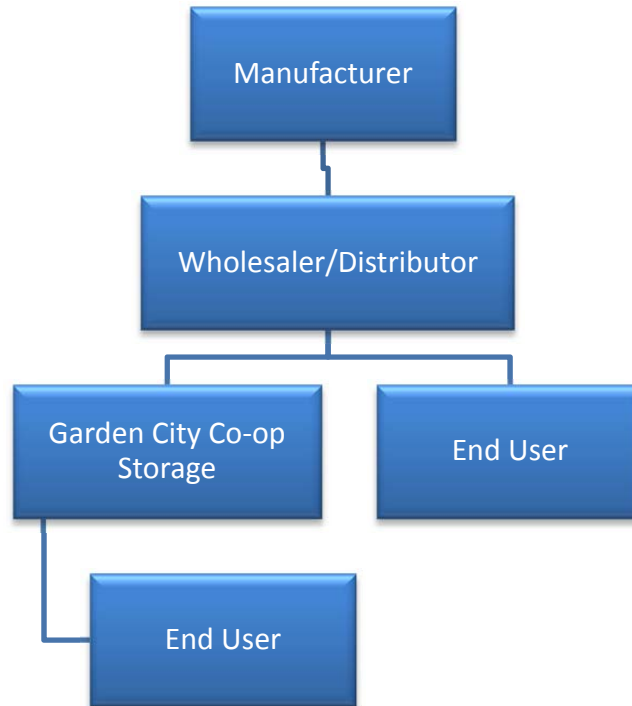


Source: Google

Within the Operations Division, Western Transport LLC provides transportation of fertilizer and petroleum products. Established in 2007, Western Transport LLC provides the cooperative with a reliable transportation source for both fertilizer delivery from the point of manufacturer to the cooperatives retail facility, and petroleum delivery from the terminal to company storage or end users. As the cooperative experienced increased demand volume of fertilizer and petroleum products, and an adequate transportation source was scarce, the cooperative chose to purchase a fleet of tractors, liquid fertilizer trailers, anhydrous ammonia bottles, and petroleum tankers to serve the cooperative's needs.

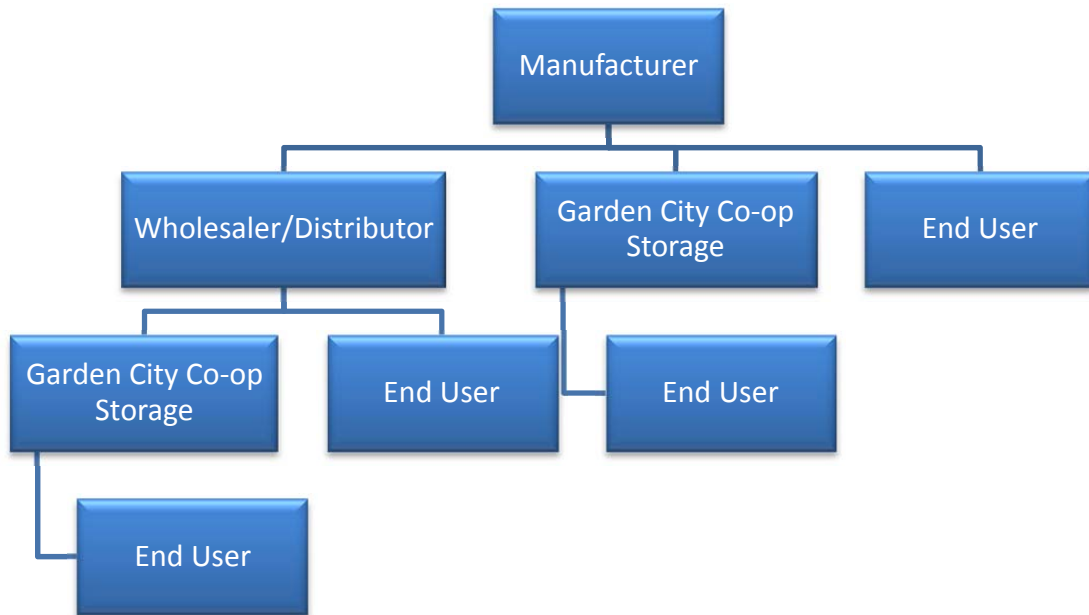
When evaluating the supply chain for Garden City Co-op Inc.'s petroleum division, specifically gasoline or diesel products, flow begins at the manufacturer (Figure 1.2). From the manufacturer product travels through a distribution network to the wholesaler. From the wholesaler, product will move to Garden City Co-op's storage facility or direct to the end user. Transportation for the petroleum products within the supply chain could consist of rail, pipeline, or truck.

Figure 1.2: Garden City Co-op Inc.'s Petroleum Product Supply Chain



The flow of fertilizer for Garden City Co-op Inc.'s Crop Production division starts with the manufacturer (Figure 1.3). Product can then flow to company storage and then to the end user. A limited amount of product flows directly from the manufacturing facility to the end user. Product could also flow from the manufacturer, to a wholesaler or distributor, and then to Garden City Co-op's storage or end user. Transportation for fertilizer products could consist of rail or truck.

Figure 1.3: Garden City Co-op Inc.'s Fertilizer Product Supply Chain



Western Transport provided numerous benefits to Garden City Co-op Inc., because it was created at a time when the cooperative was flourishing with increased demand of both fertilizer and petroleum products. The cooperative was able to source product rapidly with the luxury of a company-owned trucking fleet. Initially, the assets purchased for Western Transport provided an alternative depreciation expense to limit taxes for the cooperative. However, as depreciation declined each year, the need for Western Transport to generate an adequate source of revenue increased. Subsequently, Western Transport began to focus on providing transportation not only to the cooperative, but also to other businesses throughout the Midwest.

Initially, the cooperative hypothesized that if Western Transport could increase volume by hauling outside the company; administrative costs as a percentage of volume transported would decrease, leading to greater profitability. However, after a three year analysis of the business, it was determined that no matter how much additional volume is

captured by Western Transport, adequate profitability is not achievable at current freight rates and seasonality of business.

Garden City Co-op, Inc.'s primary problem is to increase the profitability of Western Transport and the cooperative as a whole by increasing logistical efficiencies associated with transportation and storage. For Garden City Co-op, Inc., logistical efficiency is defined and best determined by finding the optimum mix of storage and transportation assets required over the course of the year in order to satisfy real time consumer demand.

Efficiency in logistics is a key issue for the cooperative. The cooperative builds business based on the premise of providing a reliable supply of product with superior service and knowledgeable product support. The Board of Directors must ensure that the cooperative meets its commitment and values associated with trustworthiness, stability, dependability, and innovativeness. Therefore, logistical efficiency for Garden City Co-op, Inc. is vital for meeting those values.

To determine the best model for transportation and storage assets for Garden City Co-op, Inc., optimization techniques will be utilized. Research will be conducted regarding appropriate mathematical models for the given situation. The model will be constructed in Excel and utilize an optimization solver from Palisade Corporation called Evolver. Data collected will include historical sales of petroleum and fertilizer products over the course of five years as provided by the Petroleum and Crop Production divisions. Constraints will be determined via current storage capacities, and transportation capabilities as provided by Western Transport. Local weather data will be gathered to determine appropriate drought years and non-drought years.

Once constructed and modeling is complete, a report will be provided to the Garden City Co-op, Inc. Board of Directors, General Manager, and division Vice Presidents as to the optimum mix of storage and transportation assets. This will be a tool for the directors to utilize in order to make decisions regarding future investment in storage or transportation assets. Additionally, any potential assumptions as well as risks that would affect the reliability of the model will be analyzed.

CHAPTER II: LITERATURE REVIEW

Abundant literature can be found regarding supply chain management, distribution, and transportation as it relates to logistics. Garden City Co-op, Inc., in an effort to reduce logistical costs, will attempt to integrate supply chain management for petroleum and fertilizer products. Modeling will attempt to identify whether changes to distribution need to occur as it relates to the size of storage facilities. Furthermore, the model will attempt to identify an adequate transportation mix of trucks, trailers, and drivers that will satisfy demand. Modeling will be constructed utilizing the framework of a production plan and optimized with an Excel solver.

2.1 Supply Chain Management

Supply chain management is critical to any transportation problem. Management of the various facets of the supply chain can include strategic, tactical, and operational characteristics. Forecasting and inventory are important when the economy encounters an unpredicted downturn. Additionally, there is an ever-present uncertainty in demand. As such, forecasting of demand is never 100% accurate. Inventory is subsequently carried to handle a variety of demand situations such as underestimated demand. While one may meet unforeseen demand with this situation, there is a tradeoff with holding cost. Additionally good business planning would like to accurately predict demand to negate the additional capital need for inventory (Liao and Chang 2010, p. 527).

Supply chain costs are impacted by transportation mode, purchase costs, order costs, and inventory costs (Dullaert and Zamparini 2013, p. 190). Lead-time is an important factor as it relates to supply chain costs. Lead-time can be defined as the time that elapses between placing and receiving an order. As lead-time increases, the amount of

inventory to keep on hand avoiding stock out increases. By reducing lead-time as well as variability in lead-time, companies can see significant benefits (Dullaert and Zamparini 2013, p. 191). A competitive firm must recognize the importance of lead times as it relates to costs associated with inventory levels for current work in process and larger safety stocks from stochastic demand (Pahl, VoB and Woodruff 2005, p. 257). Pahl, VoB and Woodruff note, “Lead times are among the most important properties of items in the production planning and supply chain management (SCM)” (p. 258).

Supply chain management has taken on a greater significance as it pertains to business management in the last decades. Even though information technology has greatly improved supply chain management, production planning is still a critical issue (Pahl, VoB and Woodruff 2005, p. 258). Poor supply chain management, as well as production planning can create what is known as the bullwhip effect. When forecasts of demand within a supply chain are based upon direct demand experiences for products, variability in demand is magnified up the supply chain. To minimize the bullwhip effect, information sharing in regards to production processes and inventory levels within the production plan should be communicated up the supply chain. Without the proper sharing of information, decreasing lead times for individual links in the supply chain do not necessarily improve total lead-time for the entire supply chain (Pahl, VoB and Woodruff 2005, p. 259).

The cost of safety stock held by a receiver to protect against inventory stock out is a significant factor in the total logistical cost in a stochastic supply chain between a supplier and a receiver (Vernimmen, et al. 2008, p. 248). Safety stock is best suited for a buffer from uncertainty. Incorporation of an adequate safety stock at the beginning of a production plan has more benefit than one that monitors safety stocks and places new

orders accordingly. Subsequently, even though safety stocks increase service levels, they can inject instability to production plans (Tang and Grubbstrom 2002, p. 325). Safety stock levels are dependent upon demand during lead-time and its associated statistical distribution. Total logistics costs affected by transportation mode also include purchase costs, order costs, and inventory costs (Vernimmen, et al. 2008, p. 248).

2.2 Distribution

Distribution plays a key role in the supply chain functionality. Chopra and Meindl define distribution as “the steps taken to move and store a product from the supplier stage to the customer stage in the supply chain” (p. 68). Distribution plays a key role in the overall supply chain because of its impact on total cost and customer experience (Chopra and Meindl 2010, p. 68). When evaluating distribution network design one should consider customer needs and the associated costs. Customer service consists of measures in response time, product variety, product availability, customer experience, time to market, order visibility, and returnability (Chopra and Meindl 2010, p. 69-70).

Altering a distribution network design impacts costs associated with inventories, transportation, facilities and handling, and information. Increasing the number of facilities in a network will increase customer response time (Chopra and Meindl 2010, p. 70). Additionally, as the number of facilities in a supply chain increases, the inventory costs will increase (Chopra and Meindl 2010, p. 71).

Inbound transportation costs as it relates to transporting a product to a facility are typically lower than outbound transportation costs or shipping product out of a facility. With inbound transportation, lot sizes may be larger thereby reducing costs per unit. Subsequently, as long as inbound transportation meets economies of scale criteria, as the number of facilities increase, transportation costs will decrease. As inbound lot sizes

decrease (loss in economies of scale), then, as the number of facilities increase, transportation costs will increase (Chopra and Meindl 2010, p. 71).

As the number of facilities in a distribution network increase, the costs of operating the facilities will increase. By decreasing the number of facilities and consolidating (economies of scale), one can decrease facilities costs. As the number of facilities in a distribution network increase, total logistics costs (inventory, transportation, and facility costs) first decrease and then increase. This change in cost is a result of response time for customers. As a firm seeks to improve response time it must increase the number of facilities and may have costs greater than the total minimum logistics costs.

A firm should attempt to have the least number of facilities that will minimize total logistics costs at a given level of demand. As more focus is placed on response time, a firm may have to increase the number of facilities beyond the minimized logistics cost. This should only occur if the firm is confident that increased responsiveness will lead to increased revenues and will outweigh the increase in costs (Chopra and Meindl 2010, p. 72).

2.3 Transportation

Transportation is the movement of product from one location to another or from the beginning of the supply chain to the end user (Chopra and Meindl 2010, p. 362). Within the transportation framework, there is a shipper and a carrier. The shipper requires the movement of a product between two points in the supply chain. The carrier physically moves or transports the product. Carriers determine which modes of transportation to use such as locomotives, trucks, airplanes, etc. The carrier attempts to maximize the return on the investment of these assets. The shipper is interested in minimizing costs associated with transportation, inventory, information, sourcing, and facilities. In addition, they must

be responsive to customer needs. Transportation operates in a collection of nodes and links. Nodes are the point of origination or destination, while the physical assets travel on links. Transportation infrastructure such as ports, roads, waterways, and airports are required at both nodes and links (Chopra and Meindl 2010, p. 363).

Shipment of goods by truck occurs in two distinct forms. The first is truckload shipping. Truckload shipping is the movement of large quantities of a product that are homogenous in nature and will fill an entire transport vehicle. Alternatively, less than truckload shipments, consist of mixtures of products that can include various destinations or customers (Wikipedia 2012).

Truckload operations have lower fixed costs and fewer owned assets associated with business entrance. A key goal for truckload firms is the minimization of both idle and empty travel time for assets in order to maximize potential revenue. Truckload shipping is best suited for shipment between manufacturing points and warehouses or between suppliers and manufacturers (Chopra and Meindl 2010, p. 366).

Less than truckload operations price services that encourage shipment in small lots often less than half a truckload. Less than truckload shipments can involve various pickup and drop points. Ideally package size would consist of something too large to ship by mail but too small to ship by truckload. Adequate utilization of consolidation centers so that trucks arrive with small loads and can leave with small loads (maximizing truck efficiency at the expense of delivery time) lowers less than truckload costs. By placing the consolidation center in the same geographic area as the customer less than truck load carriers can lower costs as truck use is improved. Less than truckload carriers face many

hurdles as it relates to location of consolidation centers, load assignments, scheduling, routing, delivery time, and reliability (Chopra and Meindl 2010, p. 366).

When examining a transportation framework, one must take into account two important tradeoffs. The first is the transportation and inventory cost trade-off. The second is the transportation cost and customer responsiveness trade-off. Specifically, one must account for the impact on inventory costs, facility and processing costs, operational coordination costs, and customer responsiveness. When evaluating transportation one must beware that the lowest transportation cost may not lower total costs for the supply chain as it relates to inventory cost. Additionally, customer responsiveness will dictate the level of transportation costs (Chopra and Meindl 2010, p. 375).

Customer responsiveness is defined as the ability to meet customer requirements in a timely and satisfactory manner (Mackenzie 2012). Essentially, as customer responsiveness increases, transportation needs and costs increase. To balance these two, it is important to design flexibility into the transportation network. Doing so provides the added benefit of being able to handle unexpected outcomes as they arise. In short, an efficient transportation network should ultimately reduce the cost of offering a high level of customer responsiveness (Chopra and Meindl 2010, p. 387).

2.4 Production Planning

Aggregate planning is a process in which a company calculates the ideal levels of capacity, production, subcontracting, inventory, stock outs, and pricing over a specified time horizon. The ultimate goal is to satisfy demand while maximizing profitability for a firm (Chopra and Meindl 2010, p. 209). Chopra and Meindl state the aggregate planning model formally as, “Given the demand forecast for each period in the planning horizon, determine the production level, inventory level, and capacity level (internal and

outsourced) for each period that maximizes the firm's profit over the planning horizon" (p. 211). Aggregate planning ultimately will maximize profit while satisfying demand (Chopra and Meindl 2010, p. 209).

Aggregate planning models were developed in order to allow manufacturers the ability to cope with seasonality in sales (Buxey 2003, p. 331). When attempting to determine production levels, inventory and work force levels to meet the fluctuating demand requirement for a planned period, an aggregate production plan works well. A planning horizon for an aggregate production plan is usually the next seasonal peak in demand. Within the planning horizon, there are periods that can last from a typical one-month period to a three-month period. Physical resources for a firm are assumed to be fixed during the planning horizon. The resources are optimized in order to meet fluctuating demand and associated costs (Gallego 2001, p. 1).

Aggregate production planning as it relates to matching capacity with demand forecasted for a period of 3 to 18 months has two objectives. The first is to set production levels in order to meet fluctuating and uncertain demand for a future period. The second is to set decisions and policies concerning labor, and inventory levels or resources used. Aggregate production planning falls between the broad decisions involved in long range planning and the detailed decisions found in short range planning (Wang and Liang 2004, p. 17-18). Wang and Liang suggest, "APP is one of the most important functions in production and operations management" (p. 18).

Aggregate production planning is derived from the basic idea of an aggregate unit of production. An aggregate unit of production can consist of the average item as it relates to terms of weight, volume, production time, or dollar value. The plan is derived from

aggregate demand for one or more aggregate items. Once a plan is formulated, constraints are injected to simulate limits to the production process and decisions regarding quantities produced for individual items (Gallego 2001, p. 1).

There are many ways to deal with fluctuations in demand. The first can take the form of changes in work force by either hiring or firing. Second, one can vary the production rate by injecting overtime, idle time, or subcontracting into the production schedule. Third, one can accumulate seasonal inventories to deal with the highs and lows of demand. Lastly, one can plan for back orders. There are many costs associated with aggregate production planning. These include basic costs such as materials, labor, and overhead all of which can be variable or fixed. Additionally, there are costs associated with changes in production rates due to costs of hiring, training, layoffs, and overtime pay. Lastly, there are costs associated with inventory (Gallego 2001, p. 1).

There are two extreme forms of aggregate production planning. The first form is just-in-time production and the second is production smoothing (Gallego 2001, p. 1). Just-in-time production changes production rates to exactly satisfy current demands for product. Subsequently, one will find low holding costs associated with zero inventory but high costs associated with adjustments in production. This is best used when the cost of varying production rates is inexpensive (Gallego 2001, p. 2). Geoff Buxey suggests, “Contemporary business is well aware of the benefits of the JIT approach. In the present climate, substantial quantities of finished goods stocks are an anathema” (p. 335).

Production smoothing optimizes production rates to a smooth level that remains constant over time. This minimizes costs associated with changing production rates but increases costs associated with holding inventory. This plan is best used when inventory-

holding costs are low (Gallego 2001, p. 2). Ideally, one would choose the plan that minimizes total costs for the business over the calendar year (Buxey 2003, p. 331). Industry trends as it relates to a production strategy weigh heavily to the JIT approach or chase plan. The chase plan tracks the expected monthly sales and computes the direct requirements to satisfy the expected sales (Buxey 2003, p. 331). This is likely correlated to the JIT phenomena. The chase plan has a positive impact on finances for a business as it relates to cash flow and financial exposure (Buxey 2003, p. 341-342).

2.5 Optimization Techniques

When trying to maximize profits subject to a set of constraints, linear programming is a valuable tool. Linear programming will allow a company to find the highest profit given constraints within the companies supply chain (Chopra and Meindl 2010, p. 213). Linear programming can consider demand forecasts and resource constraints for several periods, determine production and inventory levels for each period, and meet demand in the most economical way. Essentially, with this type of model, the objective is to minimize total production and inventory costs associated with the cost of production, and inventory holding costs. Constraints for the model include production capacities, as well as production levels needed as it relates to demand or inventory stocking.

Evaluating the model results throughout the entire period is an important step in optimization. Re-valuating at the end of certain time intervals throughout the estimation time frame is known as a rolling process and it can improve the estimation results (Ragsdale 2012, p. 95). Additionally, some optimization problems can be non-linear in nature. The main difference between linear programming and non-linear programming is the non-linear nature of the objective function and/or constraints (Ragsdale 2012, p. 351).

2.6 Summary

In this chapter, transportation methods and framework are discussed. Also, the concept of distribution and network design is considered as it relates to logistical costs. Included in the chapter was discussion on supply chain management and the role of production planning in business management. The role of aggregate planning as it relates to meeting consumer demand while minimizing production costs as well as associated optimization techniques was introduced to provide the foundation for meeting the research objectives in this thesis.

The model for Garden City Co-op, Inc. will attempt to manage its supply chain for fertilizer and petroleum products using optimization techniques. The overall objective is to attempt to minimize total supply chain costs as it relates to inventory holding, storage asset depreciation, transportation asset depreciation, labor, operating costs and freight costs, all while satisfying consumer demand. In the next chapter, methods and data utilized in order to meet the logistics objective for Garden City Co-op, Inc. are introduced.

CHAPTER III: METHODS AND DATA

The objective for Garden City Co-op, Inc. is to minimize total logistics costs as it relates to inventory holding, storage asset depreciation, transportation asset depreciation, labor, operations, and freight while satisfying estimated consumer demand. It is hypothesized that by consolidating the supply chain, strategies for the crop production and petroleum divisions total logistical costs will be reduced and the level of transportation assets required decreased to meet real time consumer demand. The conceptual model of an aggregate production plan will be used to develop an optimization program that will provide insights on how best to minimize logistical costs. The aggregate production plan, described previously in Section 2.4 of the Literature Review, serves as the conceptual framework.

The time frame for the model is critical to estimate the appropriate amount of logistical costs for Garden City Co-op, Inc. Specifically, the impact of a non-drought year and drought year on demand will be a critical component of the analysis. In addition, the planning horizon for the model will be a fiscal year with twelve, 1-month periods. The fiscal year for Garden City Co-op Inc. is from September to August. Period one will be the month of September and period 12 the month of August. Years to evaluate as it relates to non-drought weather conditions versus drought were determined by historical weather records from Kansas State University for Finney County, Kansas.

Table 3.1 displays departure from new normal precipitation in inches for Finney County, Kansas for the years 2000 thru 2011. Kansas State University classifies new normal precipitation based upon precipitation averages for the years 1971-2000 versus normal precipitation averages for the years 1961-1990. Finney County experienced precipitation deficits in 2000, 2001, 2002, 2003, 2005, 2008, 2010, and 2011. The driest

year was in 2011 at 9.6 inches below new normal. Finney County experienced precipitation surpluses in 2004, 2006, 2007, and 2009. The wettest year was in 2009 at 4.4 inches above new normal.

Table 3.1: K-State Research and Extension Departure from New Normal Precipitation for Finney County, Kansas (Inches)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
2000	-0.06	-0.23	3.15	0.25	-1.14	-2.43	1.58	-1.6	-1.15	1.48	-0.42	-0.32	-0.88
2001	0.48	0.15	-0.64	-0.76	2.74	-0.65	0.94	-1.08	-0.06	-1.03	-0.78	-0.4	-1.07
2002	-0.16	-0.3	-0.89	-0.36	-2.57	-0.85	-1.52	0.83	-0.25	1.08	-0.76	-0.11	-5.85
2003	-0.45	0.39	-0.15	-0.35	0.51	0.56	-2.25	0.45	-0.51	-1.03	-0.85	-0.11	-3.81
2004	-0.37	0.08	-0.12	0.69	-2.94	2.81	1.1	0.51	2.39	-0.09	0.61	-0.43	4.25
2005	0.25	0.44	-0.93	-0.73	-0.57	-0.67	0.32	-0.09	0.5	1.45	-0.79	-0.28	-1.11
2006	-0.3	-0.52	-0.58	-1.15	-1.33	-1.42	-0.01	2.26	-0.27	1.28	-0.85	4.03	1.14
2007	0.1	0.06	1.34	0.87	-0.91	-0.97	-1.28	0.13	1.12	-0.62	-0.81	1.1	0.12
2008	-0.29	-0.02	-1.27	-0.22	-0.79	-1.1	-1.46	-0.68	-0.38	3.99	-0.54	-0.41	-3.16
2009	-0.43	-0.44	-0.78	3.2	-1.62	2	-0.46	0.06	1.12	2.39	-0.34	-0.31	4.4
2010	0	-0.04	0.41	0.01	-0.43	-1.69	-1.48	0.05	-1.1	-0.39	-0.59	-0.33	-5.59
2011	-0.23	-0.27	-0.87	-0.53	-2.59	-1.39	-2.58	-1.22	-0.62	-0.57	-0.17	1.42	-9.59

(Extension 2011)

Table 3.2 displays Finney County, Kansas departure from new normal precipitation correlated to Garden City Co-op, Inc.'s fiscal year for the years 2000 thru 2011. Garden City Co-op, Inc. experienced fiscal years of below new normal precipitation in 2001-2002, 2002-2003, 2003-2004, 2005-2006, 2007-2008, 2009-2010, and 2010-2011. The driest fiscal year was 2010-2011 at 12.09 inches below new normal precipitation. Garden City Co-op, Inc. experienced above new normal precipitation in fiscal years 2000-2001, 2004-2005, 2006-2007, and 2008-2009. The wettest fiscal year was 2008-2009 with 4.19 inches above new normal precipitation.

Table 3.2: K-State Research and Extension Departure from New Normal Precipitation for Finney County, Kansas by Garden City Co-op Inc.'s Fiscal Year (Inches)

Fiscal Year	Mean
2000-2001	0.77
2001-2002	-8.09
2002-2003	-1.33
2003-2004	-0.74
2004-2005	0.50
2005-2006	-2.17
2006-2007	3.53
2007-2008	-5.04
2008-2009	4.19
2009-2010	-0.31
2010-2011	-12.09

(Extension 2011)

The precipitation data in table 3.2 determines the drought and non-drought years for this study. The non-drought year used in the study is fiscal year 2008-2009 because total rainfall departure from new normal was 4.19 inches. The drought year for the model was fiscal year 2010-2011 with a total rainfall departure from new normal of -12.09 inches.

Using these years also provides the most current and reliable data available from the Garden City Co-op. Because the cooperative has been gaining demand volume in recent years for both fertilizer and petroleum as a result of an expanding customer base, the most recent demand data available will capture these changes. Therefore, the chosen model years of 2008-2009 and 2010-2011 are the most current and reliable data upon which to make a decision.

Demand for Garden City Co-op Inc. crop nutrient and petroleum products for both the non-drought and drought years modeled are displayed in Figures 3.1, 3.2, 3.3, and 3.4. It is assumed that during a drought year demand for products will be less than a non-drought year. However, after evaluating the demand variance between the two scenarios

that does not necessarily hold true. It is assumed that other factors are at play besides drought that affected demand such as crop prices, cropping strategies, and product prices.

Figure 3.1 illustrates the demand pattern for anhydrous ammonia (NH₃) during Garden City Co-op Inc.'s fiscal year. One will find that there are two periods of peak demand. The first occurs during the fall for pre-plant nitrogen applications for corn. The second occurs in mid-summer for pre-plant nitrogen applications for wheat. One will find that during a drought year, the fall application takes place approximately one month earlier than a non-drought year. This is likely due to dry conditions affecting crop maturity and an earlier fall harvest.

Figure 3.1: Garden City Co-op, Inc.'s Fiscal Year Anhydrous Ammonia (NH₃) Demand Comparison for a Drought Year versus a Non-Drought Year (Tons)

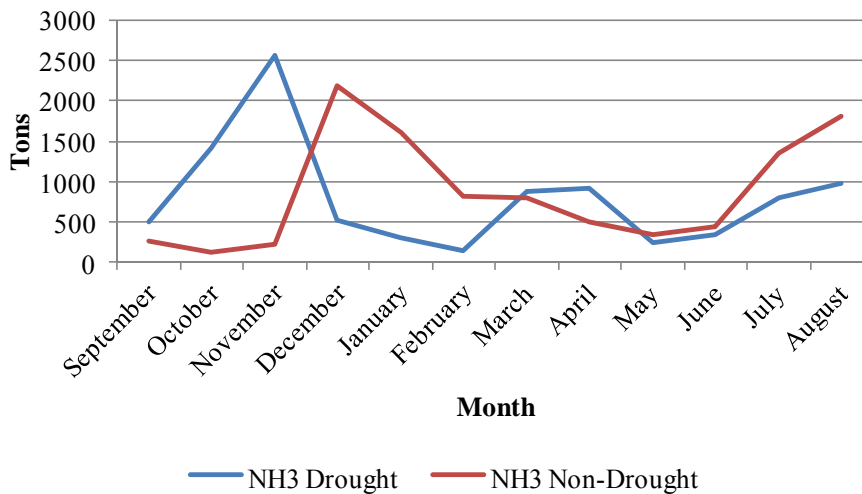


Figure 3.2 illustrates the demand pattern for 32-0-0 for Garden City Co-op, Inc.'s fiscal year. 32-0-0 is a liquid nitrogen fertilizer. There are two periods of peak demand. The first occurs during early spring when wheat is top-dressed with nitrogen. The second occurs during the summer months when nitrogen is pumped thru center pivot irrigation systems as a nitrogen treatment on growing corn. Further examination will reveal that in

spite of a drought year, demand for 32-0-0 was higher than that of a non-drought year. This could be due to product pricing, supply availability, or crop rotations.

Figure 3.2: Garden City Co-op Inc.’s Fiscal Year 32-0-0 Demand Comparison for a Drought Year versus a Non-Drought Year (Tons)

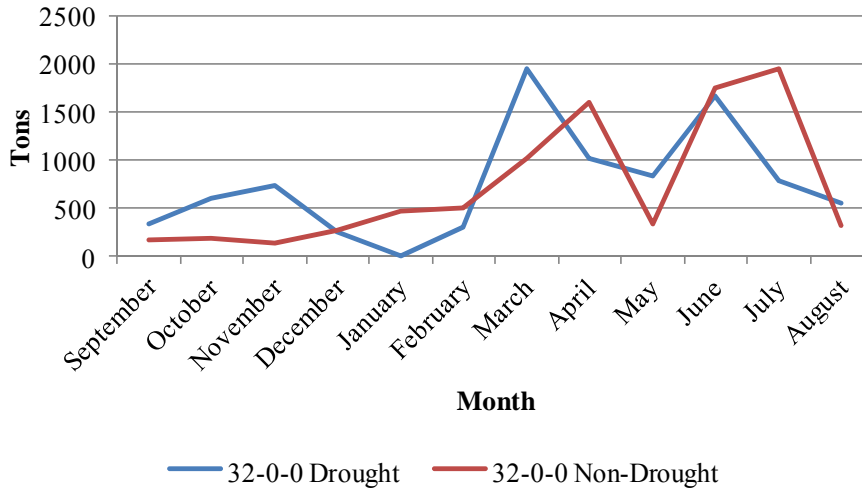


Figure 3.3 illustrates the demand pattern for 10-34-0 during Garden City Co-op Inc.’s fiscal year. 10-34-0 is a liquid phosphate fertilizer. There are two periods of peak demand. The first occurs during the fall period for pre-plant phosphorous application for winter wheat and corn. The second peak occurs during late spring and early summer for starter phosphorous applications to corn, milo, and soybeans.

Figure 3.3: Garden City Co-op Inc.’s Fiscal Year 10-34-0 Demand Comparison for a Drought Year versus a Non-Drought Year (Tons)

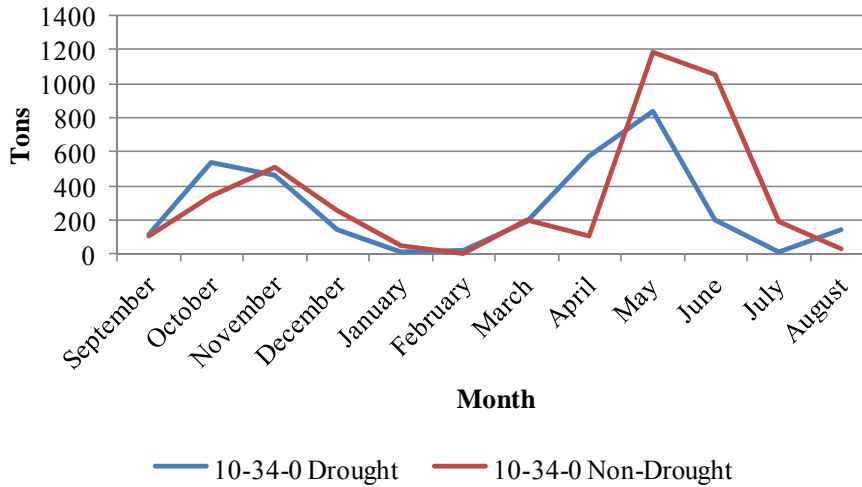


Figure 3.4 displays the demand pattern for gasoline during Garden City Co-op Inc.’s fiscal year. For a drought year, demand is relatively flat compared to that of a non-drought year. During winter holiday periods and summer months, demand peaks for a non-drought year. This might be correlated to consumer confidence and increased demand.

Figure 3.4: Garden City Co-op Inc.’s Fiscal Year Gasoline Demand Comparison for a Drought Year versus a Non-Drought Year (Gallons)

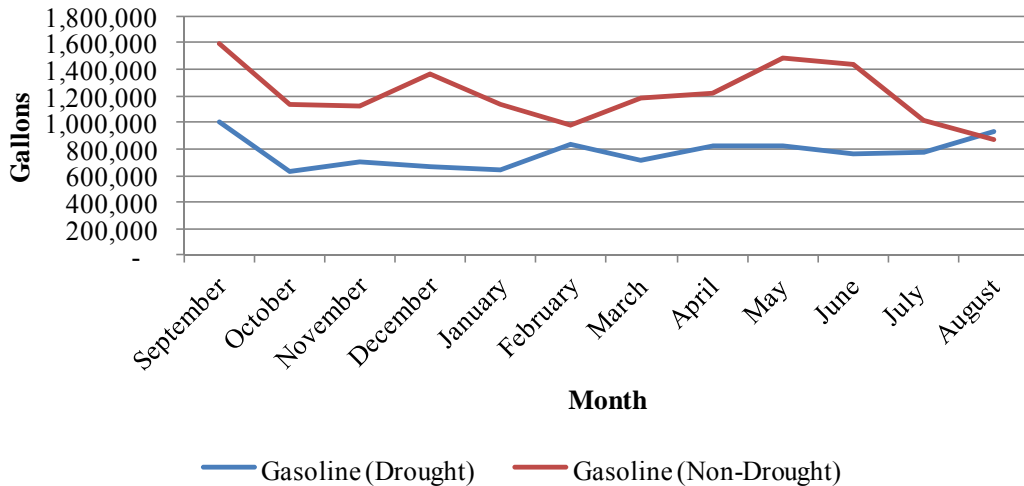
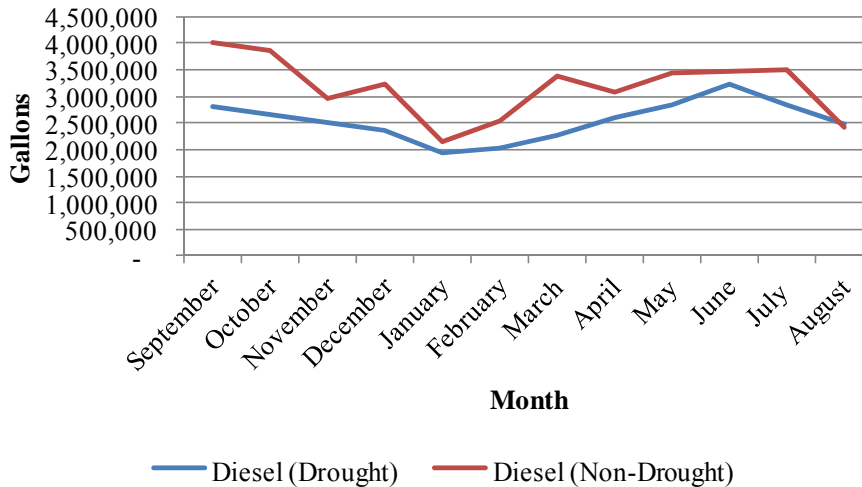


Figure 3.5 displays the seasonality in demand for diesel during Garden City Co-op Inc.'s fiscal year. There are two periods of peak demand. The first occurs during the fall months during wheat seeding and fall harvest of corn, milo, and soybeans. The second occurs during spring and summer for planting of fall crops and harvesting of wheat.

Figure 3.5: Garden City Co-op Inc.'s Fiscal Year Diesel Demand Comparison for a Drought Year versus a Non-Drought Year (Gallons)



3.1 Cost Minimization Model

The objective for this thesis and model is to minimize the total logistics costs for Garden City Co-op, Inc while meeting estimated consumer demand using mathematical programming. Logistics costs include four categories. The first category includes inventory-carrying costs associated with the interest cost of holding product in storage in order to satisfy future demand. The second category includes storage depreciation costs associated with constructing additional storage for product above current capacity. The third category involves the cost of additional transportation assets as depreciation, labor, and operating costs above current capacity. The fourth category includes freight costs for moving gasoline and diesel products from the manufacturer to Garden City storage or from

the secondary manufacturer to the end user. Garden City Co-op, Inc. minimizes costs for five products that include NH₃, 32-0-0, 10-34-0, gasoline, and diesel.

For Garden City Co-op Inc., the fertilizer supply chain decision variables as it relates to the conceptual framework for an aggregate production plan will be the quantity of NH₃, 32-0-0, and 10-34-0 to purchase and transport from the manufacturer or wholesaler to company owned storage tanks that will satisfy estimated consumer demand. Petroleum supply chain decision variables include the quantity of gasoline and diesel to purchase and transport from the manufacturer to the end user or company storage.

Gasoline decision variables are of two types. The first type is gasoline that is loaded as mix loads with diesel at the manufacturer and delivered to the end user. The second type is gasoline that is transported from the manufacturer to company storage for future mix load sales with diesel. Gasoline sold as partial loads with diesel will have to be stored for times during the year when diesel is unavailable from the manufacturer and mix loads have to be loaded via company storage.

Diesel decision variables include the quantity of diesel to transport as full loads from manufacturers at two different sites, as well as the quantity of diesel to purchase and transport from the manufacturer that will be shipped to the end consumer as a mix load with gasoline. There are decision variables for the quantity of diesel to purchase and transport from manufacturers to company owned storage at two different sites for future full load or mix load sales. Lastly, there are decision variables for the quantity of full load sales from company owned storage to the end user.

Essentially, Garden City Co-op, Inc. optimizes the quantity of product that it purchases and transports to storage or end users for each month in its fiscal year in order to

minimize total logistics costs. The decision variables for the model and associated abbreviations are listed as follows:

Decision Variables (i = period 1, ..., 12)

Np_i = NH3 purchased and transported per period (tons)

Up_i = 32-0-0 purchased and transported per period (tons)

Pp_i = 10-34-0 purchased and transported per period (tons)

Gs_i = Gasoline mix load sales from Scott City Terminal per period (gallons)

Gf_i = Gasoline for Lowe fills from Scott City Terminal per period (gallons)

$Dfss_i$ = Diesel full load sales from Scott City Terminal per period (gallons)

$Dmss_i$ = Diesel mix load sales from Scott City Terminal per period (gallons)

$Dlfs_i$ = Diesel for Lowe fills from Scott City Terminal per period (gallons)

$Dgfs_i$ = Diesel for Scott City tank fills from Scott City Terminal per period (gallons)

$Dfsm_i$ = Diesel full load sales from McPherson terminal per period (gallons)

$Dfsg_i$ = Diesel full load sales from Scott City tanks per period (gallons)

The cost minimization objective function for Garden City Co-op is expressed mathematically as follows:

Objective Function:

$$2.25(Nb_i + Np_i - Nd_i) + 1.04(Ub_i + Up_i - Ud_i) + 1.54(Pb_i + Pp_i - Pd_i) + 0.01[Gb_i + Gf_i - (Gd_i - Gs_i)] + 0.01(Dgb_i + Dgfs_i - Dfsg_i) + 0.01[Dlb_i + Dlfs_i - (Df_i - Dfss_i - Dfsm_i - Dfsg_i) - (Dm_i - Dmss_i)] + 0.63[(915n + 85,000)/7] + 0.63[(60u + 42,500)/7] + 0.63[(60p + 42,500)/7] + 0.63[(0.29g + 100,000)/7] + 0.63[(0.29d + 100,000)/7] + 0.63(150,000Nt/5) + 0.63(65,000Lt/5) + 0.63(115,000Pt/5) + 0.63(150,000T/3) + 99,576L + 96,000T + 0.04(Gd_i - Gs_i) + 0.04[(Df_i - Dfss_i - Dfsm_i - Dfsg_i) + (Dm_i - Dmss_i)] + 0.03(Dfsg_i) + 0.08(Dfsm_i)$$

Where:

Nb_i = NH₃ beginning inventory per period (tons)

Nd_i = NH₃ demand per period (tons)

Ub_i = 32-0-0 beginning inventory per period (tons)

Ud_i = 32-0-0 demand per period (tons)

Pb_i = 10-34-0 beginning inventory per period (tons)

Pd_i = 10-34-0 demand per period (tons)

Gb_i = Gasoline Lowe tank beginning inventory per period (gallons)

Gd_i = Gasoline mix load demand per period (gallons)

Dgb_i = Diesel Scott City tank beginning inventory per period (gallons)

Dlb_i = Diesel Lowe tank beginning inventory per period (gallons)

Df_i = Diesel full load demand per period (gallons)

Dm_i = Diesel mix load demand per period (gallons)

n = Additional NH₃ storage volume

u = Additional 32-0-0 storage volume

p = Additional 10-34-0 storage volume

g = Additional gasoline storage volume

d = Additional diesel storage volume

Nt = Additional NH₃ trailers

Lt = Additional liquid fertilizer trailers

Pt = Additional petroleum trailers

T = Additional trucks

L = Additional drivers

Inventory holding costs are expressed within the objective function as follows:

$2.25(Nb_i + Np_i - Nd_i) = \text{NH}_3 \text{ inventory holding cost of } \$2.25 \text{ per ton per period}$

$1.04(Ub_i + Up_i - Ud_i) = \text{32-0-0 inventory holding cost of } \$1.04 \text{ per ton per period}$

$1.54(Pb_i + Pp_i - Pd_i) = \text{10-34-0 inventory holding cost of } \$1.54 \text{ per ton per period}$

$0.01[Gb_i + Gf_i - (Gd_i - Gs_i)] = \text{Gasoline inventory holding cost of } \$0.01 \text{ per gallon per period}$

$0.01(Dgb_i + Dgfs_i - Dfsg_i) + 0.01[Dlb_i + Dlfs_i - (Df_i - Dfss_i - Dfsm_i - Dfsg_i) - (Dm_i - Dmss_i)] = \text{Diesel inventory holding cost of } \$0.01 \text{ per gallon per period}$

Storage asset costs are expressed within the objective function as follows:

$0.63[(915n + 85,000)/7] = \text{Net yearly depreciation expense of } 63\% \text{ for NH}_3 \text{ storage, at a cost of } \$915 \text{ per ton, with } \$85,000 \text{ in plumbing expense, depreciated over 7 years}$

$0.63[(60u + 42,500)/7] = \text{Net yearly depreciation expense of } 63\% \text{ for 32-0-0 storage, at a cost of } \$60 \text{ per ton, with } \$42,500 \text{ in plumbing expense, depreciated over 7 years}$

$0.63[(60p + 42,500)/7] = \text{Net yearly depreciation expense of } 63\% \text{ for 10-34-0 storage, at a cost of } \$60 \text{ per ton, with } \$42,500 \text{ in plumbing expense, depreciated over 7 years}$

$0.63[(0.29g + 100,000)/7] = \text{Net yearly depreciation expense of } 63\% \text{ for gasoline storage, at a cost of } \$0.29 \text{ per gallon, with } \$100,000 \text{ in plumbing expense, depreciated over 7 years}$

$0.63[(0.29d + 100,000)/7] = \text{Net yearly depreciation expense of } 63\% \text{ for diesel storage, at a cost of } \$0.29 \text{ per gallon, with } \$100,000 \text{ in plumbing expense, depreciated over 7 years}$

Transportation asset costs are expressed within the objective function as follows:

$0.63(150,000Nt/5) = \text{Net yearly depreciation expense of } 63\% \text{ for NH}_3 \text{ trailers, at a cost of } \$150,000 \text{ per trailer, depreciated over 5 years}$

$0.63(65,000L/5)$ = Net yearly depreciation expense of 63% for liquid fertilizer trailers, at a cost of \$65,000 per trailer, depreciated over 5 years

$0.63(115,000Pt/5)$ = Net yearly depreciation expense of 63% for petroleum trailers, at a cost of \$115,000 per trailer, depreciated over 5 years

$0.63(150,000T/3)$ = Net yearly depreciation expense of 63% for trucks, at a cost of \$150,000 per truck, depreciated over 3 years

Labor and operating costs are expressed within the objective function as follows:

$99,576L$ = Yearly labor cost per driver of \$99,576

$96,000T$ = Yearly operating cost per truck of \$96,000

Freight costs are expressed within the objective function as follows:

$0.04(Gd_i - Gs_i) + 0.04[(Df_i - Dfss_i - Dfsm_i - Dfsg_i)]$ = Lowe gasoline and diesel sales freight cost of \$0.04 per gallon per period

$0.03(Dfsg_i)$ = Scott City tanks diesel sales freight cost of \$0.03 per gallon per period

$0.08(Dfsm_i)$ = McPherson terminal diesel sales freight cost of \$0.08 per gallon per period

Model constraints are specifically relating to period demand, yearly demand, and non-negativity. For fertilizer, product purchased per period cannot exceed total yearly demand for each product. This is expressed mathematically as:

$$0 \leq Np_i \leq Ndy$$

$$0 \leq Up_i \leq Udy$$

$$0 \leq Pp_i \leq Pdy$$

Where:

Ndy = Total yearly NH₃ demand

Udy = Total yearly 32-0-0 demand

P_{dy} = Total yearly 10-34-0 demand

Additionally ending inventories for each fertilizer product for each period cannot exceed total yearly demand. This is expressed mathematically as:

$$0 \leq (N_{bi} + N_{pi} - N_{di}) \leq N_{dy}$$

$$0 \leq (U_{bi} + U_{pi} - U_{di}) \leq U_{dy}$$

$$0 \leq (P_{bi} + P_{pi} - P_{di}) \leq P_{dy}$$

The gasoline portion of the model has constraints on sales volumes that cannot exceed period demand and fill volumes that cannot exceed yearly demand expressed mathematically as:

$$0 \leq G_{si} \leq G_{di}$$

$$0 \leq G_{fi} \leq G_{dy}$$

Additionally, gasoline ending inventories per period are not to exceed total yearly demand expressed mathematically as:

$$0 \leq G_{bi} + G_{fi} - (G_{di} - G_{si}) \leq G_{dy}$$

Where:

G_{dy} = Total yearly gasoline mix load demand

Additionally there is a non-negativity constraint on gasoline ending inventories expressed mathematically as:

$$0 \leq G_{se_i}$$

Where:

G_{se_i} = Scott City Terminal gasoline ending inventory per period

Gasoline sales also include a non-negativity constraint expressed as:

$$0 \leq G_{di} - G_{si}$$

Constraints for the diesel portion of the model include non-negativity, ending inventory levels, fill quantities, and sales quantities. Sales quantities should be less than or equal to period demand and are expressed mathematically as:

$$0 \leq Dfss_i \leq Df_i$$

$$0 \leq Dmss_i \leq Dm_i$$

$$0 \leq Dfsm_i \leq Df_i$$

$$0 \leq Dfsg_i \leq Df_i$$

Fill quantities should be less than or equal to yearly demand and are expressed mathematically as:

$$0 \leq Dlfs_i \leq Ddy$$

$$0 \leq Dgfs_i \leq Ddy$$

Where:

$$Ddy = \text{Total yearly diesel full and mix load demand}$$

Additionally, there are non-negativity or volume constraints for ending inventories expressed mathematically as:

$$0 \leq Dse_i$$

$$0 \leq Dme_i$$

$$0 \leq (Dgb_i + Dgfs_i - Dfsg_i) \leq 90,000 \text{ (Current tank volume in gallons)}$$

$$0 \leq [Dlb_i + Dlfs_i - (Df_i - Dfss_i - Dfsm_i - Dfsg_i) - (Dm_i - Dmss_i)] \leq Ddy$$

Where:

$$Dse_i = \text{Scott City Terminal diesel ending inventory per period}$$

$$Dme_i = \text{McPherson Terminal diesel ending inventory per period}$$

Lastly, there are constraints for non-negative sales listed mathematically as:

$$0 \leq (Df_i - Df_{ss_i} - Df_{sm_i} - Df_{sg_i})$$

$$0 \leq (Dm_i - Dm_{ss_i})$$

3.2 Modeling

Several variations of the model will be estimated so as to stress transportation assets versus storage assets. The first model assumes no beginning period inventory and no ending period inventory for each product in company storage. The second model assumes full beginning period inventory at current capacities and no ending period inventory for product in company storage. The third model assumes no beginning period inventory and full ending period inventory at current capacities for each product in company storage. The fourth model assumes full beginning period inventory and full ending period inventory at current capacities for each product in company storage. By running different model scenarios for starting and ending inventories, an average picture of storage and transportation needs under varying scenarios is determined.

Modeling was conducted comparing non-drought year volumes for fertilizer and petroleum versus drought year volumes. Modeling also compared combined member and non-member fertilizer volumes versus member only fertilizer volumes in order to determine if costs could be reduced by focusing on serving members only. Non-member fertilizer volume is associated with the quantity of fertilizer Western Transport delivers to other area cooperatives or agri-businesses. For each model, ten optimization models were estimated in order to ensure that a best local solution or global optimum solution was achieved. Each optimization model was completed in approximately 1 hour. Total run time for all models was approximately 160 hours or 20 working days. Due to time constraints regarding solutions for the objective of this thesis, no more than 10 optimization models were estimated. Table 3.3 displays a schematic of the modeling scenarios.

Table 3.3 Modeling Scenarios

Non-Drought Year With Non-Member Fertilizer Business	Drought Year With Non-Member Fertilizer Business
Empty Beginning and Empty Ending Inventory (10 Optimization Models)	Empty Beginning and Empty Ending Inventory (10 Optimization Models)
Full Beginning and Empty Ending Inventory (10 Optimization Models)	Full Beginning and Empty Ending Inventory (10 Optimization Models)
Empty Beginning and Full Ending Inventory (10 Optimization Models)	Empty Beginning and Full Ending Inventory (10 Optimization Models)
Full Beginning and Full Ending Inventory (10 Optimization Models)	Full Beginning and Full Ending Inventory (10 Optimization Models)
Non-Drought Year Without Non-Member Fertilizer Business	Drought Year Without Non-Member Fertilizer Business
Empty Beginning and Empty Ending Inventory (10 Optimization Models)	Empty Beginning and Empty Ending Inventory (10 Optimization Models)
Full Beginning and Empty Ending Inventory (10 Optimization Models)	Full Beginning and Empty Ending Inventory (10 Optimization Models)
Empty Beginning and Full Ending Inventory (10 Optimization Models)	Empty Beginning and Full Ending Inventory (10 Optimization Models)
Full Beginning and Full Ending Inventory (10 Optimization Models)	Full Beginning and Full Ending Inventory (10 Optimization Models)

Additionally, product availability for gasoline for diesel mix loads directly from the manufacturer will be limited to 50 percent of estimated demand for the months of June, July, and August due to potential diesel shortages from the primary manufacturer during that period. Furthermore, loads of diesel for mix loads from the primary manufacturer will be restricted to 50 percent of estimated demand during June, July, and August due to potential diesel shortages from the primary manufacturer during that period. Total diesel availability from the primary manufacturer will be restricted to 50 percent of total diesel estimated demand for the months of June, July, and August due to potential shortages.

Trucking requirements as it relates to trailer, truck, and driver needs will be dependent upon the number of loads a truck can transport in a day from the manufacturer or company storage for each product. For periods of low estimated demand, loads per day

will increase; for periods of high product demand, loads per day will decrease. It is assumed that each truck will have one driver and therefore the quantity of trucks equal the quantity of drivers.

The model will be solved in an Excel spreadsheet. Because of potential non-linear features in calculations due to “IF” statements, a solver that features a genetic algorithm to find the best solution to the model will be used. Palisade Corporation’s software program Evolver can easily handle non-linear features in a model and seek out the global optimum solution to the problem.

This chapter discussed data acquisition for modeling as it relates to a drought year versus a non-drought year sales demand. Decision variables were provide for the model as it relates to the quantities of fertilizer and petroleum products that will be purchased and transported for each period. Further discussion included the objective function as it relates to minimizing total logistical costs associated with inventory holding, storage asset depreciation, transportation asset depreciation, labor, operation costs, and freight. Constraints for the model associated with non-negativity and demand limitations were provided. A schematic for the various models and optimizations were provided for each scenario evaluated. Further information was included on the solver method utilized for the optimization. In the next chapter, we will discuss the model results.

CHAPTER IV: RESULTS

As discussed in Chapter III various model scenarios and optimizations were conducted in an effort to minimize total logistics costs for Garden City Co-op, Inc. The base model varied starting and ending inventory values to stress transportation assets versus storage assets. In addition, the effect of non-drought year demand versus drought year demand was estimated on the base model results. The models optimized combined member and non-member fertilizer demand versus member only demand. Mean values for total logistics costs for each optimization were evaluated as well as the mean values for additional storage and transportation assets. These measures will help to determine the optimal amount of storage and transportation needs for Garden City Co-op Inc.

The base model of a non-drought year with combined member and non-member fertilizer business was examined first. Table 4.1 displays the base model results of a non-drought year with combined member and non-member fertilizer volumes as compared to the other model scenarios. The table displays the additional storage volume and transportation assets required above current levels as well as the total minimized logistics cost based upon the calculated decision variable values for each model. The percentage change for each precipitation scenario as well as demand scenario is also displayed.

Table 4.1 Cost Minimization Model Results

Variable	Non-Drought Year with Non-Member Fertilizer Business Additional Storage Volume, Transportation Assets, and Minimized Costs (Base Numbers)	Drought Year with Non-Member Fertilizer Business (Percent Change from Base)	Non-Drought Year without Non-Member Fertilizer Business (Percent Change from Base)	Drought Year without Non-Member Fertilizer Business (Percent Change from Base)
NH3 Storage (Tons)	657	22%	-39%	51%
32-0-0 Storage (Tons)	594	-61%	102%	127%
10-34-0 Storage (Tons)	13	-2100%	108%	-629%
Gasoline Storage (Gallons)	221,636	18%	62%	46%
Diesel Storage (Gallons)	468,862	-88%	7%	-153%
NH3 Trailers	1	100%	-1400%	-1500%
Liquid Trailers	1	-50%	-200%	-225%
Petroleum Trailers	4	-53%	7%	-33%
Trucks	3	-18%	-145%	-164%
Drivers	3	-18%	-145%	-164%
Total Costs	\$1,754,813	-13%	-38%	-42%

Evaluating the results of the base model indicates that additional storage volumes are required for all products other than 10-34-0. The model indicated a need for an additional 13 tons of 10-34-0 storage. However, because 13 tons are less than one truckload of product it is essentially a negligible amount. The model also indicated an additional need for transportation assets above current levels especially as it relates to petroleum trailers, trucks, and drivers. This is likely due to the impact of product availability at the manufacturing point and load turnaround time during peak season as was programmed into the model. For the base model, total logistics costs were minimized at \$1,754,813.

The next model to examine is the base model altered to reflect demand and costs associated with a drought year. In this model, one would expect a reduction in costs as volumes of both fertilizer and petroleum decrease in a drought situation. As indicated in the table, costs decreased by 13%. The model further indicated that additional investment

in NH₃ and gasoline storage was needed. However, even though storage investment was still required for 32-0-0 and diesel, the total cost was lower than that of the base model. Furthermore, the model indicated an oversupply of 10-34-0 storage.

When evaluating the transportation assets for the drought model, investment was reduced in the form of liquid fertilizer trailers, petroleum trailers, trucks and drivers when compared to the base model but additional assets were still required above current levels. Investment in NH₃ trailers increased when compared to the base model. In sum, the drought model favored increased investment of both NH₃ storage and transportation assets.

The next variation to the base model is to use the non-drought year demand and cost variables, but eliminate the non-member business. When eliminating non-member fertilizer business from the base model, total costs are reduced by 38%. Lower costs would be expected because a reduction in fertilizer volume transported will reduce costs associated with transportation assets.

In order to minimize costs, the model favored an inventory smoothing approach, which has implications for the optimal mix of storage and transportation assets. When evaluating storage assets, this demand scenario appeared to favor further increased investment in 32-0-0, 10-34-0, gasoline, and diesel storage as compared to the base model. The model still indicated additional investment in NH₃ storage but less than that of the base model. The elimination of the non-member fertilizer volumes indicated that the current asset levels for transportation assets could be reduced for NH₃ trailers, liquid fertilizer trailers, trucks, and drivers. However, the model still indicated additional investment in petroleum trailers. Once again, this is likely due to the impact of product

availability at the manufacturing point and load turnaround time during peak season as was programmed into the model.

The final model to examine is to alter the base model by removing non-member fertilizer business and use drought year demand and cost variables. When introducing drought as well as eliminating non-member fertilizer business costs decrease by 42% as compared to the base model. These lower costs occurred because volumes for both fertilizer and petroleum will decrease in a drought scenario as well as the loss of fertilizer volume transported to non-members. The model indicated increased investment in NH₃ storage, 32-0-0 storage, and gasoline storage over the base model. The model appeared to favor an inventory smoothing approach utilizing investments in storage. The model indicated that there was an oversupply of 10-34-0 storage as well as diesel storage. Furthermore, the effect on transportation assets was significant as there was now an oversupply of NH₃ trailers, liquid fertilizer trailers, trucks, and drivers. However, the model still indicated additional investment in petroleum trailers but less than the base model. Again, this is likely due to the impact of product availability at the manufacturing point and load turnaround time during peak season as was programmed into the model.

In this chapter, results were presented for Garden City Co-op Inc.'s logistics optimization model. Data was presented for a non-drought year versus a drought year. As well as combined member and non-member fertilizer volumes versus member only. The models varied starting and ending inventory levels to stress transportation versus storage assets. The Appendix contains the complete results of the various inventory scenarios.

In the next chapter conclusions will be presented regarding the modeling data. A determination of whether the thesis objective of increasing logistical efficiency and

reducing costs will be presented. Further conclusions will reveal whether a consolidated logistics strategy for fertilizer and petroleum products will reduce the level of transportation assets required for the cooperative.

CHAPTER V: CONCLUSIONS

Through this research, Garden City Co-op, Inc. has gained useful insight into logistical planning for the cooperative. The objective of this thesis as outlined in Chapter 1 was to determine an optimum mix of transportation and storage assets that would increase logistical efficiencies for the cooperative while minimizing costs. Costs included inventory holding, depreciation of additional storage assets, depreciation of additional transportation assets, labor, operations, and freight.

The model data provided two alternative strategies for the cooperative to pursue as it relates to the operational characteristics of Western Transport. The cooperative could choose a strategy of continuing the transportation of non-member fertilizer volume. However, this strategy had larger logistical costs in both non-drought and drought simulations. The model data indicated increased investment in transportation assets specifically as it relates to NH₃ trailers, petroleum trailers, trucks, and drivers. The model weighted a larger investment in transportation than storage in order to maintain service to non-members while meeting the demand of members. The models attempted to reduce transportation costs only to the point where non-member demand was not sacrificed. Optimization data indicated a consistent need for NH₃, 32-0-0, gasoline, and diesel storage.

Another strategy for Garden City Co-op Inc. would be to abandon transportation of fertilizer to non-member accounts. In both drought and non-drought scenarios, costs for the cooperative could be reduced dramatically. For a drought year, costs could decrease by 42%. For a non-drought year, costs could be reduced by 38%. The model reduced the investment of transportation and indicated the need for a reduced fleet size. The reduction in fleet size for NH₃ trailers, liquid fertilizer trailers, trucks and drivers occurred in both drought and non-drought years. However, there was still a need for additional petroleum

trailers due to product availability and load turnaround times during peak months. Model data continued to indicate a need for additional NH₃, 32-0-0, gasoline and diesel storage as the model shifted from a just-in-time inventory to an inventory smoothing scheme.

The hypothesis that logistical costs could be reduced by consolidating supply chain strategies for the Crop Production Division, Petroleum Division, and Western Transport holds true when the cooperative focuses on serving member fertilizer volume only and reducing fleet size. The study did not take into account reducing the volume of petroleum transported to non-member accounts. Further reductions of costs might occur if the cooperative were to reduce services to those accounts. However, this could come at a risk and affect the level of patronage the cooperative receives for its purchases of petroleum with CHS.

Garden City Co-op, Inc. has several risks associated with either strategy. The largest risk is purchasing product when the market price is not favorable due to a bear price market. The cooperative is tasked with purchasing product at favorable prices for its patrons. By focusing on a purchase of a commodity in a bear price market in order to smooth purchases over the year, patrons may risk paying higher prices for inputs or switch purchases to competitors. Any reduction in the size of the transportation fleet could reduce the cooperatives ability to respond to favorable market conditions for commodities such as a bull market.

Garden City Co-op, Inc. operates in a semi-arid environment, which means weather and climate are significant risks for the cooperative. Precipitation data from 2000 thru 2011 in Finney County indicates almost a decade of below normal moisture. The deficit since 2000 is approximately 21 inches. The question must arise on whether this is a

permanent shift in the climate for the area. If so, any reduction in rainfall will likely reduce crop yield and future fertilizer application rates. This could affect the volume of fertilizer the cooperative transports and stores in the future. As such, investment in storage and transportation assets could be a risk. This could be further amplified if future water allocations for irrigated crops were to decrease significantly.

One area that was not analyzed with model as it relates to precipitation was the timing of the moisture event and the impact on crop conditions and customer purchase volumes. Customer buying habits will vary based on perceptions of crop condition. Even if you were experiencing a year with a precipitation deficit, a timely rain may allow the crop to maintain normal yields and as such purchase volumes of commodities may not vary from that of a non-drought year. Subsequently the model could be constructed to analyze a larger data set based upon daily or weekly demand versus daily or weekly precipitation values.

The cooperative also faces a risk from commodity prices and the current political environment. If commodity prices were to decline levels of input volume for fertilizer would likely decline as well. This could affect any potential investment in storage or transportation as volumes decline. Future Farm Bill policy is also a risk. Crop Insurance is a valuable risk management tool in a semi-arid environment. It encourages the production of crops on a yearly basis despite weather conditions. If future funding of Federal Crop Insurance were to diminish as the Federal Government seeks cuts to the fiscal budget, future crop plantings and input purchases could be in jeopardy. This would affect both fertilizer and petroleum volumes.

Further risks are associated within the cooperative's supply chain. For instance, the model factored in product availability at primary manufacturing and terminal points that are close to the cooperatives trade area. If a manufacturing facility or terminal were to face an outage, the cooperative would be forced to source product from supply points farther away. This would increase demand for transportation assets. Therefore, reducing transportation assets could be risky in the face of potential supply point outages.

In order to mitigate the supply chain risk and bull whip effects from product outages, the cooperative could attempt to share information on its logistics strategy with both its wholesaler as well as the manufacturer. This would decrease potential costs for all parties involved in the supply chain.

Western Transport provides transportation to a large volume of non-member petroleum and fertilizer accounts. The cooperative could face a risk if those accounts were to source product from another seller or carrier thereby reducing volume for the cooperative. The cooperative might then have an abundance of both storage and transportation assets. Therefore, it is important for the cooperative to maintain its relationships with its non-member accounts in order to minimize the risk of customer defections and the potential oversupply of assets.

While the model optimized the transportation schedule for the cooperative, a schedule is only as good as its implementation. Without proper management and implementation, any purchase and transportation schedule could lead to a loss in efficiency. The cooperative must ensure adequate management and implementation of the optimized schedule in order to maximize investment in storage and transportation assets.

Future energy policy in the United States and the increasing abundance of natural gas is also a risk to the cooperative. The cooperative sells a large volume of refined fuel in the form of gasoline and diesel. With the abundance of natural gas, there is a possibility of future vehicles in the United States relying on natural gas as an energy source. This could decrease demand for gasoline and diesel thereby decreasing demand for storage and transportation assets for the cooperative.

Future study in regards to the optimization model might include the incorporation of the cooperatives propane transportation. As this is a relatively new practice for the cooperative, it was not implemented in the model. This could significantly affect the level of transportation investment for that product. In addition, future study for the cooperative might also incorporate uncertainty in the demand for products and assign probability distributions to demand for modeling.

While total logistics costs are minimized for the cooperative, the model could be adjusted to reflect unit costs of product. This would provide a deeper understanding of profitability for the cooperative as it relates to its margin structure based upon product costs with the addition of logistical costs. In addition, as the cooperative increases volumes of fertilizer and petroleum there is a cost savings per unit of product due to economies of scale. Logistical costs would take up a smaller percentage of the products overall unit cost.

With this optimization study, Garden City Co-op, Inc. now has a clear picture in regards to investment direction for assets. With a strategy of continued service to non-member accounts, a greater investment emphasis is placed on transportation assets. With a strategy of focused member only service, a relatively equal investment in storage and transportation is required. Both strategies require further investment in storage assets to

optimize logistical efficiency. With proper implementation, focused investment, and sound management, the cooperative can fulfill its objective of increasing logistical efficiencies and decreasing costs.

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APPENDIX A: LIST OF ADDITIONAL TABLES

Table A1: Additional Assets Needed and Total Costs Estimated Using the Cost Minimization Model: Base Model Scenario of Non-Drought Year with Non-Member Fertilizer Business

Inventory Scenario	NH3	32-0-0	10-34-0	Gasoline	Diesel	NH3 Trailers	Liquid Trailers	Petroleum Trailers	Trucks	Drivers	Total Costs
	Storage (Tons)	Storage (Tons)	Storage (Tons)	Storage (Gallons)	Storage (Gallons)						
Empty Beginning, Empty Ending	-236	-282	-97	62730	70898	0	1	3	3	3	\$ 1,555,435
Empty Beginning, Full Ending	549	837	242	275442	1485180	1	1	4	4	4	\$ 2,196,941
Full Beginning, Empty Ending	83	37	-106	253369	-1154966	0	0	3	2	2	\$ 1,330,771
Full Beginning, Full Ending	2233	1782	13	295003	1474336	1	2	5	2	2	\$ 1,936,106
Mean	657	594	13	221636	468862	1	1	4	3	3	\$ 1,754,813

Table A2: Additional Assets Needed and Total Costs Estimated Using the Cost Minimization Model: Altered Base Model Scenario of Drought Year with Non-Member Fertilizer Business

Inventory Scenario	NH3	32-0-0	10-34-0	Gasoline	Diesel	NH3 Trailers	Liquid Trailers	Petroleum Trailers	Trucks	Drivers	Total Costs
	Storage (Tons)	Storage (Tons)	Storage (Tons)	Storage (Gallons)	Storage (Gallons)						
Empty Beginning, Empty Ending	746	668	-927	159192	-1492941	1	0	1	3	3	\$ 1,489,568
Empty Beginning, Full Ending	584	335	0	254709	867562	1	1	4	4	4	\$ 2,032,019
Full Beginning, Empty Ending	1156	-76	-113	245570	-477302	0	0	0	0	0	\$ 853,618
Full Beginning, Full Ending	729	0	0	387907	1332084	2	1	2	2	2	\$ 1,742,918
Mean	804	232	-260	261845	57351	1	1	2	2	2	\$ 1,529,531

Table A3: Additional Assets Needed and Total Costs Estimated Using the Cost Minimization Model: Altered Base Model Scenario of Non-Drought Year without Non-Member Fertilizer Business Additional Assets and Total Costs

Inventory Scenario	NH3	32-0-0	10-34-0	Gasoline	Diesel	NH3 Trailers	Liquid Trailers	Petroleum Trailers	Trucks	Drivers	Total Costs
	Storage (Tons)	Storage (Tons)	Storage (Tons)	Storage (Gallons)	Storage (Gallons)						
Empty Beginning, Empty Ending	621	333	-307	580115	-1027024	-7	-1	5	0	0	\$ 865,628
Empty Beginning, Full Ending	497	2813	0	226242	1674311	-5	0	5	-1	-1	\$ 1,271,355
Full Beginning, Empty Ending	-273	1094	415	230977	-42602	-7	-1	3	-1	-1	\$ 951,804
Full Beginning, Full Ending	747	548	0	397350	1410970	-7	-2	3	-3	-3	\$ 1,292,848
Mean	398	1197	27	358671	503914	-7	-1	4	-1	-1	\$ 1,095,409

Table A4: Additional Assets Needed and Total Costs Estimated Using the Cost Minimization Model: Altered Base Model Scenario of Drought Year without Non-Member Fertilizer Business

Inventory Scenario	NH3	32-0-0	10-34-0	Gasoline	Diesel	NH3 Trailers	Liquid Trailers	Petroleum Trailers	Trucks	Drivers	Total Costs
	Storage (Tons)	Storage (Tons)	Storage (Tons)	Storage (Gallons)	Storage (Gallons)						
Empty Beginning,											
Empty Ending	541	2061	-1081	244373	-1339902	-7	-1	3	-1	-1	\$ 840,401
Empty Beginning,											
Full Ending	572	0	743	347382	479106	-7	-1	4	0	0	\$ 1,032,913
Full Beginning,											
Empty Ending	1002	465	-113	517934	-996994	-7	-2	1	-4	-4	\$ 849,308
Full Beginning, Full											
Ending	1857	2855	176	182187	867024	-7	-1	2	-2	-2	\$ 1,347,063
Mean	993	1345	-69	322969	-247692	-7	-1	3	-2	-2	\$ 1,017,421