IMPROVED INVENTORY CONTROL STRATEGIES

FOR FARM SUPPLY COOPERATIVES

By

FITRYANTI PAKIDING

Bachelor of Science
Bogor Agricultural University
Bogor, Indonesia
1997

Master of Science
Oklahoma State University
Stillwater, Oklahoma
2003

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
In partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
May, 2007

IMPROVED INVENTORY CONTROL STRATEGIES

FOR FARM SUPPLY COOPERATIVES

Dissertation Approved:

Dr. Phillip Kenkel
Dissertation Adviser

Dr. Francis Epplin

Dr. Rodney Holcomb

Dr. David Pratt

Dr. A.Gordon Emslie
Dean of the Graduate College

ACKNOWLEDGEMENT

I would like to acknowledge the Fulbright commission for opening the opportunity for me to pursue a graduate program in the United States and for the invaluable experiences I have had as a Fulbright fellow. Many thanks also due to the staffs of American Indonesian Exchange Foundation (AMINEF) for their hard work to make sure my starting the graduate program in Oklahoma State University went well. I deeply thank the Rector of Papua State University as well as my colleagues at *Fakultas Pertanian dan Teknologi Pertanian* for their continuous support as I studied overseas.

I wish to acknowledge many people that have contributed in the process of completing the graduate program at the Department of Agricultural Economics, Oklahoma State University. My sincere appreciation goes to Dr. Philip Kenkel for offering me a research assistantship position, without which the entire degree program would not have been possible and for guiding me throughout the whole program. I also wish to thank my other committee members, Dr. Francis M Epplin, Dr. Rodney Holcomb and Dr. David Pratt, for their invaluable comments and encouragement throughout the research process. Many thanks are also due to all faculty members that contributed towards upgrading my academic capabilities through courses, critical evaluation and/ or encouragement. I would also like to thank many staffs at the Department of Agricultural Economics that have assisted me on several nonacademic and procedural issues. I also wish to recognize all of my friends who helped me in my research work: Arif Muljadi,

Haerani Agustini, and Fuad Rakhman for their help on data analysis; Grace Bowden, Elisha Basford, Shelly Stricklen, Steve and Laura Schley, Anna Childers, Yemisi Olukuya, and Jon Hornung for their help on making this dissertation understandable, to them I owe a lot of “Tylenols”.

My acknowledgment would not be complete without acknowledging all family and friends whose love, support and presence make the whole process of learning in Oklahoma State University more enjoyable. In particular, I would like to thank my parents, Mr. and Mrs. Pakiding Lamba, for their continuous support through prayer, hope and love which have helped me to stand firm throughout the whole process of completing this program. My sincere appreciation also goes to Sharon Hanson, the Watkins (Noel, Anne, and Nicholas), the Hendersons (Gene, Marilyn, and Elisha), Henry Njoo and Nina Sugiarti, the Keatings (Bill, Lisa, and Fred), Gary and Grace Bowden, and John and Retha Regnier. Their priceless support through their prayer and friendship, both during happiness and otherwise, blessed me in countless ways.

Further, I wish to express my gratitude to the many good friends that I met in Stillwater, Oklahoma; to Indonesian Students and Community, to Hillcrest International Meeting group, to my fellow students at the Department of Agricultural Economics and to many friends that I wish to be able to mention each by name, your friendship will be forever cherished.

Finally, I dedicate this work to Jesus Christ, my Lord and Savior. He has begun the good work in me and has proven Himself to be faithful in finishing it. To Him be the glory forever and ever.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Problem Statement

Inventory management is practiced from the smallest organization such as fruit stands to multimillion dollar industries. Effective inventory management allows an organization to reduce total costs by decreasing ordering and holding costs as well as achieving wide-scale operational efficiencies. It also acts as an insurance by improving product availability and buffering against everyday uncertainties the organization faces.

Having effective inventory management has been a challenge to many industries. All organizations have some difficulty managing their inventory. The main reason for this is the inability to forecast the demand adequately. Materials are added to inventory in anticipation of demand. If the demand occurs sooner or is larger than anticipated, the result is an inadequate stock. If the demand occurs later than expected or never materializes, the result is an excessive stock. An inadequate stock and an excessive stock —along with periodic lack of storage space and large numbers of obsolete items—are some of the symptoms of poor inventory management systems.

Generally, 49 percent of current asset of farm supply cooperative is in inventory (Wadsworth). As organization with large investment in inventory, having efficient inventory management system could be a challenge to farm supply cooperatives. This

problem may be differs from one cooperative to another and the problem often depends on the products sold by each cooperative. To date, there has not been a study to measure the performance of the inventory systems of Oklahoma farm supply cooperatives. Information about the performance of each cooperative's inventory management system is needed for further use in developing efficient inventory management systems.

The major decisions in inventory control of any organization concern the time to replenish an order and the quantity of such an order. The failure to manage these two concerns can significantly increase the total cost of an organization. Numerous studies have developed inventory-ordering models, but none has applied these models to improve the inventory ordering systems of farm supply cooperatives in Oklahoma.

Farm supply cooperatives, in common with all retail merchandisers, designate their inventory for sale. They serve their members/patrons by buying and selling products. Providing quality, timely service, and desired products with competitive prices to their customers have constituted a challenge to farm supply cooperatives. Overcoming this challenge is becoming more important especially in keeping (or increasing) their share in farm supply markets.

As organizations with large investments in inventory, farm supply cooperatives could reduce their inventory cost through maintaining more effective inventory management systems. The remaining question is: "How can Oklahoma farm supply cooperatives' inventory management systems be reorganized to reduce inventory cost while still meeting consumer demands?"

Objectives

General Objective

The general objective of this research is to examine farm supply cooperative inventory management performance and to identify improved inventory management strategies.

Specific objectives

1. To investigate the rate of return on inventory items and to determine the variation across product and category.
2. To investigate a simple strategy for improving inventory performance.
3. To estimate optimal ordering quantity and replenishment time for individual items based on sales patterns and holding costs and to determine potential reduction in inventory costs from optimal purchase quantities.
4. To investigate the apparent efficiency or inefficiencies from inter branch transfers and centralized warehousing.

CHAPTER II

CONCEPTUAL FRAMEWORK

Agricultural cooperatives have been encouraged as vehicles for economic development because the cooperative form of organization enables producers to capture economies of size and increase marketing power. Although cooperatives have been the leading handler of agricultural production inputs for the past 50 years, the size of the market available to the traditional farm supplier is shrinking (Coffey). Direct competition to traditional farm supply businesses coming from the expansion of mass merchandisers such as K-Mart and Wal-Mart and regional firms, such as Atwoods and Tractor Supply Company. These companies are not only big in size; they are also equipped with advanced management systems. Despite the threats of competition from these large companies, however, farm supply cooperatives still have the advantage of being owned and controlled by their farmer members, thereby tying their futures closely together.

As with any profit organization, farm supply cooperatives can be price-competitive and profitable by minimizing their costs. A survey conducted by the Rural Business-Cooperatives Service (RBCS), United States Department of Agriculture (USDA) in 2002 found that “increasing cost” and “low margin” were among the foremost problems for farm supply cooperatives. With a significant proportion of farm supply cooperatives’ investment in inventory 25 percent of total assets and 49 percent of

current assets (Wadsworth)— the problems mentioned above could be due to poor inventory management system.

Developing a good inventory management system has been a challenge to many organizations mainly because inventory deals with two complex activities named supply and demand. Figure 1 depicts this concept. While supply activity adds stock to the inventory, it carries with it several problems such as the availability of the suppliers to provide the orders and the length of time to replenish the inventory. The demand does the opposite: it subtracts stock from the inventory. The uncertainty of the demand is one of the most difficult issues for an inventory system. These two activities, supply and demand, can be enormously complex especially when dealing with multiple inventory items in multiple locations.

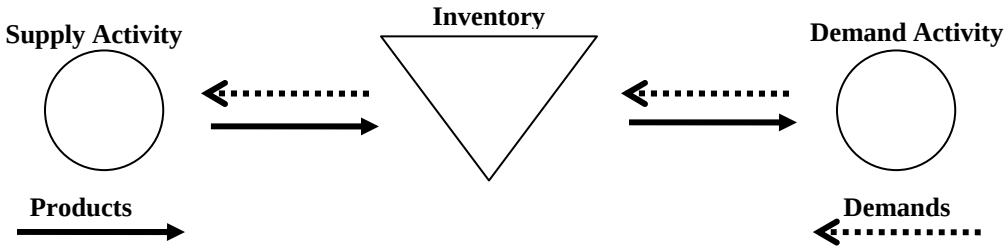

Figure 1. Inventory Buffering the Demand Activity and the Supply Activity

An ideal inventory management system is one with the ability to perfectly match these two activities. In other words, an ideal inventory system translates every demand correctly into supply decisions that provide quantity demanded as well as immediate response. In the real world, however, there is no such thing as an ideal inventory management system. Indeed, countless works have been conducted in developing inventory systems based on the limitations of matching supply and demand activities.

Regardless of the nonexistence of an ideal inventory management system, a "better" system, effective inventory management, can be achieved through planning and measurement. This work integrates not only the systems but also individuals who implement the system. Furthermore, good inventory management involves goals with strategies to meet the goals. Inventory management goals include two types of goals: broad and performance goals. Examples of broad goals are service, efficiency, cost containment, and competitiveness and example of performance goals are sales, capital investment, gross margins, and turnover. The goals and the strategy need to be understood by every individual in the organization (Wadsworth). Management of farm supply cooperatives is unique compared to other profit oriented companies because it emphasizes both profits and the service its patrons require. For that reason, there is a need for developing inventory strategies that incorporate these two aspects for farm supply cooperatives.

Numerous research studies have been conducted to improve inventory management systems in different fields. As a result, many inventory methods are available to be used as references in building the strategy for the inventory management systems of farm supply cooperatives. Two factors can be taken into consideration when deciding which method should be used: objectives to be achieved as well as the simplicity of the method. The rest of this section presents an overview for each of the specific objectives of different approaches used to improve inventory management of farm supply cooperatives.

The first objective of this study is to investigate the rate of return on inventory items and to determine variations across groups of products. Inventory turnover ratio and

inventory management index are used to achieve this objective. An explanation of how these ratios can be used for the purpose of this research is provided.

Inventory Turnover Ratio (ITR)

Inventory turnover ratio is a ratio that indicates the liquidity of the inventory. In other words, it shows how many times an inventory item is sold during a period of time and is calculated as:

(1) $$ITR_i = (COGS_i)(AIC_i)^{-1}$$

where *i* is each item in the inventory system and *COGS* is the cost of good sold. *AIC* is the average inventory cost. The average inventory is calculated as:

(Beginning inventory + ending inventory)/2

A ratio of seven, for instance, implies that a particular item is sold seven times in a period of time. A low inventory turnover ratio indicates the inventory moves very slowly and as a result more capital is tied up in inventory. Usually, inventory turnover ratio is evaluated by comparing the ratio calculated with the industry averages as well as the past and future ratio expected by the management. Most management strives for the ratio to be within or above the industry averages. Extreme departure above the industry averages, however, could be a sign of shortage in inventory and poor inventory management. Therefore, caution is advised when examining the performance of inventory items with extreme ITR above the industry average.

Another weakness with the ITR is that it does not consider the profits associated with the sales activity. Firms with higher profit margins (such as automotive dealers) can

tolerate low inventory turnover while firms with low profit margins (such as grocery stores) must turn frequently. For this reason standards for ITR vary across inventory types.

Inventory Management Index (IMI)

IMI is also a measure of inventory performance. It is also referred to as "Turns to Earns". IMI corrects the deficiency that the ITR has by considering both activity and profitability. This ratio measures how efficiently a company produces earnings and whether it has done a good job selecting, merchandising, and pricing the "right" products for their customers in generating sales. A company has to be skilled at many different aspects to achieve a good Turns- to-Earns ratio.

IMI relates the inventory turnover ratio of a particular item with the gross margin it generates as shown in equation:

(2) $$\textit{Inventory Management Index}_i = (ITR_i)(GMP_i)$$

where *i* is each item in the inventory and *GMP* is the gross margin percent. The gross margin percent is calculated as follow

(3) Gross Margin Percent = (Revenue - Cost of Goods Sold) / Revenue

Gross margin percent reveals a percentage of revenue that becomes the profit to the management. A firm can improve its IMI (and hence its profits associated with inventory items) by either improving the gross margin received or the frequency that the inventory items turn over. There is no exact standard for IMI. The profits generated by an item in the inventory must obviously cover all of the inventory carrying costs and

ordering costs and provide a return on the firm's investment in facilities, personnel and management. Inventory carrying costs include a variety of costs including financing or opportunity cost of invested funds, taxes and insurance, material handling, warehouse overhead costs, inventory control and counting and the cost associated with obsolescence and spoilage. Total inventory costs are generally considered to range from 20-40% of an item's value. Most managers, therefore, conclude that they need minimum IMI performance of one (1) to cover all inventory costs and generate sufficient profits to cover their non-inventory investments in their retail operation.

The second objective of this study is to investigate a simple strategy for improving the case-study firm's IMI index. The strategy involved eliminating items with the lowest IMI and determining the impact on the firm's IMI. Eliminating items that are not profitable to the cooperatives was first introduced, as a potential strategy to improve inventory management systems of farm supply cooperative, by Wadsworth in his work on inventory strategies for local farm supply cooperatives. It is the first of the ten strategies he developed for local farm supply cooperatives to achieve an effective inventory management (Figure 2). This strategy, "attain proper inventory mix", requires the cooperative to remove items that are unprofitable, no longer serve the needs of patrons, and face declining demand in the future market.

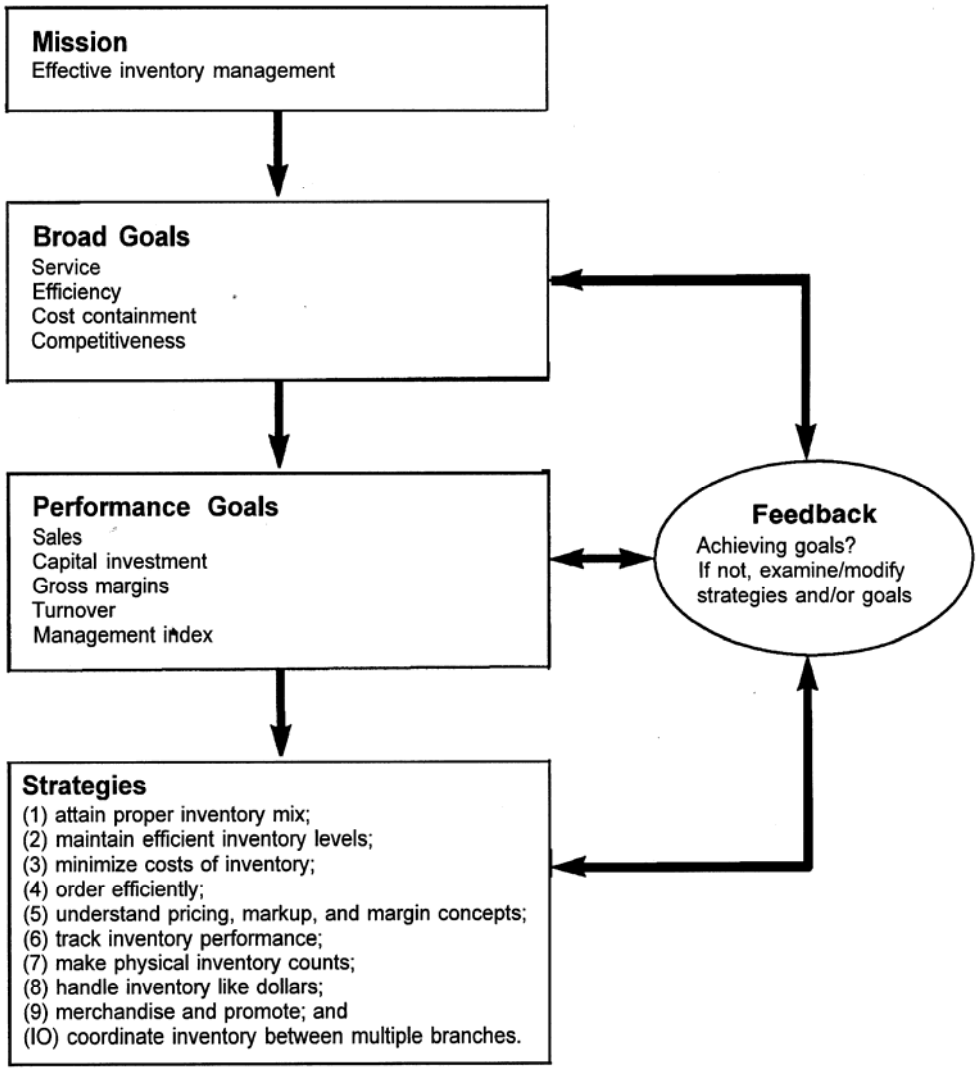

Figure 2. Planning Inventory Management (Wadsworth)

The third objective of this study is to estimate the optimal ordering quantity and replenishment time for individual items based on sales patterns and holding costs. The estimation is intended to be used to develop a purchasing strategy for farm supply cooperatives. A strategy based on the economic order quantity (EOQ) and the dynamic economic lot-size (DEL) model is developed in this study to answer the basic purchasing questions: how much to order and when to place such an order. This purchasing strategy

is in line with Wadsworth's fourth strategy: "order efficiently". Further discussion on EOQ and DEL is presented below.

Economic Order Quantity Model

Inefficient inventory management systems can lead to increasing cost and low margin because inventory brings with it a number of costs that generally fall into two categories: ordering costs and holding costs. Frequent ordering increases the ordering costs through the salaries of the purchasing staff, labor costs for placing the items in storage, and transportation costs. The holding costs, on the other hand, increase by less frequent ordering. Balancing these two costs (holding and ordering costs) to minimize the total inventory costs (which is the sum of the ordering cost and holding cost) is one of the critical decisions for an inventory control system. Many inventory control strategies have been developed to assist managers on this particular subject: the EOQ model is one of them. Figure 3 depicts the concept how EOQ balance these two costs.

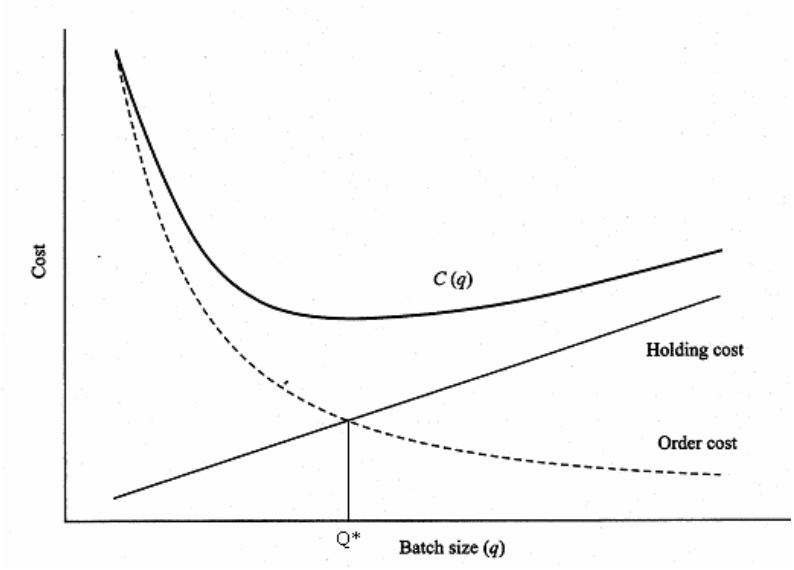

Figure 3. Inventory Costs and Economic Order Quantity

The derivation of a basic EOQ model as well as its sensitivity analysis, see Appendix A.1. EOQ is designed to minimize the total inventory cost and is robust with respect to the changes in its parameters. As long as the error is not too large, the EOQ remains useful. For that reason, EOQ is widely used in spite of its rigid assumptions. A traditional EOQ works with the assumption that the rate of demand is relatively constant and is known. The item is produced or purchased in lots or batches and not continuously. Order preparation costs and inventory holding costs are constant and known, and replenishment occurs all at once.

Dynamic Inventory Control Model

Inventory control can be defined as a system of monitoring inventory levels. The purpose of this monitoring is to detect the need for replenishment, to determine the quantity to be ordered, and physically manage and maintenance of security over the inventories, while the dynamic of a system is how the system works over time. Therefore, the dynamic inventory control model is useful for monitoring inventory levels over time.

Zipkin explains the dynamic inventory model (Figure 4).

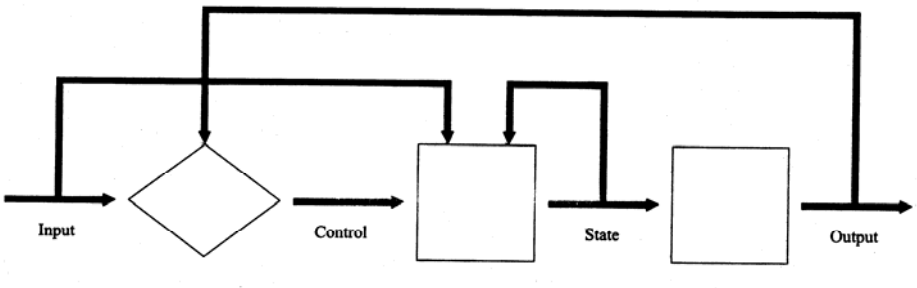

Figure 4. Block Diagram for Dynamic Model

Input is anything that enters the system; control is an action taken to modify the behavior of the system; state is a complete description of the system's element at a particular point in time; and the output is a product of the operation of the system. The right block shows that the output is determined by a transformation of the state, the middle block shows that the input and the control influence state; also, the state affects itself. Finally the left-most block tells us that the control depends on the input and also the output. This block diagram shows the fact in a dynamic control model that decisions taken today affect the alternatives available on later day. This concept is widely used when dealing with inventory control over time.

A dynamic inventory control model that uses EOQ with demand and the purchase cost varying over a discrete time is called the dynamic economic lot-size. Figure 5 depicts the use of the EOQ in placing replenishment orders. Results in stock levels vary from period to period. The inventory starts with the beginning inventory, q_0 at time t(0). At time t_1 an order, with lead time t_1-t_1', is placed to replenish the quantity q_1 to q_2 at time t_1'. Another order is placed at time t_2, with the same lead time as the first one, to replenish the quantity q_3 to q_4.

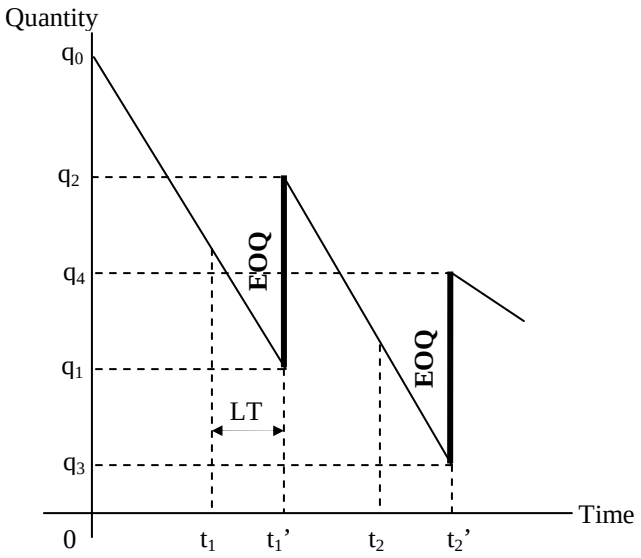

Figure 5. Replenishment Order with EOQ Method

In a multiple locations case such as multiple warehouse locations or store locations, replenishment can be done either by each location, or by joint replenishment among all branches. The advantages of doing a joint replenishment are: discount in purchase costs through a quantity discount, saving on unit transportation and ordering cost, as well as the ease of scheduling. Conversely, possible disadvantages of joint replenishment are a possible increase in the average inventory level, an increase in system control cost and reduction in management flexibility (Silver, Pike, and Peterson).

Using Zipkin joint replenishment model for centralized purchasing model: let denotes k_j specific cost of item j and k_0, incurred on ordering any item or combination of items. If only one item is ordered, the total fixed cost is k_0+k_1. If two items are ordered, the total cost is $k_0+k_1+k_2$ instead of $2k_0 + k_1 + k_2$. Therefore, under certain condition the total cost by ordering jointly is less than by ordering individually. When the items are assumed to have the same order interval, say u, thus the ordering cost is $k = k_0 + \sum_{j=1}^{J} k_j$ and

the holding cost per item is $g_j = h_j$ $_j$ and the total holding cost is $g = \sum_{j=1}^{J} g_j$. Given u, the overall average cost is $C(u) = k/u + 1/2\, gu$, which is equal to the cost function of single-item EOQ model.

An explanation of the dynamic economic load size model is available in Appendix A-2. The model can be expressed as a linear mixed-integer programming model (MILP) which is a mathematical programming model with linear constraints in which a specified subset of the variables are required to take on integer values. This problem can be solved with MILP software developed during last ten years. MILP has been used in many different fields (Karlof). MILP software uses several algorithmic approaches such as branch and bound methods, cutting plane methods, decomposition methods, and logic based methods. Nemhauser and Wolsey present an exposition of theoretical, algorithmic, and computational issues of the alternative methods. CPLEX is a commercial solvers that apply the branch and bound methods in solving problems such as the dynamic economic load size model. Attamturk and Savelsbergh present an overview of CPLEX along with other commercial solvers.

The fourth objective of this research deals with stocking locations. For a company with many branches/locations, coordinating the inventory system among the branches is one important strategy to achieve an efficient inventory. A typical question arising from a coordinated inventory system is whether or not to have a centralized stocking location. Although many studies on multiple locations inventory system have favored centralized over the decentralized stocking locations, the complexity emerges when the inventory system consists of multiple items.

With a solid coordination on both sale and purchase activity among the branches, centralized stocking locations will reduce the inventory costs as well as increase the customer service. Although centralizing stocking locations increases delivery cost, this could lower both the holding cost (by lowering the level of safety stock) and the ordering cost (by reducing the frequency of placing inventory order). While expansive analysis of centralization is beyond the scope of this research, insight into stocking locations is developed through analysis of the transfer costs.

In conclusion, farm supply cooperatives can improve their inventory management system by improving their inventory control strategies. The improvement in inventory control strategy can be done through many different approaches. Indeed, there is no ideal inventory control that can work efficiently for all inventory systems. Therefore, the inventory control strategies developed in this study provide improved alternatives to existing inventory strategies for farm supply cooperatives in managing their day-to-day inventory systems. Although the effectiveness of a control strategy needs to be evaluated over time, an indication of an inventory control strategy is lowered inventory cost. Therefore, a lower inventory cost (compared to the actual inventory costs spent by the cooperative throughout the time this study is conducted) is expected to occur as a result of adopting the inventory control strategies develop in this study.

CHAPTER III

LITERATURE REVIEW

Farm supply cooperatives made up 38.2 percent of total farmer cooperatives in the United States (U.S.) in 2002. The cooperatives represented a total of 1,637,061 members and 15,495.4 million dollars in total assets (Adams et al.). In general, farm supply cooperatives invest approximately 25 percent of their total assets in inventory (Wadsworth). With such large investments in inventory, Wadsworth argues that inefficient inventory management systems could be a reason why increasing cost is identified as one of the foremost problems of farm supply cooperatives (Gray and Kraenzle). Two general costs associated with inventory are holding cost and ordering cost (Arnold and Chapman).

Numerous development strategies have been devised to improve inventory management systems which can balance inventory costs (Robison; Chen; Yu). Few attempts, however, have been made to address inventory management systems of agricultural product-oriented firms. Moreover, most of these works emphasize inventory control for grain (Johnson and King; Chavas et al), livestock (Bierlen et al; Hamilton and Kastens), and food supply chain (Menkhaus et al.; Miller).

Most, if not all, works in inventory management systems agree that there is no ideal inventory management system for every organization or company. In developing an efficient inventory management system there are many factors that need to be

considered. Type of inventory, for example, is one of the significant factors in designing an efficient inventory system (Moon, Giri, and Ko). Many authors categorize types of inventory in different ways (Williams; Toelle and Tersine; Goyal and Giri; Wadsworth), for the purpose of this research the focus is on that of Wadsworth whom categorizes the inventory based on products that commonly carried by farm cooperatives.

One important step in evaluating any inventory management system is to determine the performance of its system. Inventory turnover ratio is the most common device used for this purpose (Robison; Edelman; Vergin). It is widely used in many sectors of industry —such as restaurants (Reynolds), hospitals (Edelman) as well as farm supply cooperatives (Wadsworth)—due to its ease of computation from readily available financial data. Despite its convenience in computing the ratio, Robison argues that inventory turnover ratio as a financial ratio forfeits a great amount of information when converting quantity to cost. For this reason, Wadsworth suggests an evaluation of inventory turnover ratio for each stock keeping unit (SKU).

Although, inventory turnover ratio is a common device to measure inventory performances, Wadsworth advises to be careful when comparing inventory turnover ratios to industry averages and explains that departure from industry averages does not necessarily indicate whether an inventory is managed well, good, or poorly. This is particularly true when evaluating the inventory performance of slow moving-inventory stocks, i.e. SKUs with low inventory turnover. One would judge that slow moving stocks are bad for inventory management because these increase the inventory carrying cost. A study by Johnson, Boylen and Shale, however, shows that this is not always the case. Slow moving stocks were considered important to the inventory management they

studied because they generated 40 percent of the total income of that particular business. For this reason, Wadsworth recommends to use another measurement called inventory management index, in addition to inventory turnover ratio, to make a better judgment of inventory management performance. Furthermore, in a survey of retailing firms conducted by Gaur et al., it is found that managers in this field tradeoff inventory turns and gross margin in their decision making. With this tradeoff (referred to as "earns versus turns" tradeoff) items with higher margin are given lower turns target, while items with lower margin are given higher turns target. They researched the correlation between inventory turnover and gross margin and concluded that inventory turns should not be used in performance analysis. They based their conclusion on the fact that inventory turnover varies widely across retailers and over time (hence this variation undermines the usefulness of inventory turnover in performance analysis).

Another measurement that has been widely used in estimating a performance is called residual income. It is defined as excess of net earnings over the cost of capital (Solomon). As a performance measurement, it is designed to influence management decision on investment in capital assets: reject the investment if the net earnings over the cost of capital negative and conversely, undertake the investment with positive residual income (Christensen, et al). Levy et al. studied the residual income analysis for inventory investment allocation and stated that the residual income can be used to help the managers to make decision on how to allocate total inventory budgets across merchandise classification.

Two major concerns must be considered when inventory management is to provide the required demand level and to reduce the sum of all costs involved. First,

when an order should be placed and secondly, what quantity should be ordered at each time. Frequent ordering might lower the average holding cost but may increase ordering costs and vice versa. Many works completed in inventory management use a model called economic order quantity (EOQ) in addressing the concerns of the "right" quantity to order. Basic EOQ works with the assumption that the rate of demand is relatively constant and is known; the item is produced or purchased in lots or batches and not continuously; order preparation costs and inventory carrying costs are constant and known, and replacement occurs all at once (Yu; Arnold and Chapman). EOQ is widely used because of the relative simplicity of the model and the small number of variables contained within it as well as its robustness property (Ptak).

The basic EOQ model, however, has been criticized for being unrealistic in its assumptions (Schwaller). Therefore many studies have been conducted to relax these assumptions –such studies focus on stochastic demand, stochastic supply, various back ordering systems, and uncertain holding and carrying cost (Yu; Schwaller; Hojati). Furthermore, models have been developed that could propose a possible approach for specific inventory management problems (Goyal and Giri; Moon, Giri and Ko). David and Mehrez, for instance, have relaxed the assumption that items can be stored indefinitely to meet the future demands, and have developed the EOQ model for perishable goods with a fixed lifetime.

In the case of uncertain holding cost; Vuvosevic, Petrovic and Petrovic develop an EOQ model with *fuzzy* parameters, while Lowe and Schwarz have developed a probabilistic-parameter EOQ model. The fuzzy parameter EOQ model is based on the assumption that the decision maker is uncertain about the exact value of the holding and

carrying costs but subjectively estimates costs in the form of a range of values. The probabilistic-parameter EOQ model, on the other hand bases its assumption on these costs being random variables. Although both methods prove to work empirically well in different scenarios that the authors design, according to Hojati, it is difficult to manipulate the probability distribution of parameters. Therefore, he cites this problem as the reason for scarcity of research of the EOQ model with uncertain parameters.

While the development of the EOQ model is one way to answer the question "how much to order", countless works have been devoted to answer another important question in inventory management, namely, "when to place the order". These works contribute to the abundance of methods available to be used in replenishment decisions. The dynamic economic lot size model is one of these methods. This model is commonly used in the area of production planning and inventory control for dealing with changes in either the demand or the purchase cost over a discrete time (Zipkin).

The "classical" dynamic lot-sizing problem was first introduced by Wagner and Whitin. This model considers a problem of a facility/warehouse that was facing a deterministic time-varying demand for a single item over a discrete-time. In association with each inventory replenishment decision at this facility/warehouse, a fixed ordering cost and a linear holding cost were incurred for each unit held in inventory. The objective of this model is to develop an inventory replenishment plan that satisfies the demand at minimum cost. A significant number of researchers have generalized the classical with various considerations. The work of Aggarwal and Park; and Federgruen and Tzur, for instance, incorporate the possibility of backorders into the basic model; while Hsu uses the backorder assumption in developing a dynamic programming

algorithm for perishable products. Eynan and Kropp relax the assumption of the deterministic condition of the demand and include the stock-out cost, while Li et al. develop a dynamic lot sizing method with batch ordering and truckload discounts.

Several other researchers extend the basic model to the multi items and multi locations system and consider a joint replenishment as an alternative to the individual replenishment system. The study of joint replenishment itself has extended widely in order to mimic real life problems. Moon and Cha, for instance, have incorporated the capital constraint into the joint replenishment model. Stadler has taken into consideration the cost of transporting the items, from the central purchasing location to the destination, into the joint replenishment model. A number of works in joint replenishment model have used the mixed integer program method to solve their objective (Hariga et al.; Shih)

Theoretically, an effective inventory management system is one that can meet customer demand precisely. Therefore, any practitioner who works in this field will aim to satisfy customer demand when it occurs and in the quantity that is required. In the real world, however, the goal of meeting customer demand precisely is hard or even impossible to achieve, mainly because the precise demand will not be known until it materializes. For this reason, instead of aiming to meet the demand precisely, making a good prediction of the demand is a more reasonable goal in pursuing an effective inventory management system. Although, according to Nahmias, forecasts are almost always wrong, a good prediction is generally defined as one with the lowest possible error/bias. Safety stock is a common device to protect inventory against the fluctuation not only in demand but also in supply. Hence, it is used as a strategic weapon to prevent

the stock-out and therefore enhances and maintains customer satisfaction and loyalty (Krupp).

Many studies have been conducted in selecting the best safety stock method for either work in progress products or finished products inventories. Although most of the scenarios developed in those studies are examined by data simulations, few works such as that of Das and Tyagi and Kanet and Cannon are conducted by evaluating primary data from US apparel and health care industries respectively. These works not only emphasize single stocking locations, but recent logistics research has focused attention on the effects of consolidating multi-location inventory facilities on safety stock (Schneider and Rinks; Tallon; Meller; Evers and Beier; Das and Tyagi). Although the works on multi-location inventory are done under different scenarios, most of them employ the portfolio effect to measure savings in safety stocks due to inventory centralization. The notion of a portfolio effect was first studied by Zinn et al. who defined the portfolio effect as "the percent reduction in aggregate safety stock made possible by centralization of inventories" (pg. 2). Using the square root law, they found that the relationship between aggregate safety stock and the number of stocking locations used in the distribution of a product is a function of the relative sizes of the standard deviations of demand and the correlation coefficient of sales between stocking location.

In a traditional inventory planning for multiple locations, known as pull-type system (Ballou and Burnetas), the safety stock is held locally and the level is set based on demand, costs, and service requirements associated with the defined demand territory of the inventory locations. In other words, the safety stocks determination in one location is completely independent from any other locations. If demand occurs above the expected

demand plus the safety stock then either backorder or loss will take place. Alternatively, safety stock can be located in particular locations such that when a location can not meet the demand from its primary source, both from the regular stock and the safety stock, the secondary source, from another location's stock, is available to encounter this demand. Figure 6 depicts a two stock locations distribution.

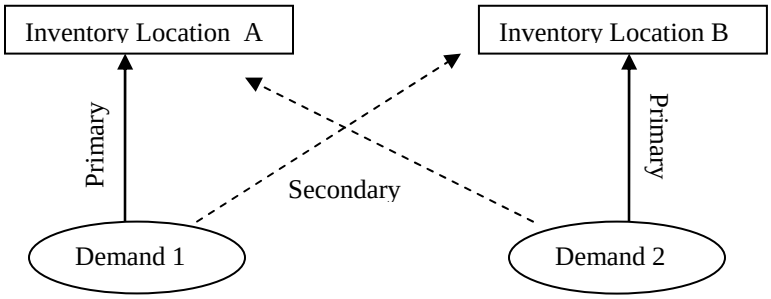

Figure 6. A Two Stock Locations Distribution

Furthermore, because transportation costs accrue as the consequence of having a centralized safety stock location, it is coherent to place the stock at locations closest to any possible "secondary" source. This idea is in line with the conclusion of the work of Ballou and Burnetas on N safety stock "stocking" locations.

Substantial research on centralizing inventory control has taken into account the transportation cost when deciding the stocking locations. Ballou and Burnetas stated that although the delivery cost is increased as the result of implementing centralizing stocking locations, it could reduce the safety stock, therefore reducing the holding cost, as well as maintaining the customer service level. Cardos and Sabater study the trade-off between inventory management policies for each shop and delivery policies from the central

warehouse when targeting the client service with the total minimum cost. Ozdemir et al. incorporated transportation capacity such that transshipment quantities between stocking locations are bounded to transportation media or locations' transshipment policy. In the light of the constraint in locations' transshipment policy, they found that incorporating the constraint into the model modify the inventory distribution throughout the network.

When comparing the central versus local multiple stage inventory planning, Simpson argues that even though, under a perfect information assumption, policy developed under localized planning conditions hardly ever exceed the performance of the centralized policy, there are conditions where independent policy would be more beneficial than joint policy. Furthermore, he elucidates that the centralized management is suitable for goods which are easy to transport and or easy to assembled from several valuable components. Conversely, goods with low unit cost that are relatively more inconvenient to transport and stock at downstream locations are better handled with decentralized management.

CHAPTER IV

DATA SOURCES AND PROCEDURES

The data for achieving the four specific objectives of this research were obtained from inventory data of a farm supply cooperative in Oklahoma. This particular farm supply cooperative has fourteen (14) branches that are located in the northwestern region of the state. The cooperative currently maintains a decentralized inventory with items stored at each branch location. Items are transferred between branches or between the headquarter activities are also fairly decentralized. A purchasing manager coordinates most of the purchases across branches. However the individual branch managers make requests for needed purchases. The cooperative maintains a perpetual inventory through their point of sale system. Transfer activities make the electronic inventory somewhat unreliable when the logging of transfer activities does not keep up with the pace of the physical transfers. The cooperative also supplements the electronic inventory with physical counts and measurements. These validations occur at various intervals varying from monthly counts for high volume products to quarterly, semi-annual or annual valuations for other product categories.

Inventory performance is currently monitored for the overall cooperative and for major branches of petroleum, fertilizer and farm supply. The cooperative currently monitors gross margin and inventory turnover. However the cooperative does not consider the IMI measure that combines those two metrics.

The data were collected from March 2004 to February 2006, and they consist of daily transactions of this cooperative in three major trading activities: sale, purchase, and transfer of items between braches. These data are used to calculate the annual cost of goods sold (COGS), the average inventory cost (AIC), the gross margin (GM), the gross margin percent (GMP), the total demand of each item per year, inventory holding cost (IHC), inventory ordering cost (IOC), and average price per item. An assumption of minimum beginning inventory is employed when calculating the average inventory of each item to ensure positive inventory conditions throughout the time frame of this study.

The beginning time period of the sales and purchase data did not correspond with the cooperative's fiscal year and physical inventory counts. For this reason, accurate information on beginning inventories was not available. For the purpose of the study, beginning inventories were estimated based on the quantity needed for item to maintain a positive inventory balance for the study period. This assumption may have underestimated actual inventory levels of all items.

The first objective addresses how well the inventory management system of this particular farm supply cooperative performs. Inventory turnover ratio (ITR) and inventory management index (IMI) are used for achieving this objective. Since there are 1,871 items traded in this cooperative, a grouping system is employed to narrow the evaluation. With this grouping system, all of the items are categorized into eleven (11) groups of items that are commonly carried by farm supply cooperatives. These categories are petroleum (Ptr), hardware (Hrd), fence (Fen), feed (Fed), seed (Sed), tires/batteries/auto (TBA), insecticide/herbicide (IH), equipment/parts (EP), fertilizers (Frt), animal health (AH), and miscellaneous items (MI).

The turnover ratio for each item in each group of items is calculated according to the following equation:

(4) $$ITR_{ij} = (COGS_{ij})(AIC_{ij})^{-1}$$

where *i* is the number of SKU in each cooperative (*i*=1,2,3,) and *j* is the product categories (*j* = 1,2, ,6). $COGS_{ij}$ is the annual cost of goods sold. The AIC_i is calculated as the average value of inventory per year.

Although ITR is the common device for determining the performance of an inventory management system, Wadsworth argues that departures from the recommended ITR do not always indicate how well a business is performing. Therefore, he recommends using IMI for further judgment of inventory performance. The IMI relates the turnover of inventory with the gross margin return the inventory generates and is calculated as:

(5) $$IMI_{ij} = (ITR_{ij})(GMP_{ij})$$

where *GMPij* is the GMP of each SKU in each category. According to Wadsworth, the cooperative should strive for an index greater than 1.0, because an index number greater than one indicates the profitability of item. The conclusion will be the greater the resulting index exceeds 1, the better the performance of inventory management. The results of this test provide insights into how easily the cooperative could improve overall inventory performance by addressing a small subset of the lowest performing items.

The second objective of this study is to investigate simple strategy for improving the case-study firm's IMI index. A simple strategy for improving IMI was investigated. The strategy was to eliminate items with the lowest profit margins. A threshold of three

(3), five (5), seven (7) and ten (10) percent of total items in each branch is used to determine the number of items to be removed from the inventory. A simple algorithm, Figure 7, is employed for this strategy.

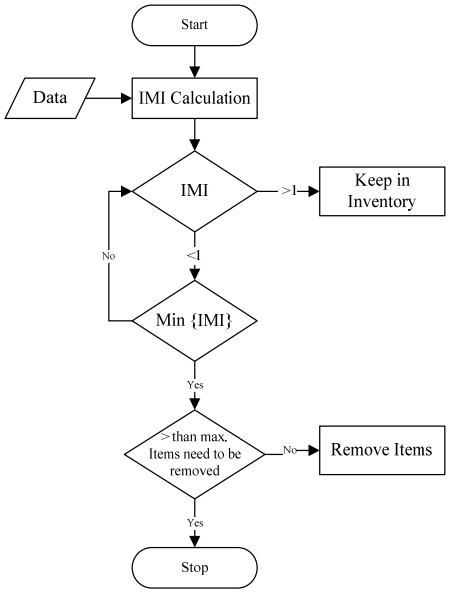

Figure 7. Hierarchy of Determining the Proper Inventory Mix Based on the Profitability of the Items to the Cooperative

Nevertheless, there is a down side of putting weight only on the turnover and profit of items when deciding which items to eliminate. An item may perform ineffectively compared to other items, but is important in serving the needs of many patrons. Therefore, removing that particular item from the inventory list will result in the cooperative not serving its patrons efficiently. For this reason, another approach that incorporates the importance of each item to the cooperative in the process of implementing this strategy is studied.

In addition to the data needed to run the first approach, the importance status of each item is required in developing the second simple algorithm, Figure 8, for both strategies. The importance of each item is assumed to be known. Fifty (50) percent of

items with an IMI of less than one (1) in each branch are assumed to be not important, and this status, for the purpose of this study, is randomly assigned to each item. As for the first approach, a threshold of three (3), five (5), seven (7) and ten (10) percent of total items in each branch is used to determine the number of items to be removed from the inventory. The result of both strategies is also tested to determine the impact of these strategies on the firm's IMI and the inventory residual income (IRI).

IRI is calculated as:

$$IRI_{ij} = GM_{i\,j} - IHCij \tag{6}$$

where *GMij* the GM and *IHCij* is the IHC of each item in each group. Inventory holding cost per unit is account for 20 percent of average inventory cost per item for non-bulk items and 10 percent for bulk items.

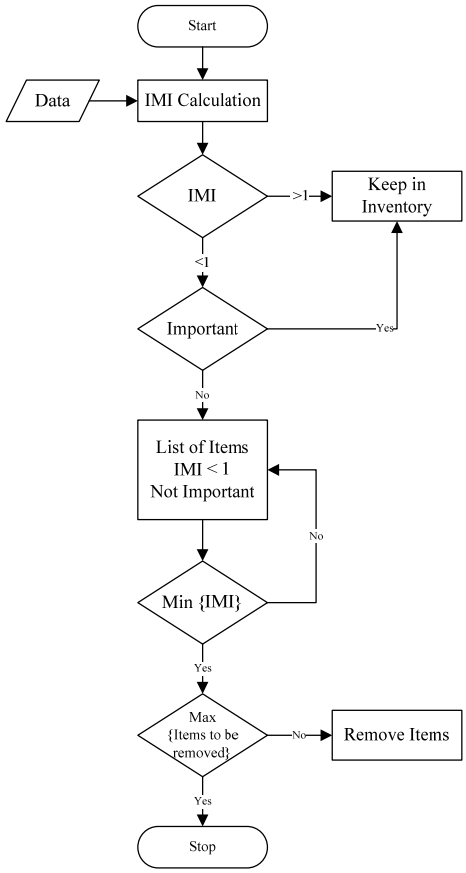

Figure 8. Hierarchy of Determining the Proper Inventory Mix Based on the Importance and Profitability of the Items to the Cooperative

The second strategy for improving the inventory control construct relates to purchasing activity. One of the ten strategies that Wadsworth recommended for local farm supply cooperatives to have an efficient inventory management is what he called "order efficiently." Efficient ordering, he elucidates, will help the cooperative to lower the inventory cost by balancing the ordering cost and the cost of maintaining the inventory. Controlling the size of an order can be used to lower the inventory holding cost; while, the inventory ordering cost can be lowered through controlling the amount of time needed to place such orders. In this study, economic order quantity is used to determine the optimal order quantity, and the replenishment time to place orders is

determined by using an integer programming model to solve an inventory model which is built based on the dynamic economic lot size model. The description of the models, data sources, and the assumptions are presented in this section.

Economic Order Quantity (EOQ)

The economic order quantity is calculated using this formula:

(6) $$Q_i^* = \sqrt{\frac{2U_i(IOC)_i}{IHC_i}}$$

Where U_i is the demand rate of each item i, in this case the demand rate is assumed to be known and constant per unit of time. IOC_i is the ordering cost of each item and $IHCi$ is the inventory holding of each item. The holding cost is calculated by multiplying the price per unit merchandise being purchased by the annual inventory maintenance cost as a percent of annual inventory value. In this study the inventory maintenance cost is assume to be twenty (20) percent for non bulk items and ten (10) percent for fuel and fertilizer.

For the purpose of this study, the ordering cost is assumed to be fixed per order and is the same for all items. Furthermore, it is assumed that the main office makes the decision of how much to order for each item in all branches. This analysis therefore compares the costs of centralized ordering with the cooperative's current system of decentralized ordering. The ordering cost is calculated as the sum of the salary for the employee who does the ordering and the cost of placing an order. The salary of the employee is determined by averaging the average of job earning in Grant County, where the head of the branches is located, and the average of job earning in the state of

Oklahoma. The salary calculated is $29,755.5. The cost of placing an order, which in this study is limited to the cost of making a phone call and/or faxing the order, is assumed to be fifty (50) percent of the cost of subscribing to the local telephone companies. The cost of subscribing to the local telephone is assumed to be $1,200 per year. Hence, the cost of placing an order is $600 per year, and the total ordering cost per year is $30,355.5.

Dividing the total ordering cost per year by the number of orders placed in a year calculates the ordering cost per order. Using the two years' of purchasing data available for this study, the daily ordering cost of year 1 is $ 93.40 and year 2 is $96.98. The average ordering cost per item for the same time frame is $13.65.

Replenishment Time

The replenishment time for each item is determined in two steps. First, finding out the optimum number of orders for the time frame given, and second, determining the replenishment time by using the optimum number of orders calculated in the first step. The optimum number of orders for each item for the time frame given in this study is determined by dividing the total demand by the economic order quantity.

(7) $$N_i = \frac{U_i}{Q_i^*}$$

The replenishment time is determined by using a multi-period mixed integer mathematical programming model. This model is used to determine both the optimum order size and the time to place such orders to achieve the minimum inventory cost. Assuming that the replenishment occurs at once, the optimization model is specified below.

(8) $$\underset{INV,O}{\text{Minimize}} \; Z = \sum_{i=1}^{n}\sum_{t=3}^{26}(IHC)P_i(INV)_{it} + \sum_{i=1}^{n}\sum_{t=3}^{26}O_{it}(IOC)$$

Subject to:

(8.1) $$\sum_{i=1}^{n}\sum_{t=3}^{26}(INV)_{it} + U_{it} - O_{it}Q_i - (INV)_{(i,t-1)} \geq 0, \forall_i \forall_t$$

(8.2) $$\sum_{i=1}^{n}\sum_{t=3}^{26}O_{it}Q_i = Q_i N_i, \; \forall_i$$

(8.3) $$O_{it} \text{ is a nonnegative integer}, \quad INV_{it} \geq 0, \; \forall_i, \forall_t$$

The objective function (8) expresses the total inventory cost which consists of the cost of holding inventory and the ordering cost. The parameter *IHC* in Equation (8) represents the inventory holding cost which is assumed to be 20 percent of the value of inventory on hand for non-bulky items and 10 percent for the bulky items. The value of inventory on hand is determined by multiplying the price of item *i*, P_i, by the quantity of inventory on hand of item *i* in time *t*, INV_{it}. The parameter *I*OC in this equation represents the cost of placing an order which is assumed to be fixed at $13.65 per order. The decision variable O_{it} is the integer number of placing orders of items *i* in time *t*.

Constraint (8.1) ensures the inventory on hand of item *i* in time *t* is positive by balancing the supply ($O_{it}Q_i$), demand (U_{it}), and the inventory on hand from the previous time period of each item ($INV_{i,t-1}$). Parameter Q_i in this equation represents the economic order quantity of item *i*. Constraint (8.2) requires that the total quantity being purchased throughout the time frame given in this case will not exceed the optimum quantity purchased for item *i*. Finally, constraint (8.3) imposes the nonnegative condition on the integer number O_{it} and inventory on hand *INVit.*

Lastly, the fourth objective of this study is to investigate the apparent efficiency or in-efficiencies from inter-branch transfer and centralized stocking locations. In achieving this objective, an investigation is conducted on the transfer activity, both in and out of the branches. Information such as how many times items were transferred among the branches as well as the frequency of transferring items between branches is calculated from the data available. Transportation costs of each group of items in each branch are calculated. Transportation costs are assumed to be comprised only of mileage cost. The cost per mileage is fixed and assumed to be constant at $0.50 per mile. The comparison between the quantity sold and the quantity being transferred among the branches is investigated to examine the effectiveness of the transfer system throughout the time frame of this study.

A scenario of placing optimal stocking locations is developed. This scenario is intended to give a better picture of how the cooperative could benefit from having centralized locations. The stocking location is determined by combining the least-cost transportation model and the plant (factory) location model. Modification is made by assuming that the cost of choosing any of the branches to be the stocking location is the same and every branch is capable of holding unlimited stocks. Thus, the distance between the branches is the only variable considered when deciding which branch is chosen for the stocking location.

The optimization model is specified below:

(9) $$\underset{Y}{\text{Minimize}}\ Z = \sum_{j}\sum_{k} Y_j D_{jk}$$

Subject to:

(9.1) $$\sum_{j} Y_j = S$$

(9.2) $$Y_j \in \{0,1\},\ \forall_j$$

The objective function (9) expresses the total distance to be minimized. Y_j is a binary choice variable. It is equal to one if the sum of the distance from branch *j* to branch *k* is the minimum distance and zero otherwise. *S* is an integer to determine the scenarios under which the model is solved. *S* is set equal to one under a single stocking location scenario. It is set equal to two for the scenario that permits two stocking locations and it is three with three stocking locations and so on. For the purpose of showing how the cooperative can benefit from the centralized stocking location, the number of stocking location is chose to be one (1) among the 14 branches.

CHAPTER V

RESULTS

This chapter includes a presentation of the general trading information of the cooperative during the time frame of the study. The information includes the number of transactions and items traded, sales and gross margin, as well as the type of each activity –sale, purchase, and transfer for the time period of February 2004 to March 2006.

The inventory turnover ratio (ITR) and the inventory management index (IMI) calculation, as well as what those numbers mean to the inventory management performance of the cooperative, are discussed following the general information. The rest of the chapter includes a discussion of the inventory control strategies developed in this study.

Trading Information

General trading information, such as the number of items traded and the number of transactions occurring during the time frame of this study; the gross margin by branch as well as by each group of items; trading activity history of each group of items; and the inventory cost of each group of items at every branch are discussed in this section. The discussion on the trading activity is conducted yearly: Year 1 represents the activity from March 2004 to February 2005 and Year 2 represents the activity during March 2005 to February 2006.

Transactions and Items Traded

Three main trading activities involved in this cooperative are: sale, purchase, and transfer of items among branches. The number of transactions as well as the amount of money involved in each activity in the cooperative during the study time frame is presented in Table 1. The figures shown in Table 1 indicate the growth of trading activities as well as the number of money involve in each activity in the cooperative during this time frame.

Table 1. Yearly Sale, Purchase and Transfer Transactions

Activity	Transactions			$ Involved		
	Year 1	Year 2	% change	Year 1	Year 2	% change
Sale	136,755	207,310	52	13,689,194	20,975,571	53
Purchase	5,514	9,009	50	9,084,282	19,083,870	100
Transfer	7,707	8,856	19	1,933,239	2,307,895	63
Total	149,976	225,175		24,706,715	42,367,336	

Year 1 = March 2004-February 2005
Year 2 = March 2005-February 2006

An increase of 52 percent in the number of sales transactions existed at all of the branches from year 1 to year 2. Similarly, the sales dollars increased by 53 percent. The number of purchase transactions increased by 50 percent and the amount of money for purchasing activity throughout this time increased by 100 percent. The amount of money involved in transfer of items activity increased only by 19 percent from year one to year 2, while transfer transactions increased by 63 percent.

As the sale, purchase and transfer transactions increased, the gross margin, average inventory value, holding costs and transfer costs also increased. Information on the gross margin, inventory performance, inventory costs, and transfer costs is presented in Table 2. Unlike the gross margin, inventory costs, and transfer cost, the ITR

experienced an insignificant change from year 1 to year 2, while the IMI decreased from year 1 to year 2. The ITR for both years were lower than the average ITR of farm supply cooperatives the US (according to Wadsworth, the average ITR for farm supply cooperative in the US is 7). Therefore, there is a need for the cooperative as a whole to improve its turnover. As for the IMI, the average IMI for both year were less than 1, indicates a need to improve not only the turnover but also the gross margin. In order to develop greater insights into the gross margin, inventory performances, and inventory costs, further analysis on these subjects was conducted by group and by branch. The result of this analysis is presented throughout the rest of this section.

Table 2. Gross margin, Inventory Costs, Transfer Costs, and Inventory Performance

	Year 1	Year 2
Gross Margin	$ 1,068,855	$ 1,922,435
Average Inventory	$ 3,556,039	$ 7,189,268
Holding Costs	$ 3,614,668	$ 5,232,343
Transfer Costs	$ 26,796	$ 31,039
ITR	3.59	3.58
IMI	0.59	0.34

The total number of items traded in each branch during the first and second year is presented in Table 3. The number of items traded increased from year 1 to year 2 for almost all branches. The percentage increase ranges from 1.95 percent, at Headquarters, to 51.92 percent, at B. Conversely, branches that experienced a decrease in the number of items traded were A, F, J, and L. Table 3 shows the number of items traded in each branch by group of products.

Table 3. Number of Items Traded By Branch

Branch	Year		Percentage Different
	1	2	
A	152	114	-25.00
B	104	158	51.92
C	322	444	37.89
D	133	173	30.08
E	312	376	20.51
F	51	44	-13.73
G	233	245	5.15
H	311	330	6.11
I	129	150	16.28
J	154	153	-0.65
K	397	479	20.65
Headquarters	820	836	1.95
L	208	134	-35.58
M	148	168	13.51

The number of items traded in each branch is not identical. Likewise, the type of items sold varies among the branches. This variation of items is more likely dependent upon the marketing strategy of each branch or competition in the local area. One branch, L, for instance, demonstrates an emphasis on trading items in Feed, whereas Headquarters focused more on trading items in Hardware as well as Equipment/Parts. The variation of the number of items traded in each branch is presented in Table 4.

Table 4. Number of Items Traded by Branch and By Group

Branch	Year	Group of Items										
		Ptr[a]	Hrd[b]	Fen[c]	Fed[d]	Sed[e]	TBA[f]	IH[g]	EP[h]	Frt[i]	AH[j]	MI[k]
A	1	2	1	14	26	10	14	62	3	9	1	10
A	2	3	3	22	26	9	22	16	3	2	0	8
B	1	0	0	10	32	9	29	16	1	1	1	5
B	2	6	1	23	34	7	57	18	2	2	1	7
C	1	15	2	6	180	10	24	34	2	10	5	34
C	2	16	3	12	219	17	37	57	6	24	2	51
D	1	3	2	19	57	5	17	18	0	4	1	7
D	2	3	5	27	47	6	40	30	3	4	0	8
E	1	5	0	19	149	38	36	33	3	10	2	17
E	2	6	1	26	144	70	66	25	4	8	3	23
F	1	0	0	1	35	0	0	1	1	5	3	5
F	2	0	0	1	31	0	0	2	0	4	1	5
G	1	6	1	24	114	6	21	20	2	10	6	23
G	2	4	3	28	98	4	42	13	2	11	9	31
H	1	7	3	19	78	10	51	62	54	8	3	16
H	2	7	8	38	72	22	79	48	16	9	2	29
I	1	5	0	6	36	1	24	43	1	7	1	5
I	2	6	2	10	43	6	39	26	3	8	1	6
J	1	3	1	13	31	3	10	45	30	9	0	9
J	2	3	1	21	30	5	18	32	24	7	0	12
K	1	13	12	24	75	17	45	50	130	10	2	19
K	2	14	11	36	74	25	79	53	147	9	4	27
Headquarters	1	10	125	24	66	26	84	109	345	24	2	5
Headquarters	2	14	137	41	59	14	146	112	280	23	4	6
L	1	3	13	15	25	8	11	12	105	7	2	7
L	2	3	9	30	33	9	22	15	2	4	2	5
M	1	4	0	4	39	16	16	50	0	11	0	8
M	2	7	1	14	42	17	25	48	2	7	0	5

[a]Prt = Petroleum [b]Hrd = Hardware [c]Fen = Fences
[d]Fed = Feed [e]Sed = Seed [f]TBA = Tires/Batteries/Auto
[g]IH= Insecticide/Herbicide [h]EP = Equipment/Parts [i]Frt = Fertilizer
[j]AH= Animal Health [k]MI = Miscellaneous Items

Gross Margin

Table 5 summarizes gross margin earned by the branches in the first and second years. The total gross margin, for the whole cooperative, increased 80 percent from year one to year 2. Likewise, the average gross margin increased by 80 percent. The standard deviations of the gross margin for both years show that there is a wide dispersion of the gross margin among the branches.

Table 5. Statistic of Gross Margin by Branch

Year	1	2
Gross Margin		
Total	$ 1,068,855	$ 1,922,435
Average	$ 76,336	$ 137,316
Minimum	$ (359,003)	$ (163,451)
Maximum	$ 964,419	$ 735,243
Standard Deviation	$ 314,171	$ 209,501.

Similar to the average gross margin by branch, the gross margin by group also exemplifies an increase from year 1 to year 2. As shown in Table 6, there was an 80 percent increase in the average gross margin made by each group. There is also a wide dispersion in the gross margin made among the groups of products. Fertilizer earned the highest gross margin among all other groups of products in both years, whereas petroleum earned the lowest gross margin in year one, and seed earned the lowest gross margin in the second year.

Table 6. Statistic of Gross Margin by Group of Products

Year	1	2
Gross Margin		
Average	$ 97,155.04	$ 174,766.82
Minimum	$ (722,725.78)	$ (273,175.10)
Maximum	$ 1,370,448.45	$ 1,312,698.30
Standard Deviation	$ 494,229.94	$ 480,814.40

Sale

Figure 9 shows monthly sale transactions by group of products. The secondary y-axis (at the right side of the graph) points to the number of transactions of Petroleum items. The x axis of the graph represents the time of the study. Month three represents March 2004, four represents April 2004 and so on until month 26 which represents February 2006. This explanation of the x axis applies for all the graphs that have "Month" as the x axis. Petroleum, Feed, and Fertilizer items have higher numbers of sale transactions than those of other groups. More detail on the maximum transaction as well as number of items traded is presented in Table 6.

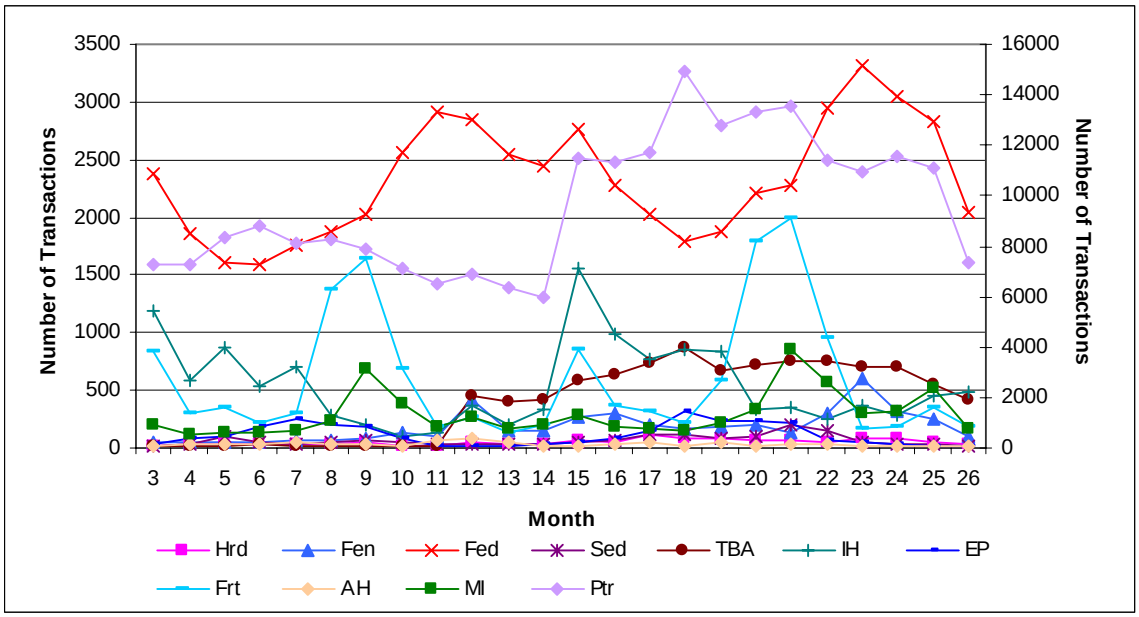

Figure 9. Monthly Sale Transactions by Group

As shown in Table 7, the maximum transaction of Petroleum, Hardware, Fence, Feed, Insecticide/Herbicide, Fertilizer, and Miscellaneous Items, occur in the same month every year. This fact could be an indication of a seasonal demand patterns for these groups of items. However, given only two years data, the available information may not

be sufficient to come to that conclusion. While not exhibiting a consistent seasonal pattern, Petroleum, Tires/Batteries/Auto, and Insecticide/Herbicide had relatively large differences between their peak sales month and their minimum sales month. For the rest of the groups, the maximum transactions occur in different months from year 1 to year 2. For instance, the maximum transactions of Seed items take place in the month of May (Month 5) in the first year and occur in the month of September (Month 21) in the second year.

Table 7. Maximum and Minimum Quantity of Transaction and Item Traded by Group

Group	Year	Transaction				Item Sold			
		Max	Max-Month	Min	Min-Month	Max	Max-Month	Min	Min-Month
Ptr	1	8768	June	5943	Nov, Feb	45	Feb	39	Sept
Ptr	2	14956	June	7355	Feb	67	March, Jan	57	July
Hrd	1	58	May	20	Nov	40	May	15	Nov
Hrd	2	118	May	36	Feb	57	May	26	Feb
Fen	1	420	Dec	43	June	134	Dec	9	Apr
Fen	2	609	Nov	94	Feb	167	Nov	56	Feb
Fed	1	2910	Nov	1599	June	391	Jan	297	June
Fed	2	3321	Nov	1785	June	385	March	303	Feb
Sed	1	95	May	12	March	36	May	4	March
Sed	2	206	Sept	24	Feb	49	Sept	3	Jan
TBA	1	445	Dec	12	March	183	Dec	8	Aug
TBA	2	875	June	426	Feb	274	June	151	Feb
IH	1	1189	March	93	Oct	178	May	32	Nov
IH	2	1551	March	249	Oct	203	Apr	38	Dec
EP	1	243	July	16	Nov	153	July	14	Nov
EP	2	314	June	15	Feb	170	June	11	Feb
Frt	1	1641	Sept	141	Jan	75	Sept	28	Jan
Frt	2	1986	Sept	172	Nov	72	Sept	24	Dec
AH	1	77	Oct	17	March	12	June	7	Oct
AH	2	55	July	10	Feb	18	May	4	Nov
MI	1	691	Sept	124	Apr	46	Dec	20	March
MI	2	857	Sept	158	June	69	Nov	45	Feb

Figure 10 shows monthly sales earned by group of products; the secondary axis refers to the sales earned by Fertilizer. As shown in Figure 10, Fertilizer, Feed and Petroleum earned higher sales than other groups of items. In general, all groups

experienced an increase in sales from the first to the second year. Detail on the total sales for each group is presented in Table 8, whereas Table 9 presents the statistics of sales at each branch.

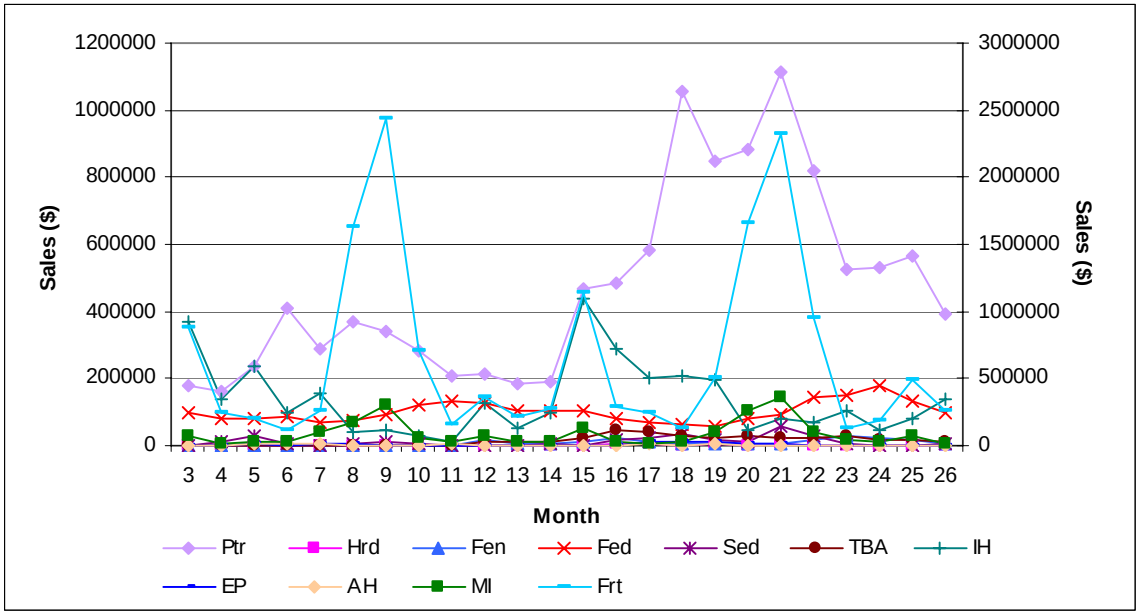

Figure 10. Monthly Sales by Group

As shown in Table 8, all of the groups of item, with exception of Animal Health items, experienced an increase in the total sales earned from year 1 to year 2. The percentage change, however, varies among the groups. Tires/Batteries/Auto, Hardware, and Fence are groups with higher percentage changes in sales from year 1 to year 2. Table 9 shows that Fertilizer, Petroleum, and Feed are the groups of items that contributed the highest sales to the branches, either in one or both years.

Table 8. Total Sales By Group

Group	Year	Total Sales ($)
Ptr	1	3,068,871
Ptr	2	8,279,389
Hrd	1	4,784
Hrd	2	30,107
Fen	1	35,686
Fen	2	161,733
Fed	1	1,173,152
Fed	2	1,255,705
Sed	1	82,022
Sed	2	204,224
TBA	1	39,802
TBA	2	300,404
IH	1	1,394,014
IH	2	1,887,695
EP	1	20,500
EP	2	59,213
Frt	1	7,464,465
Frt	2	8,305,668
AH	1	30,465
AH	2	21,467
MI	1	375,432
MI	2	469,966

Table 9 shows that Fertilizer, Petroleum, and Feed are the groups of items that contributed the highest sales to the branches, either in one or both years. Headquarters has the highest sales on Fertilizer among other branches, whereas branch C and K make the highest sales on Petroleum, in the second year. Hardware, Equipment/Part, Hardware, Animal Health, Miscellaneous Items, and Fence are items that earn the lowest sales among the branches. The standard deviations of sales in each branch for both years show that there is a wide dispersion of the sales of groups of items within the branch.

Table 9. Sales Statistics By Branch by Group

Branch	Year	Maximum		Minimum		Average	Standard Deviation
		Sales	Product	Sales	Product		
A	1	254,717	Frt	10	Hrd	26,140	75,885
A	2	160,214	Frt	398	EP	24,735	48,317
B	1	21,683	Fed	325	EP	6,981	8,158
B	2	198,344	Frt	78	Hrd	30,608	60,107
C	1	897,849	Ptr	6	EP	100,827	267,102
C	2	1,560,618	Ptr	29	Hrd	176,423	463,329
D	1	251,304	Frt	67	AH	50,954	88,381
D	2	253,019	Ptr	836	MI	57,467	93,791
E	1	573,970	Frt	566	AH	70,722	178,518
E	2	761,059	Frt	900	Hrd	137,205	262,444
F	1	218,170	Frt	175	Fen	50,558	87,985
F	2	266,346	Frt	7	Fen	58,210	106,188
G	1	513,375	Fed	753	EP	108,331	176,408
G	2	474,533	Fed	4,687	Hrd	140,206	196,192
H	1	425,791	Frt	708	Hrd	93,037	154,955
H	2	537,037	Frt	695	AH	134,203	206,453
Headquarters	1	3,658,604	Frt	721	Hrd	435,878	1,092,194
Headquarters	2	3,995,600	Frt	4,987	AH	741,151	1,305,054
I	1	301,317	Ptr	231	Fen	65,179	113,297
I	2	476,274	Ptr	40	Hrd	64,051	145,820
J	1	400,785	Frt	36	Hrd	70,724	127,109
J	2	443,055	Frt	572	Hrd	82,229	144,168
K	1	877,015	Ptr	1,946	Hrd	140,369	277,212
K	2	1,078,250	Ptr	276	AH	150,778	320,550
L	1	430,451	Frt	5	Hrd	43,073	128,641
L	2	578,280	Frt	721	AH	62,763	171,889
M	1	327,167	Frt	55	Fen	56,673	113,802
M	2	707,375	Ptr	239	MI	114,155	222,934

Details on the number of items traded in each branch for each group of items are discussed below:

Petroleum (Ptr)

There is a total of 26 Petroleum items that are sold throughout the time frame of this study in the entire cooperative. Figure 11 displays the number of Petroleum items sold monthly at each branch. (The numbers after the name of the branch at the legend are the total number of items in this group that are sold in the correspondent branch). The

figure indicates the continuous demand for Petroleum items in the majority of the branches. Other than Headquarters, the number of items sold in other branches shows slight variation throughout the time frame of the data. The number of Petroleum items sold at Headquarters and branch M were significantly higher from the first year to the second year. Branch C sold the highest number of items in this group, while branch F sold none of the items in this group throughout this time frame.

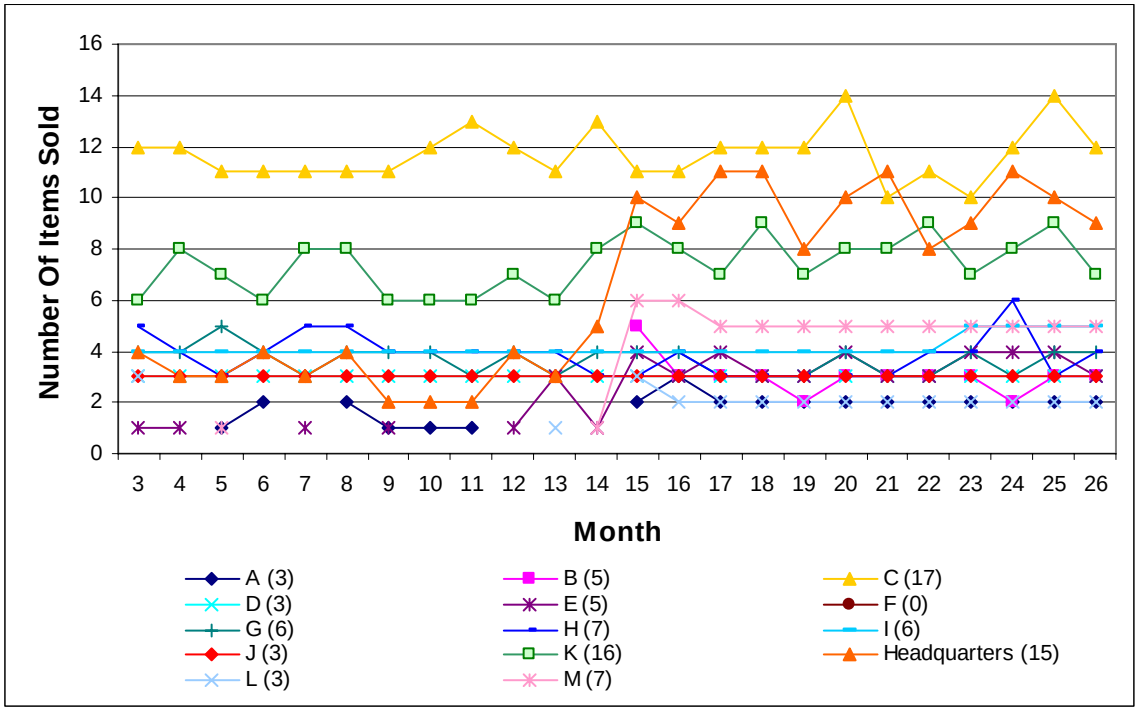

Figure 11. Petroleum: Monthly Items Sold

Hardware (Hrd)

The total numbers of Hardware items sold for the entire cooperative is 153 items. Figure 12 displays the number of Hardware items sold at each branch. The secondary y-axis (at the right side of the graph) points to the number of items sold in this group at the Headquarters. It clearly depicts in Figure 12 that the Headquarters sold the largest number of items in this group: it sold 144 items in this group. On the contrary, branch F

sold none of the items in this group. Unlike Petroleum items, which were sold almost every month in the majority of the branches, Hardware was sold continuously only at Headquarters and branch K. The other branches, such as A, D, E, I, and M started to sell items in Hardware in the second year. The rest of the branches sold Hardware items at the end of the first year. Other than the Headquarters, all branches sold less than 10 items in this group of products. Most of them were able to sell only one or two items in many months.

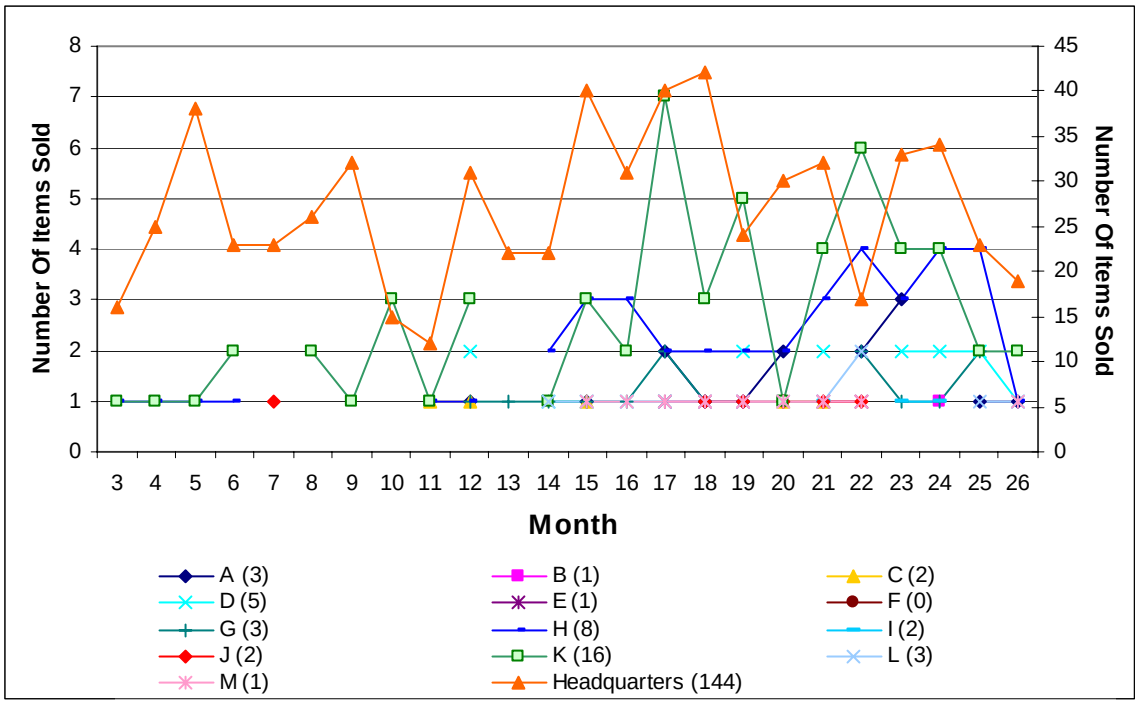

Figure 12. Hardware: Monthly Items Sold

Fence (Fen)

There were 70 items sold in the Fence group in the entire cooperative. Unlike the sales for Hardware items, which was dominated by the Headquarters, branch H and K (along with the Headquarters) sold about 50 percent of the total numbers of items in this group. The number of Fence items sold monthly is shown in Figure 13. This figure

shows that there was a significant increase in the number of items sold at almost every branch in the month of November 2004 (Month 11).

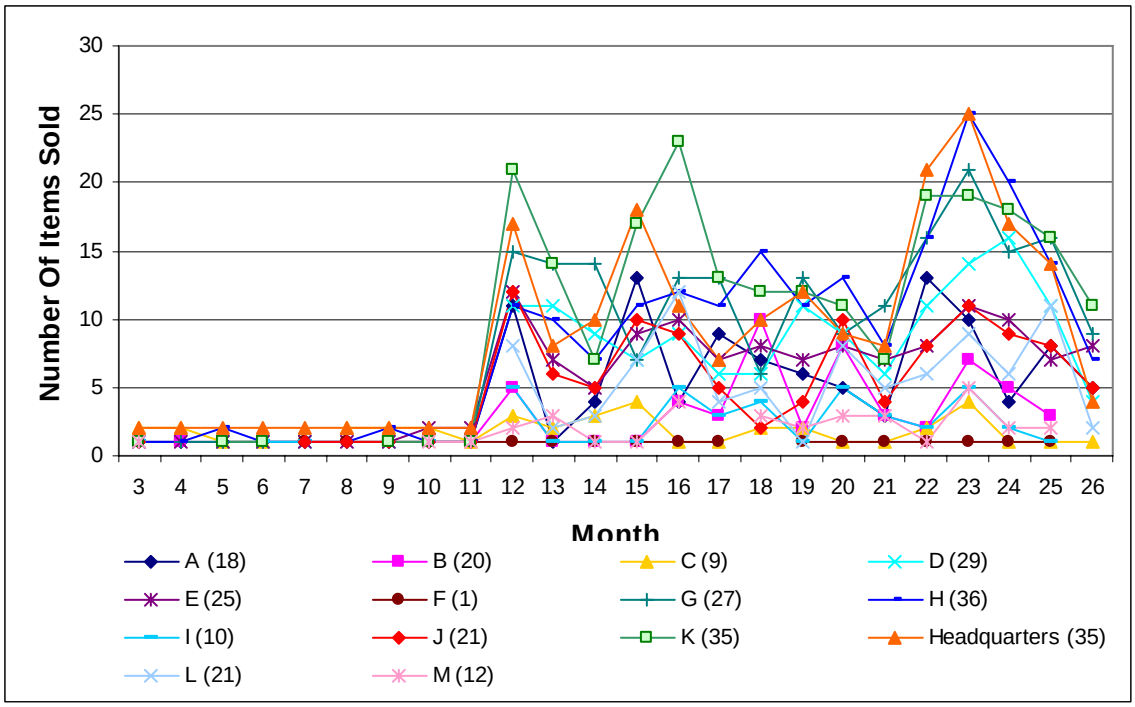

Figure 13. Fence: Monthly Items Sold

Feed (Fed)

The total numbers of Feed items sold in the entire cooperative during the time frame of this study was 343. The number of Feed items sold was the second largest number of items sold, after the Equipment/Parts group. The number of items sold in Feed items at each branch, which is displayed in Figure 14, does not vary much. Other than in branch C, which exhibits an increasing number of items sold throughout the year, the number of items sold in other branches seems to be stable throughout the year. Branch C sold the largest number of items in this group, followed by branch G. Branches A and I sold the least number of items among other branches

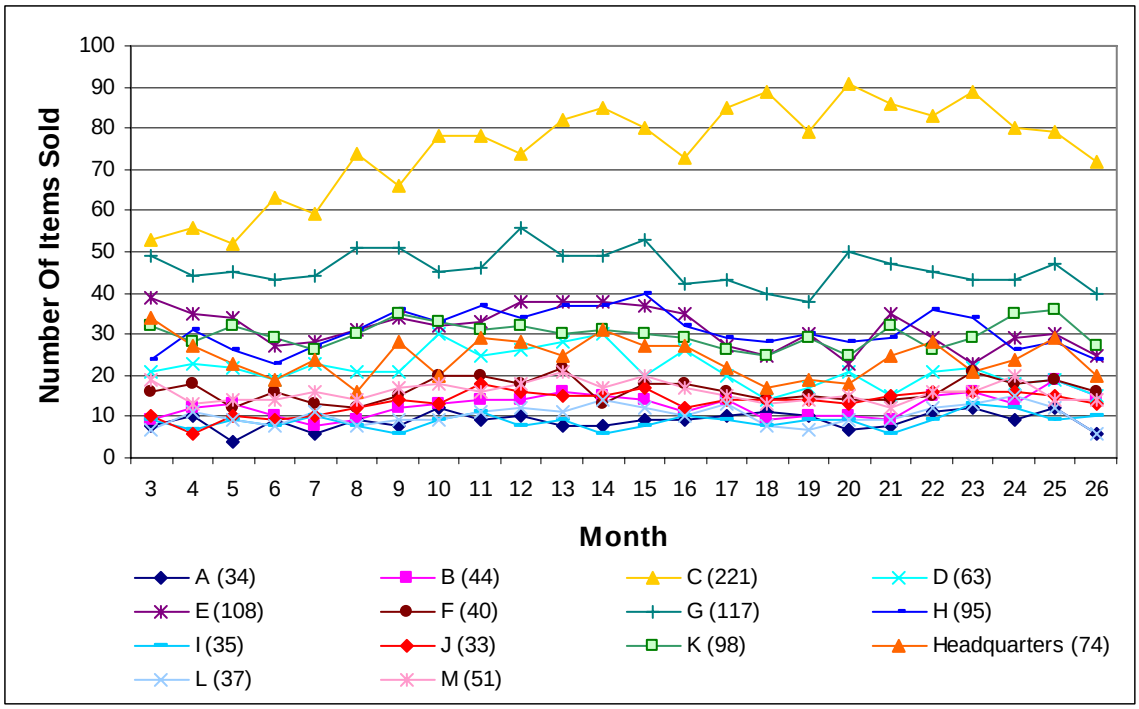

Figure 14. Feed: Monthly Items Sold

Seed (Sed)

A total of 91 items in the Seed group were sold in the entire cooperative. Figure 15 displays the number of Seed items sold at each branch. The number of items sold in this group varied more dramatically than those of Feed items. For some branches, such as C and E, the number of items sold in this group varied significantly in the second year, but some branches, for instance branch G, sold only one or two items in this group throughout the first and second year. Other branches, excluding branch F which sold none of the items in this group, sold the items sporadically.

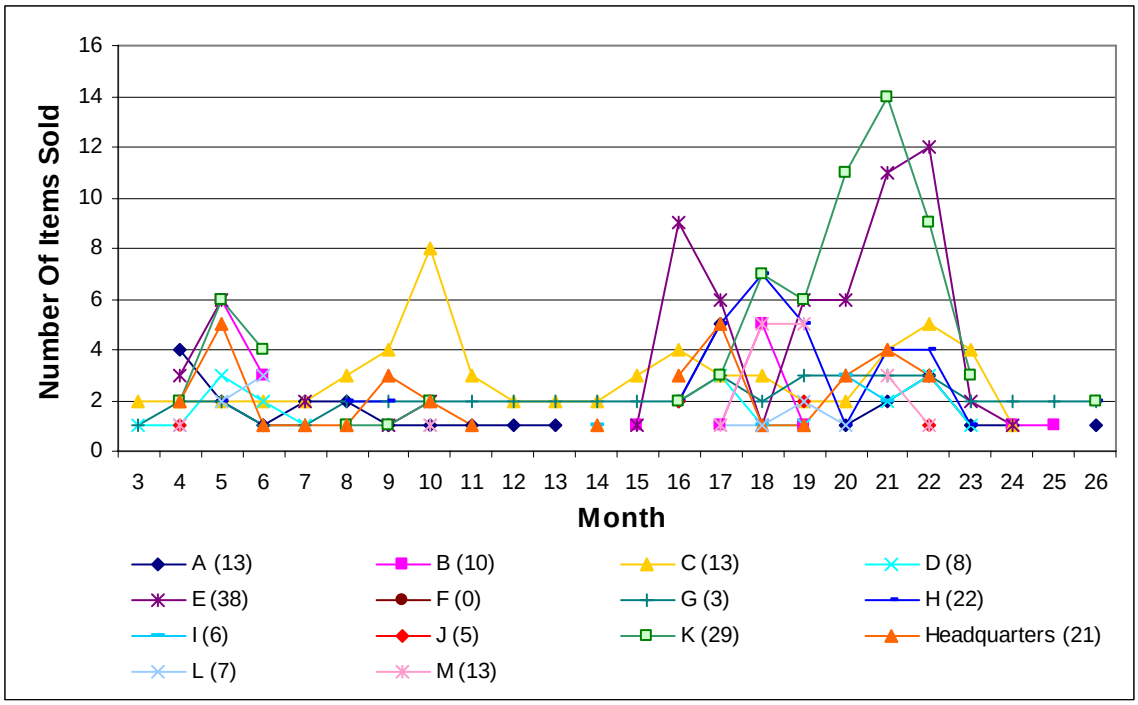

Figure 15. Seed: Monthly Items Sold

Tires/Batteries/Auto (TBA)

The total numbers of Tires/Batteries/Auto items sold in the entire cooperative was 205. 132 of them were sold at the Headquarters. Excepting branch F which sold none of the items in this group, other branches sold 18 to 76 items. Figure 16 displays the number of items sold in the Tires/Batteries/Auto group at each branch. The figure shows a significant increase in the number of items sold in this group in the majority of branches starting in December 2004 (Month 12). After December 2004 (Month 12), the pattern of the number of items sold at each branch shows little variation for the rest of the year. In the second year, the Headquarters sold the largest number of items in this group, followed by branch H and K. Although branch C sold the largest number of items in the first year, the number of items sold in the second year was among the least.

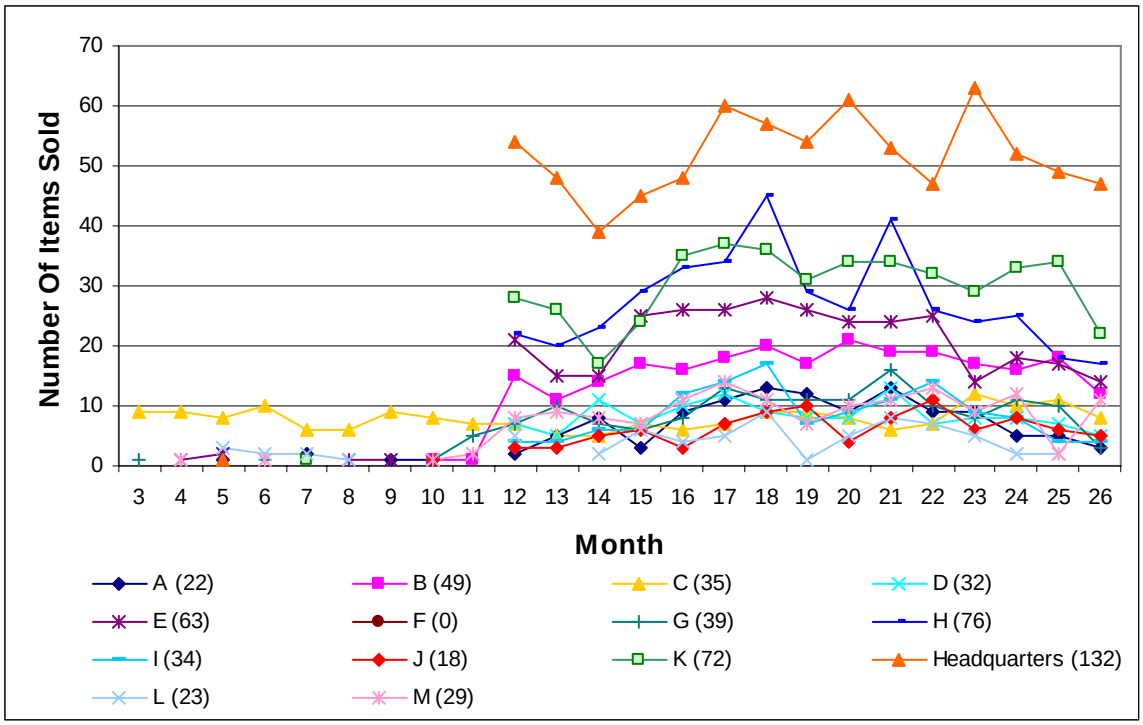

Figure 16. Tires/Batteries/Auto: Monthly Items Sold

Insecticide/Herbicide (IH)

A total of 156 Insecticide/Herbicide items were sold in the entire cooperative. Most of these items (125 items) sold from the Headquarters. Branch C, H, K, and M sold 59, 55, 60, and 56 items respectively. The rest of the branches sold less than 35. Figure 17 displays the number Insecticide/Herbicide items sold at each branch. For the majority of the branches, the largest number of items sold in the first year occurs in the month of May (Month 5). As for the second year, the largest number of items sold occurs in either March (Month 15) or April (Month 16).

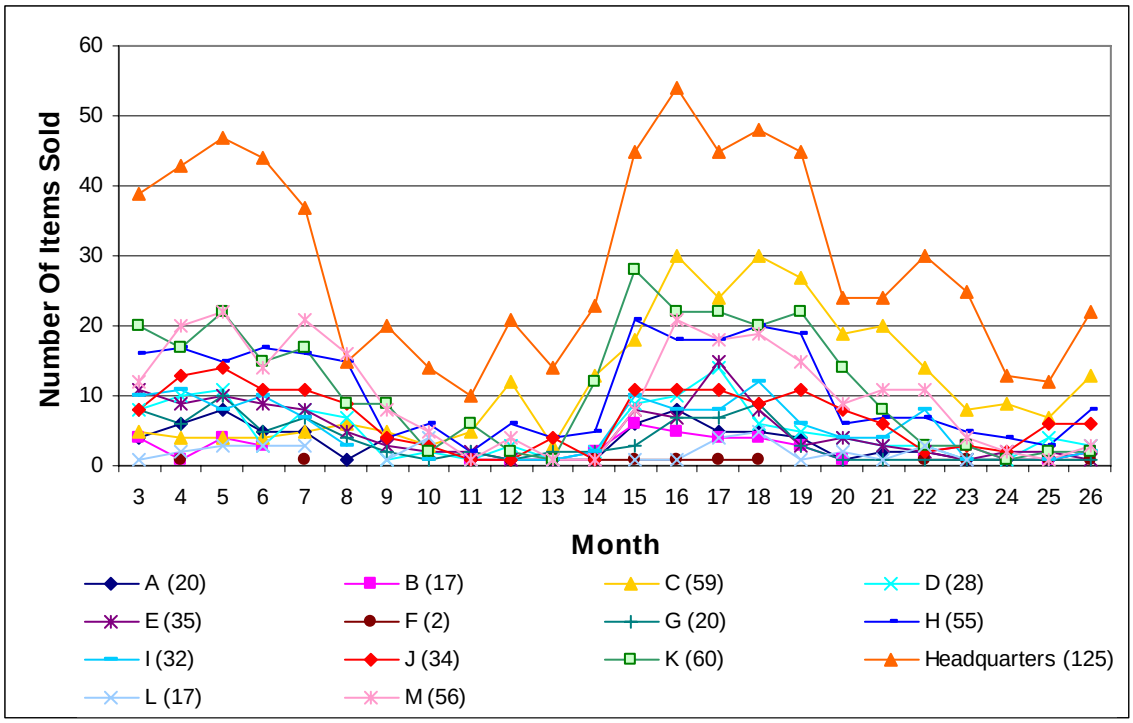

Figure 17. Insecticide/Herbicide: Monthly Items Sold

Equipment/Parts (EP)

The total numbers of Equipment/Parts items sold in the entire cooperative was 404, which is the highest number of items among the groups of items. The Headquarters sold the largest number of items in this group followed by branch K. The total number of Equipment/Parts items sold in the Headquarters and branch K were 330 and 108, respectively. Conversely, other branches, such as branch B, D, G, I, L, or branch M, sold only one or two items in this group. In the first year, the largest number of items sold at the Headquarters and branch K occurred in the month of June (Month 6) and July (Month 7) respectively. In the second year, the largest number of items sold in both branches occurred in June (Month 18). Figure 18 displays the monthly number of items in this group sold.

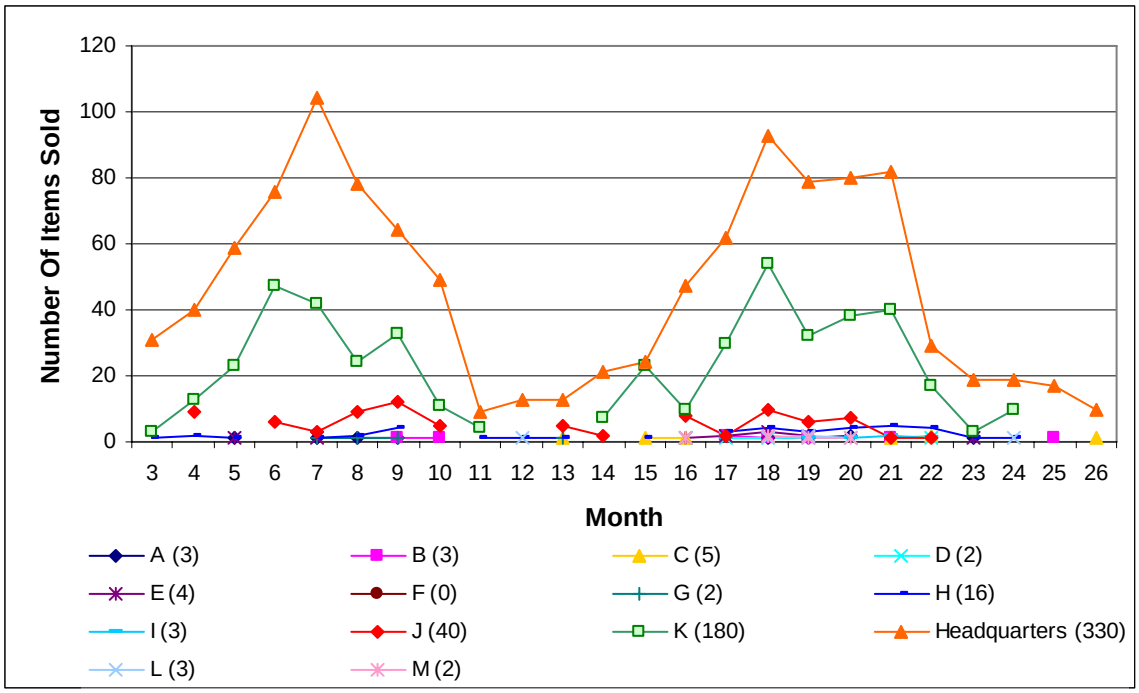

Figure 18. Equipment/Parts: Monthly Items Sold

Fertilizer (Frt)

A total of 54 items, in Fertilizer group, were sold in the entire cooperative. Figure 19 displays the number of Fertilizer items sold at each branch. Headquarters sold the largest number of items, 26, in both the first and second year. The largest number of items sold in this group occurs in different months for different branches. Branch K, for instance, sold the largest number of items in this group in October (Month 10 and Month 22) both in the first and second year. The Headquarters, sold the largest number of items in September (Month 9) for the first year and in August (Month 20) and September (Month 21) for the second year.

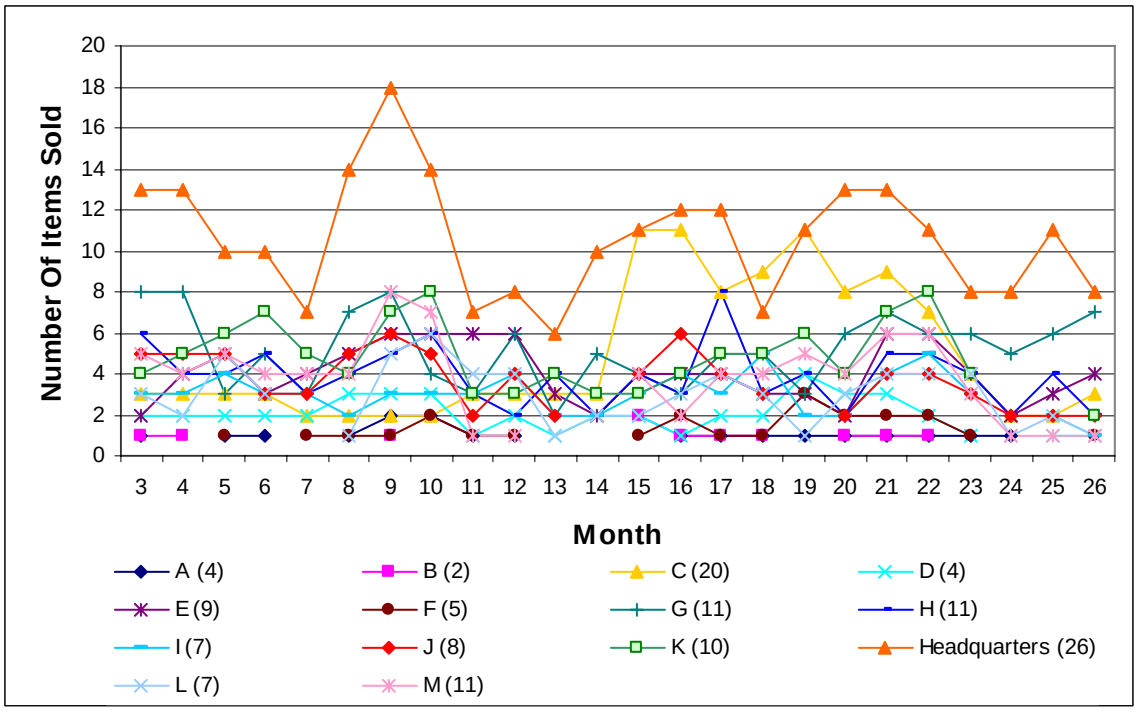

Figure 19. Fertilizer: Monthly Items Sold

Animal Health (AH)

The total number of items sold in Animal Health group was 20, which was the lowest total number of items sold among all the groups. The largest number of items sold in this group occurred at branch G. The rest of the branches sold only one or two items, in both the first and second year. Figure 20 displays the number of Animal Health items sold monthly at each branch.

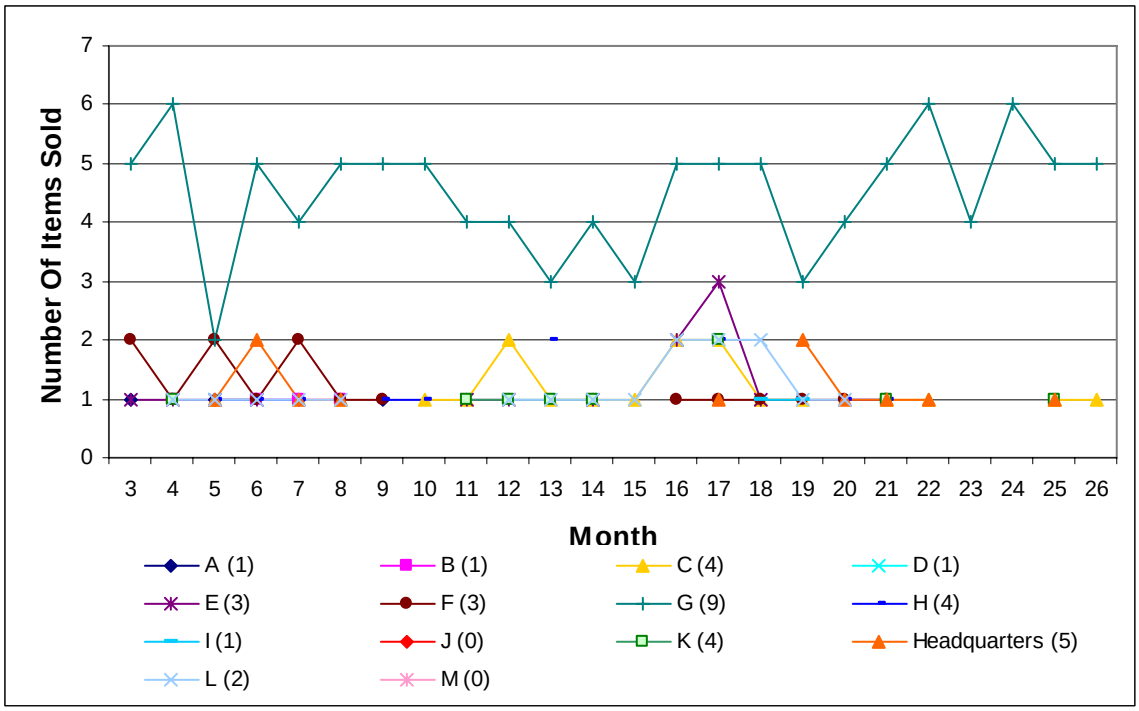

Figure 20. Animal Health: Monthly Items Sold

Miscellaneous Items (MI)

The total number of items sold in Miscellaneous Item group was 117. Branch C, which is an urban store, sold the largest number of items in this group (47 items). The largest number of items sold in each branch occurred in different months both in the first and second years (Figure 21). Branch C, for instance, sold the largest number of items in November (Month 11) and December (Month 12) of the first year, whereas, in the second year, it sold the largest number of items in June (Month 18). Similarly, in the first year, branch K sold the largest number of items in December (Month 12); while the largest number of items in the second year was sold in November (Month 23). The sales of Miscellaneous Items from this cooperative were spread out over the year.

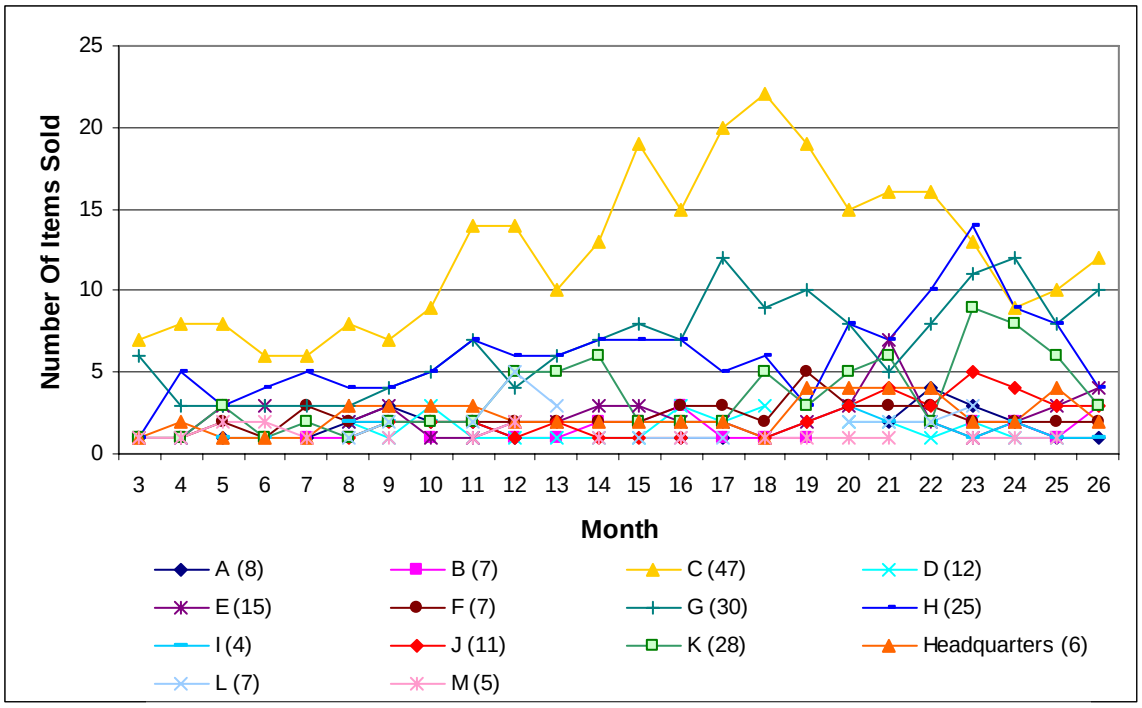

Figure 21. Miscellaneous Items: Monthly Items Sold

Purchase

Purchase activity is one of the three main trading activities (along with sale and transfer of items between the branches). There were 1,452 items purchased with total purchasing cost of $ 9,084,282 in the first year and $ 19,083,870 in the second year. This section is devoted to discuss details of purchasing activity. The discussion covers the number of purchasing orders in each group of items; the average number of items per order and the average total cost per order for each group of items; and details on the number of items purchased monthly for each group of items as well as the cost accrued from purchasing of those items. Information on purchasing presented here was based on the assumptions that each branch made its own purchasing order, and purchase was conducted for individual items (no joint replenishment).

Monthly numbers of purchasing orders for each group of items is presented in Figure 22. This figure shows that Fertilizer, Feed and Petroleum are groups with higher purchasing transactions throughout the years than other groups. The largest number of purchasing orders for Fertilizer occurred in the months of August (Month 8 and Month 20) and September (Month 9 and Month 21), whereas the number of purchasing orders for Feed has less variation throughout the years. The purchasing orders increased in the second year for groups such as Petroleum, Tires/Batteries/Auto, and Insecticide/Herbicide.

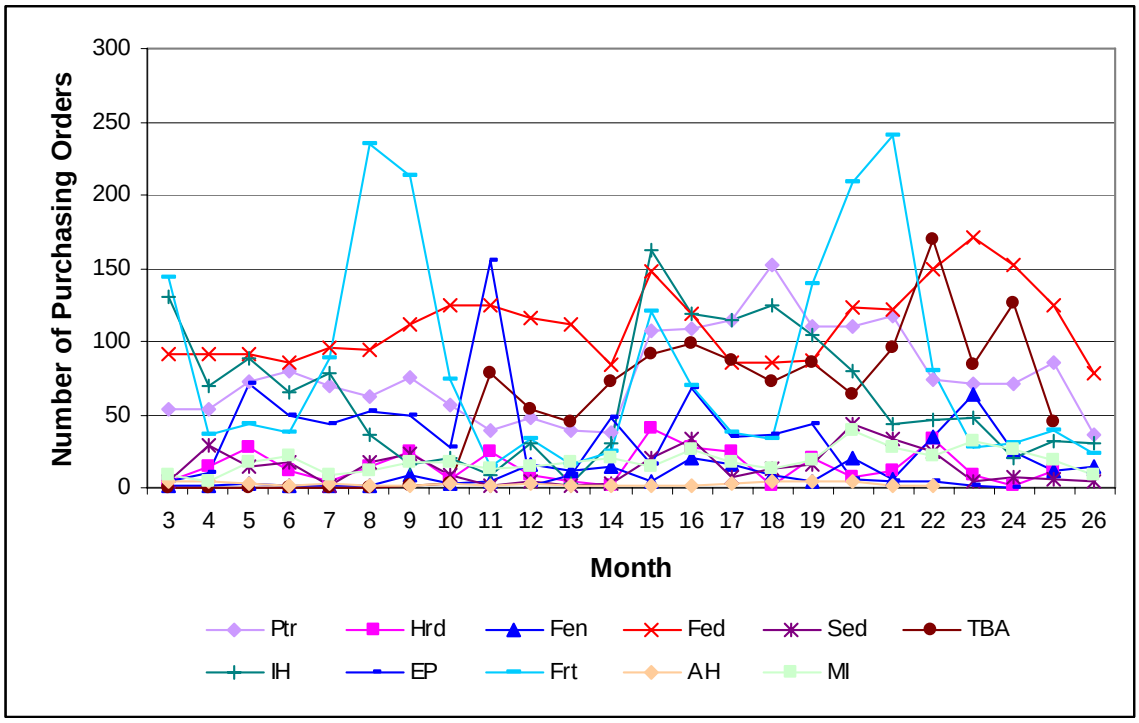

Figure 22. Monthly Purchase Order by Group

The average number ordered per item by product group as well as the total purchasing cost for each group of items is shown in Table 10. Petroleum and Fertilizer are groups that demonstrate a higher than average ordering per item in both years. The average numbers of ordering activities per month of these groups, in both years, are 23.56

and 18.49, respectively. In average, ordering activity per item for other groups of items ranged from 1.61 to 4.94 per month for both years. As for the total purchasing cost, Petroleum, Feed, Insecticide/Herbicide, and Fertilizer are groups with higher total purchasing cost among all other groups of items. All groups of items, except Animal Health, experienced an increase in total purchasing cost as well as the average number of orders per item from year 1 to year 2.

Table 10. Average Number of Order per Item and Total Cost per Order

Group	Year	Total Purchasing Cost ($)	Average Number Of Order Per Item (per month)	Average Total Cost Per Order (per month)
Ptr	1	3,067,446	19.18	3975.63
Ptr	2	8,265,302	27.95	5029.76
Hrd	1	16,592	1.53	108.25
Hrd	2	21,269	1.69	104.52
Fen	1	40,073	1.95	541.02
Fen	2	145,747	2.33	499.38
Fed	1	1,249,370	4.44	882.89
Fed	2	1,324,696	5.45	646.03
Sed	1	128,314	1.88	752.97
Sed	2	281,682	2.02	774.55
TBA	1	31,337	1.93	129.14
TBA	2	340,011	4.37	201.77
IH	1	1,627,219	2.36	2463.82
IH	2	1,922,786	3.6	1543.95
EP	1	17,147	1.56	29.63
EP	2	35,585	1.41	118.68
Frt	1	6,922,881	16.73	4494.19
Frt	2	7,899,406	20.24	4350.95
AH	1	43,823	3.44	1043.35
AH	2	21,625	2.58	697.64
MI	1	95,232	2.74	442.66
MI	2	140,507	3.37	285.63

Details on the number of items traded as well as the total purchasing cost at each branch for each group of items are conducted for each of the items:

Petroleum (Ptr)

Figure 23 displays the number of Petroleum items purchased. Total number of Petroleum items purchased for the whole cooperative was 20 with the total purchasing cost of $11, 332, 748, whereas the number of Petroleum items throughout the time this study was conducted was 26. This fact implies that the demands of some Petroleum items were met from existing stocks or perhaps an error in the data. Branch C purchased the largest number of Petroleum items, 11 items, among other groups. (The numbers in parentheses, after the name of the branch in the legend of Figures 23, refer to the total number of Petroleum items purchased at each branch). Other than the Headquarters, which purchased significantly larger numbers of Petroleum items in the second year compared to the first year, the number of Petroleum items purchased by other branches varied slightly across years. Branches A, B, E, and L began purchasing Petroleum items in the second year.

Figure 24 portrays the total cost accrued from purchasing Petroleum items. The total purchasing cost increased from year 1 to year 2. This increase might have resulted from the purchasing of additional Petroleum items, such as in the Headquarters, and/or the increase in unit cost of items being purchased.

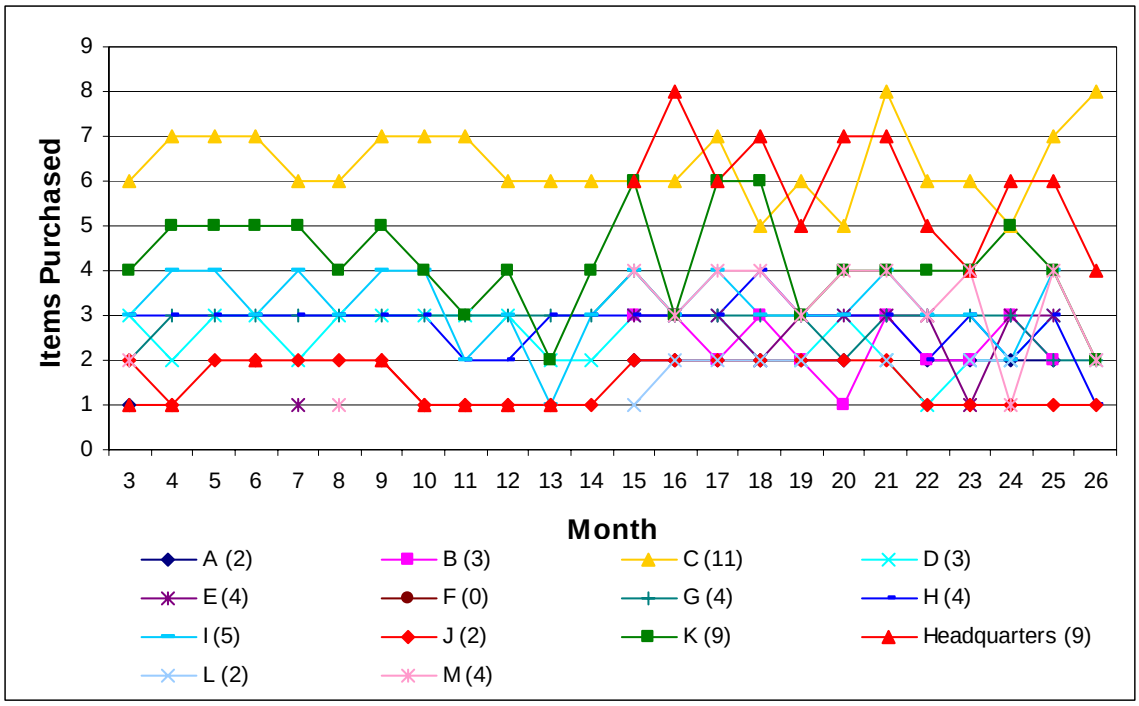

Figure 23. Petroleum: Monthly Items Purchased

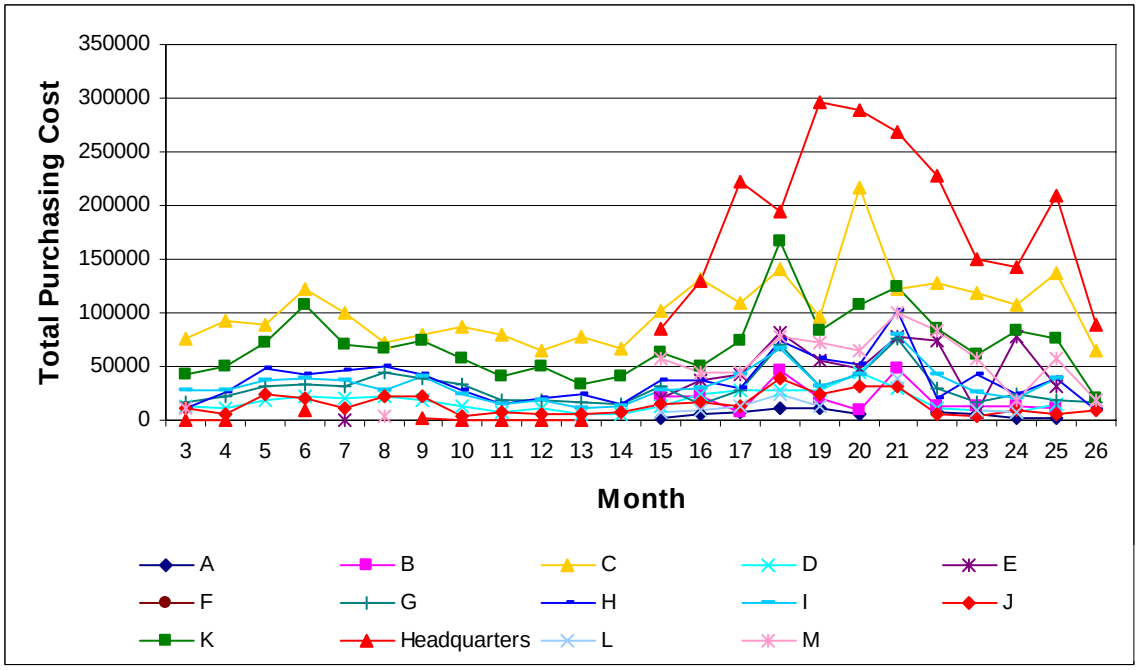

Figure 24. Petroleum: Total Purchasing Cost

Hardware (Hrd)

There were 141 Hardware items purchased in the entire cooperative with total purchasing cost of $ 37,861. Figure 25 depicts number of Hardware items purchased monthly. Unlike the purchasing of Petroleum items, purchasing activity for Hardware items is dominated by the Headquarters. Headquarters purchased 133 items in total, whereas other branches either did not purchase any Hardware items (such as branch B,D,E, F, I, and J) or purchased only one item (branch A, C, and G), or three items (branch H and K) or eight items (branch L and M). Relating the number of Hardware items purchased and sold at each branch shows that for almost all branches, with the exception of branches L and M, the number of Hardware items sold in each branch is larger than the number of items purchased. Therefore, it is suspected that most branches fulfilled their demand of Hardware items with either their existing stocks, or by transferring stock from other branches, most likely from the Headquarters.

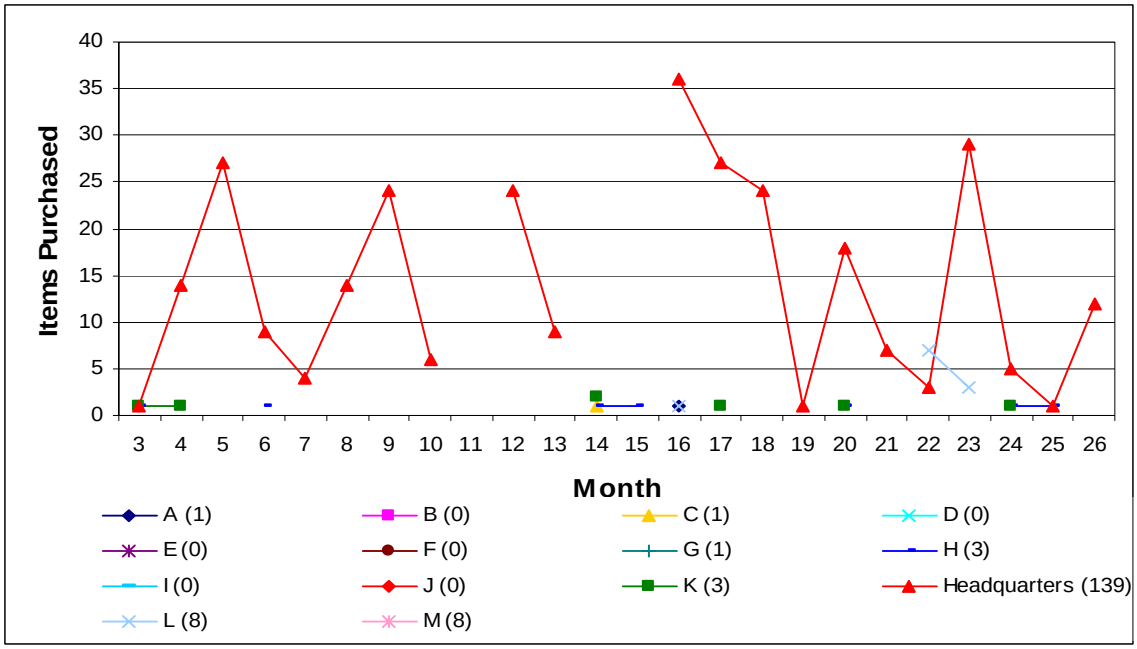

Figure 25. Hardware Items Purchased

Figure 26 shows the total cost of purchasing Hardware items per month in each branch. The largest total cost of purchasing Hardware occurred at Headquarters in September 2004, although this month was not the month with the highest number of items purchased. This phenomenon may be due to the larger quantity purchased or the larger unit cost of items purchased in this particular month compared to the other months.

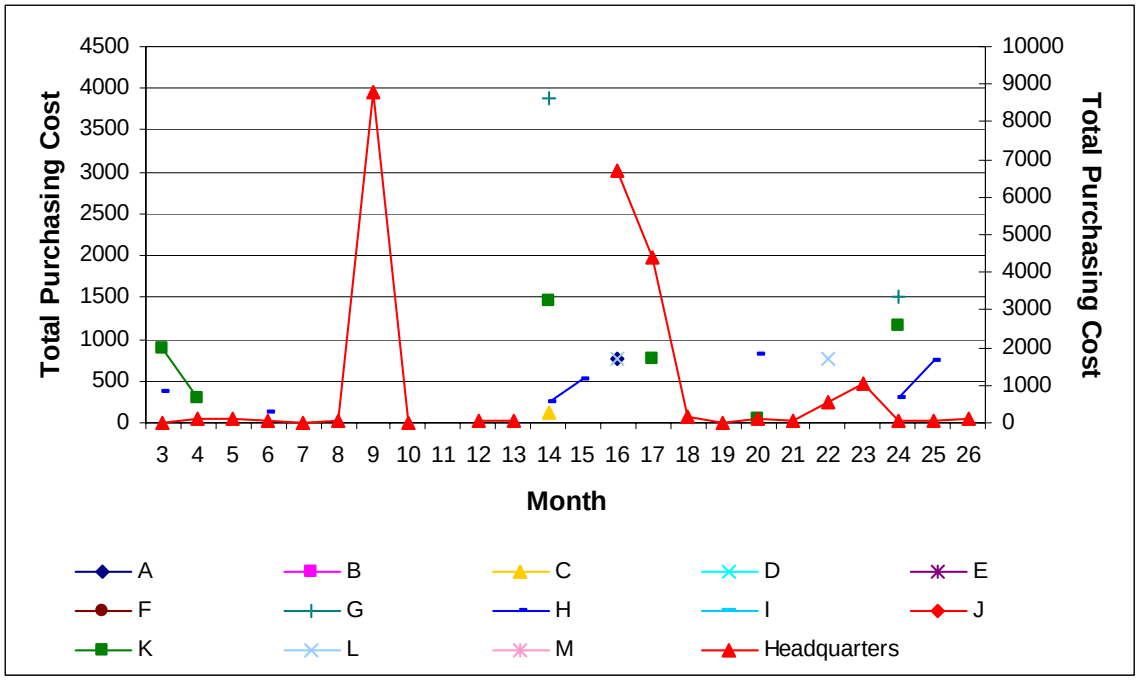

Figure 26. Hardware: Total Purchasing Cost

Fence (Fen)

There were 53 fencing items purchased with the total purchasing cost of $185,820. The number of fencing items purchased monthly is depicted in Figure 27. There was an increase in the number of fencing items purchased in branches such as branch H, D, K, and G, as well as at the Headquarters. However, when comparing the number of fencing items that were sold with the items, both for the entire cooperative as well as in each branch, it shows that there were significant differences in the number of items of these

two activities. The total number of fencing items sold, for instance, was 70, whereas the total number of items purchased was only 53. Furthermore, the total number of fencing items purchased in all branches (and at the Headquarters) was less than the total number of items sold. These differences imply that the branches, along with the Headquarters, fulfilled their demands from either their stocks and or through transferring from another branches or that the data have errors.

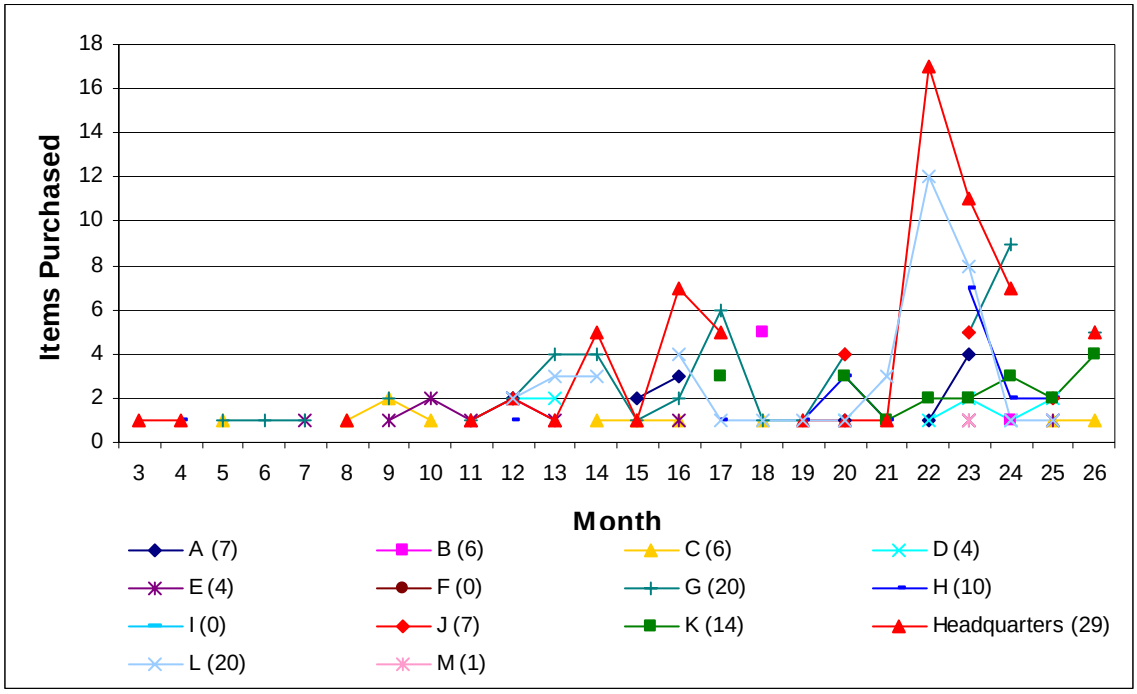

Figure 27. Fence: Monthly Items Purchased

Figure 28 shows the total purchasing cost of fencing items in each branch. The total purchasing costs of fencing items increased in the second year at the Headquarters and branch G. The highest total purchasing costs at both locations, however, did not occur in the month where they purchased the largest number of fencing items. This difference could be due to the quantity and or the unit price of items being purchased.

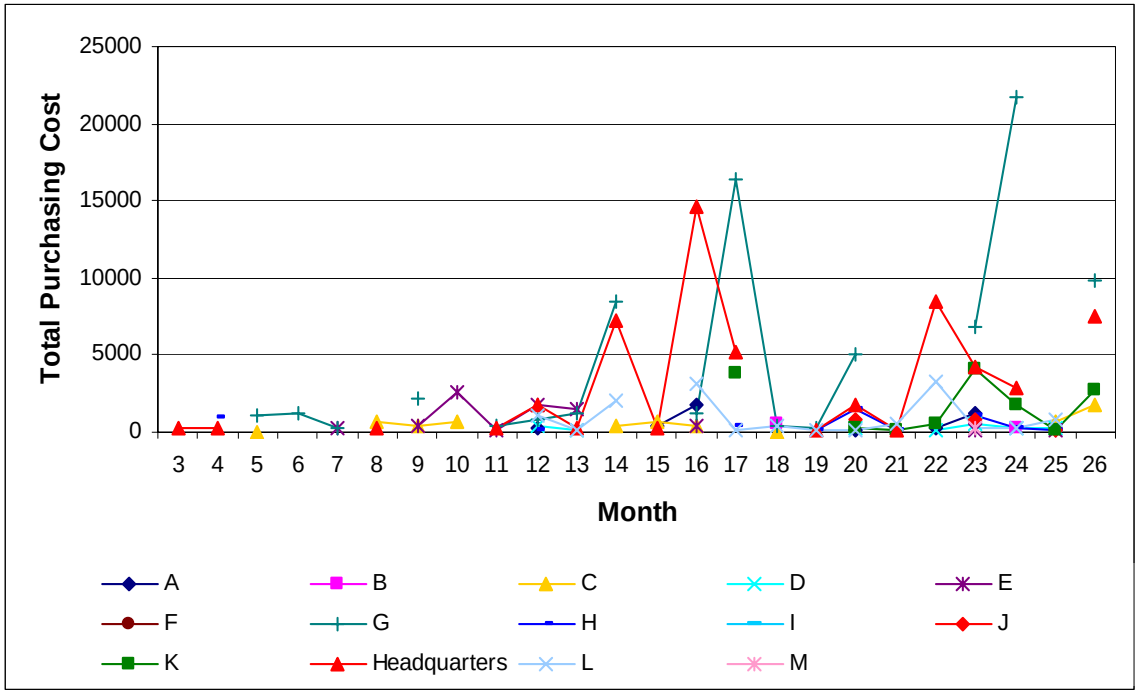

Figure 28. Fence: Total Purchasing Cost

Feed (Fed)

A total of 319 Feed items were purchased with the total cost of $ 2,574. Branch C, E, and G purchased a higher number of Feed items during this time (Figure 29). The rest of the branches purchased less than five items per month. When comparing the number of Feed items purchased with the number of Feed items sold, it is found that there is a significant difference between the number sold and the number purchased. Branch K, for instance, sold 98 Feed items but purchased only 17 Feed items. Similarly, Headquarters sold 74 Feed items yet purchased only 15 items. This phenomenon implies that all branches fulfill their demands of Feed items by either using their stocks or transferring the items needed among the branches or that the data have errors.

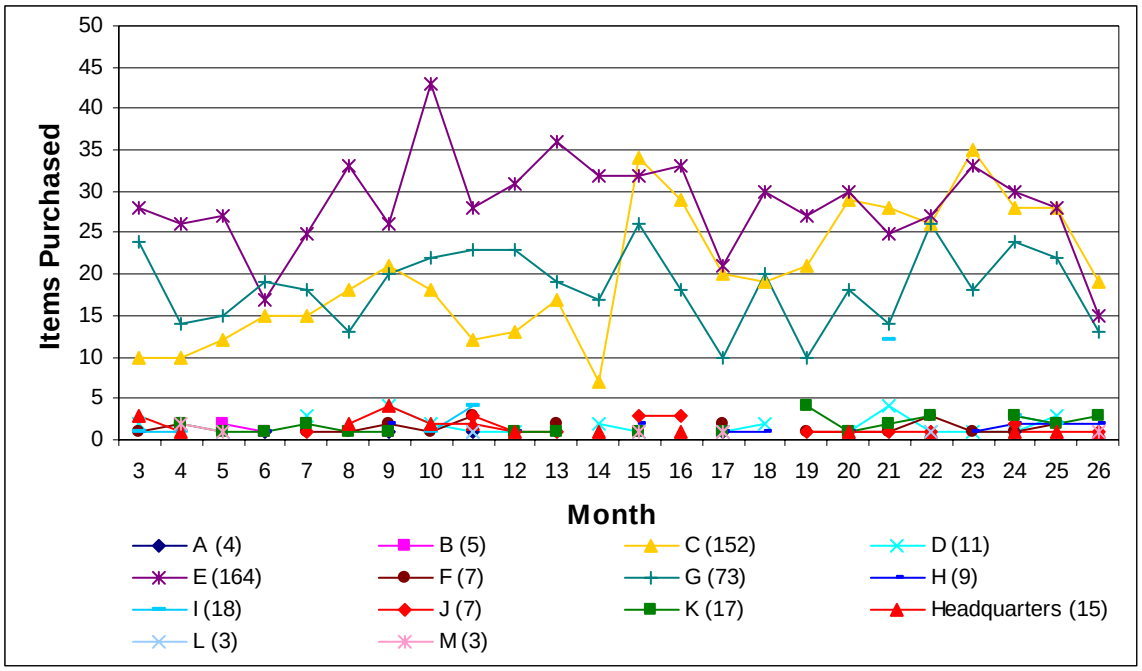

Figure 29. Feed: Monthly Items Purchased

The total purchasing cost of Feed items is presented in Figure 30. Unlike the branches with higher numbers of Feed items purchased (which are branch C, E and G), higher total purchasing cost appear to be only at branch E and G. This fact implies that most of Feed items purchased by branch C were items with lower unit costs. The highest total purchasing cost of Feed items at most of the branches occurred in either the month of November (Month 11 and Month 23) or December (Month 12 and Month 24) for both years.

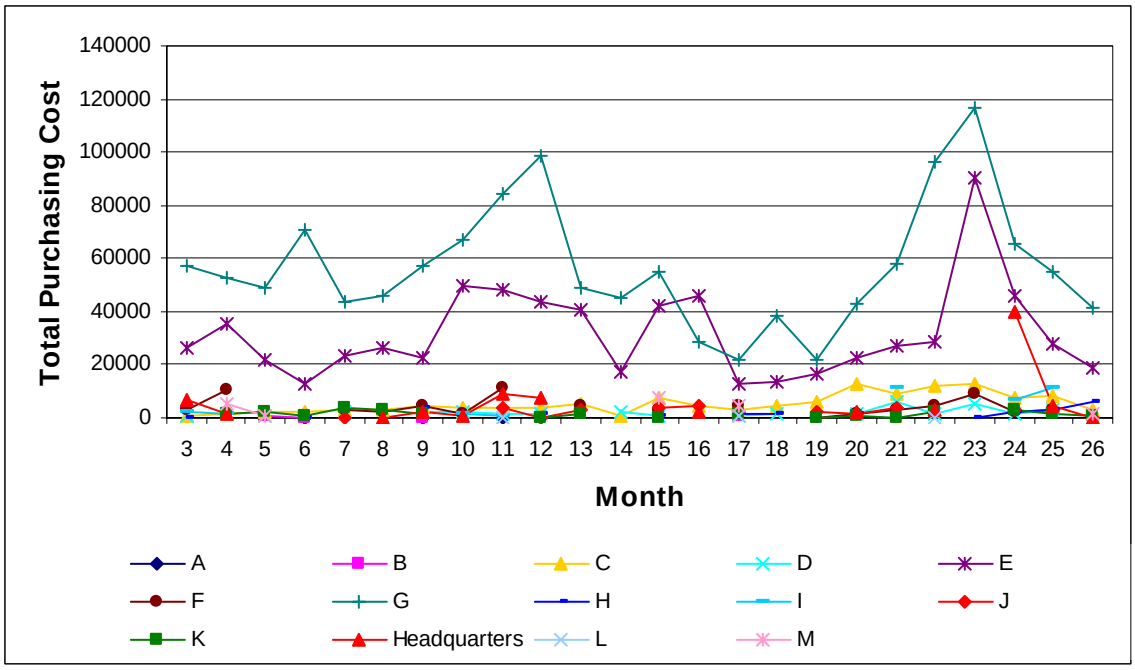

Figure 30. Feed: Total Purchasing Cost

Seed (Sed)

There were 103 Seed items purchased with the total purchasing cost of $ 409,996. Unlike the previous groups of items, the total number of Seed items purchased in the entire cooperative was greater than the number of items sold (91 items). Four branches (C, E, G, and, J) purchased more items than the number of items they sold. Branch G, for instance, purchased 70 Seed items but sold only 38 Seed items. Figure 31 depicts the number of Seed items purchased monthly. The Headquarters and branch E had higher numbers in the first year. However, the highest number of Seed items purchased in the second year occurred only at branch E. The total purchasing cost accrued for Seed items at each branch is presented in Figure 32. This figure shows that total purchasing cost at each branch increase as the total number of items increase.

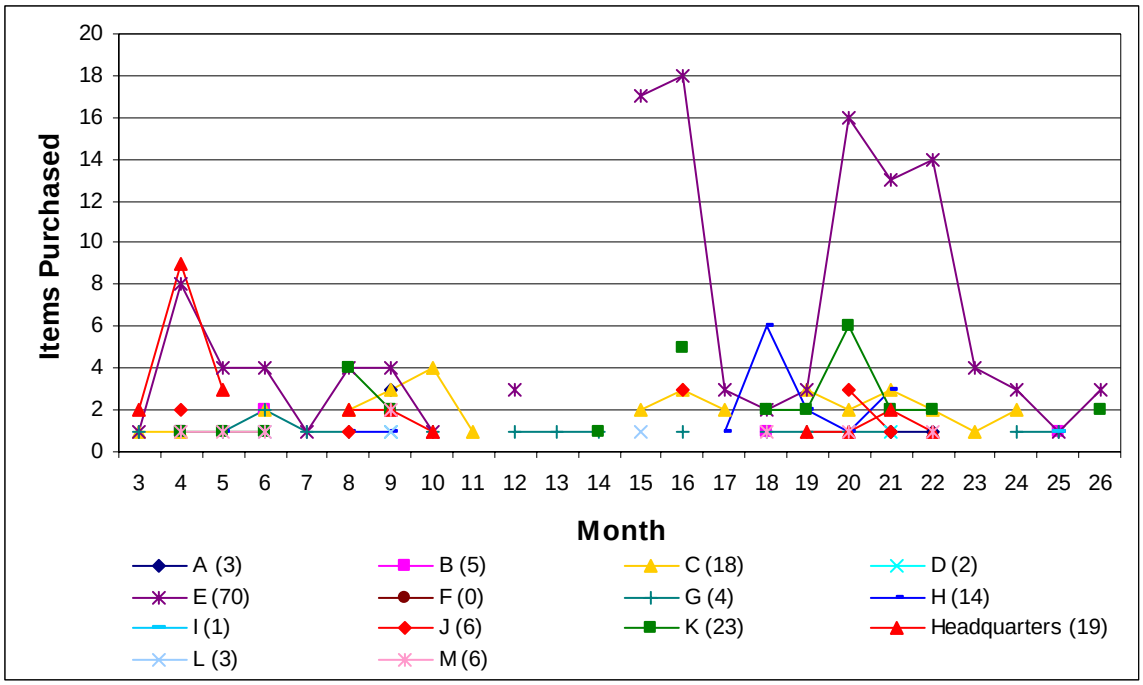

Figure 31. Seed: Monthly Items Purchased

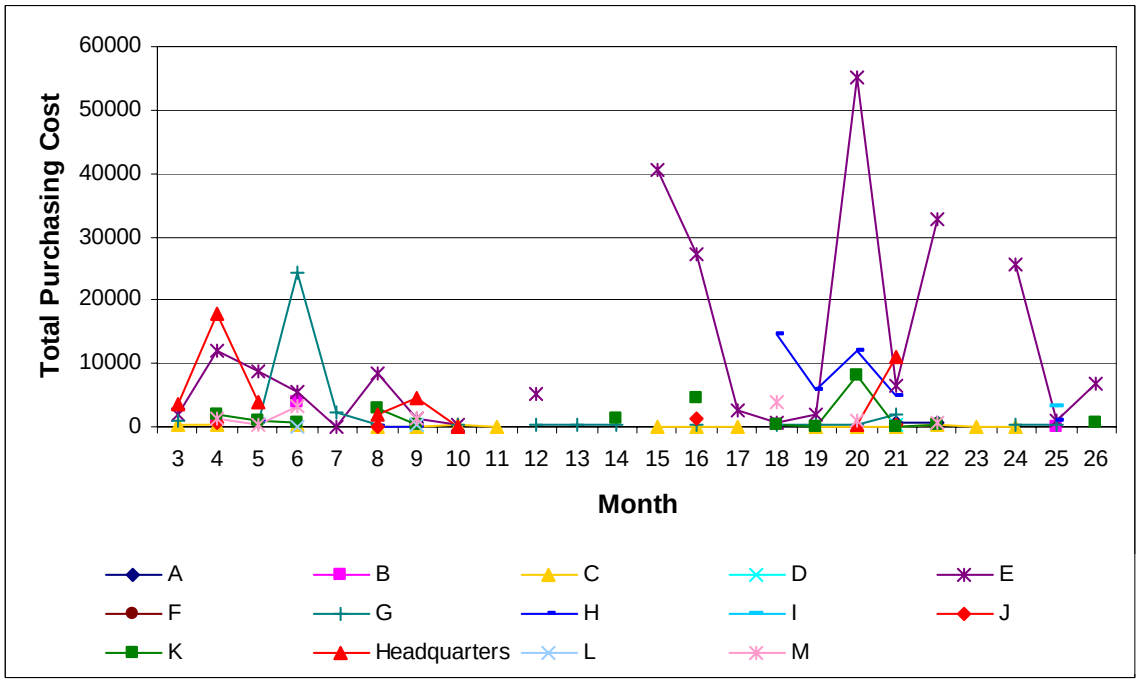

Figure 32. Seed: Total Purchasing Cost

Tires/Batteries/Auto (TBA)

A total of 174 Tires/Batteries/Auto items were purchased with the total cost of $ 371,345. When comparing the total number of Tires/Batteries/Auto items purchased with the number of items sold, it is found that the total number of items sold (205 items) for the entire cooperative is greater than the number of items purchased. This is also true for all branches. The fact that the number of Tires/Batteries/Auto items purchased was less than the number of items sold implies that the branches materialized their customer's demand either with their stocks or through transferring the items among the branches. Figure 33 presents the number of items purchased. This figure shows that the purchasing of Tires/Batteries/Auto started at December 2004 (Month 12) and the Headquarters purchased the largest number of items in this group among other branches. The total purchasing cost for this group is displayed in Figure 34. The highest purchasing cost accrued at Headquarters; the purchasing cost increased as the number of items purchased increase.

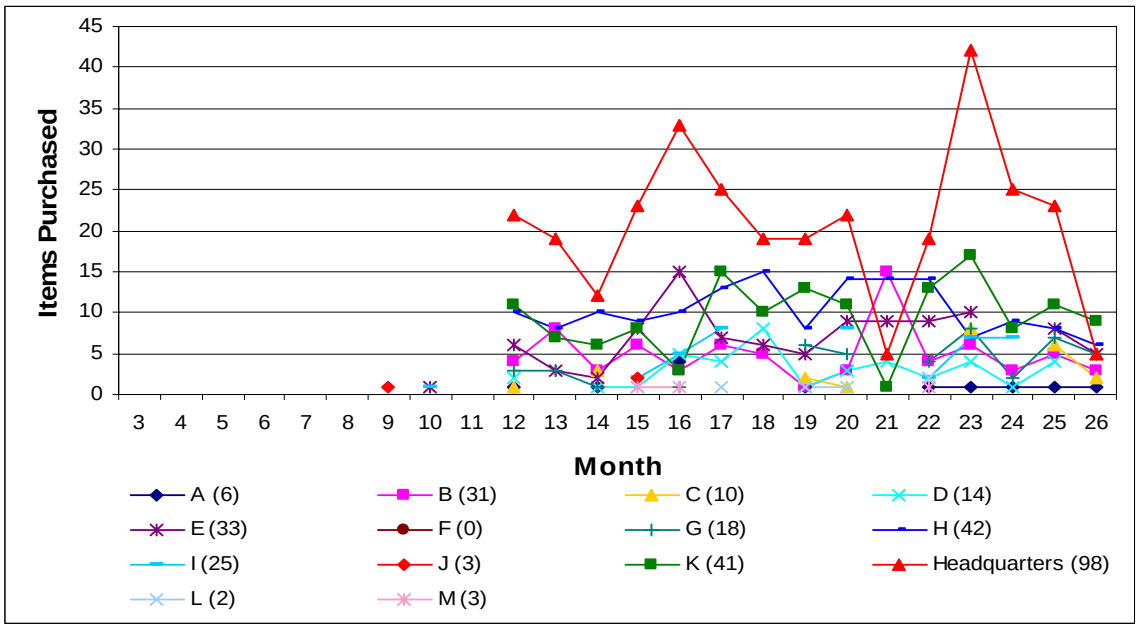

Figure 33. Tires/Batteries/Auto: Monthly Items Purchased

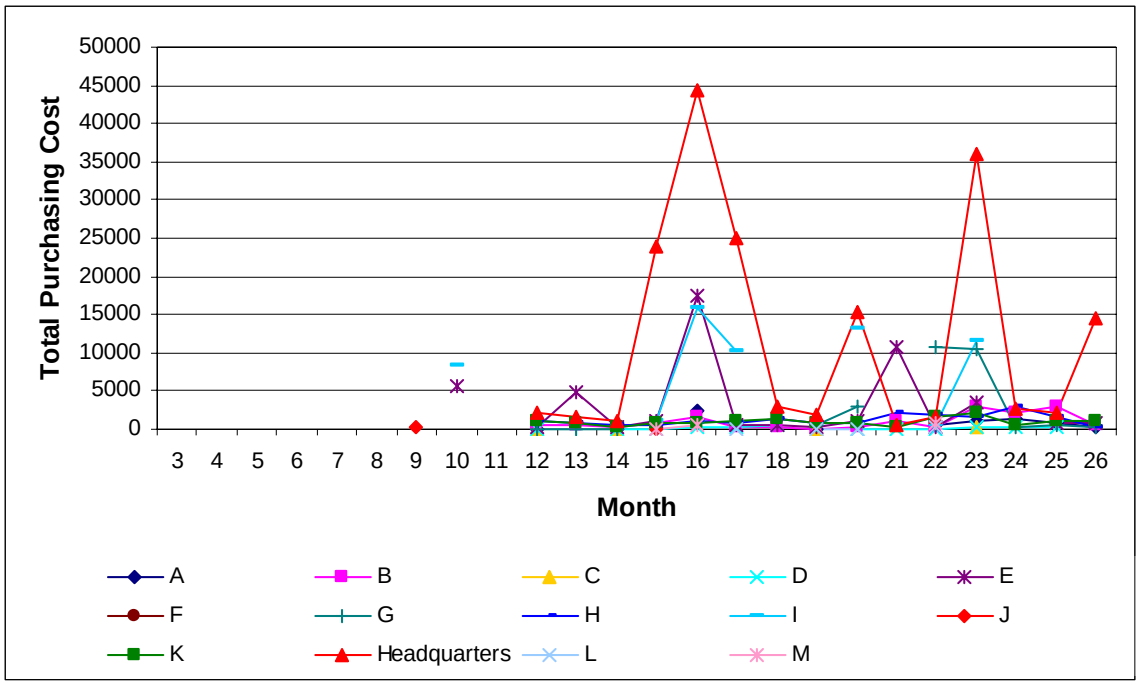

Figure 34. Tires/Batteries/Auto: Total Purchasing Cost

Insecticides/Herbicides (IH)

There were 138 Insecticide/Herbicide items with the total purchasing cost of $ 3,550.005. As with most of the groups of items, the total number of Insecticide/Herbicide items purchased in the entire cooperative was less than the total number of items sold in this group. This fact implies that the branches materialized their demand for Insecticide/Herbicide items not only by purchasing the items but also by utilizing their stocks and/or transferring the items needed. The number of Insecticide/Herbicide items purchased monthly is depicted in Figure 35. In both years, the highest number of Insecticide/Herbicide items purchased in most of the branches occurred in April (Month 4 and Month 16). Additionally, there was a decreasing pattern in the number of items purchased throughout both years. However, the total purchasing cost of Insecticide/Herbicide items, shown in Figure 36, does not portray this pattern.

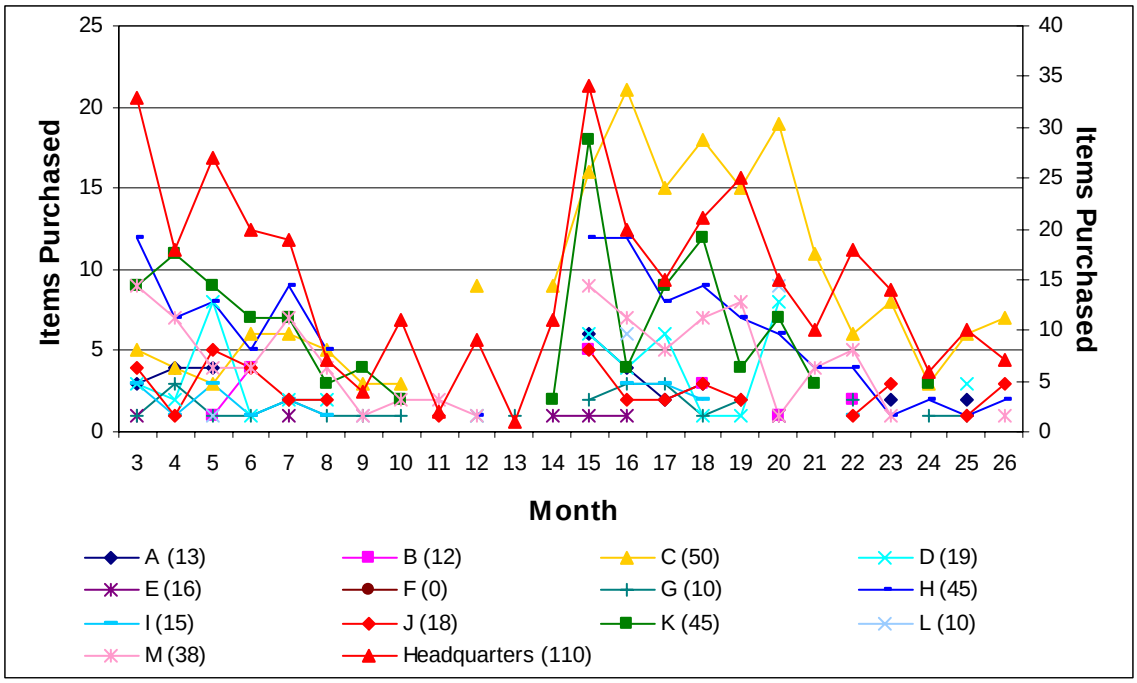

Figure 35. Insecticide/Herbicide: Monthly Items Purchased

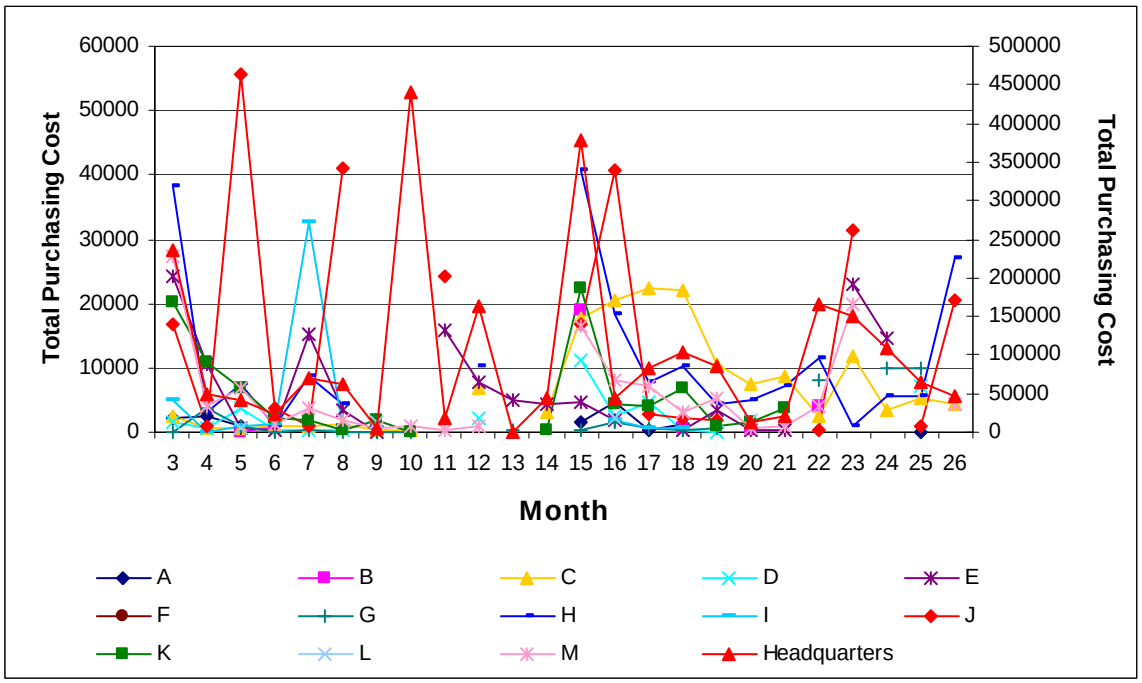

Figure 36. Insecticide/Herbicide: Total Purchasing Cost

Equipment/Parts (EP)

Figure 37 displays the number of Equipment/Parts items purchased. The total number of Equipment/Parts items purchased for the whole cooperative was 349 items with the total purchasing cost of $ 52,732, whereas the number of Equipment/Parts items sold in the same time frame was 404 items. Similarly, the number of Equipment/Parts items purchased in all branches is less than the number of Equipment/Parts items sold. However, the total number of Equipment/Parts items purchased at the Headquarters is not significantly different from the number of items sold (330 items) in this location. This information implies that most of other branches materialized their demand of Equipment/Parts items either from their stocks or transferred the items needed from the Headquarters. The total cost involved with the purchasing of Equipment/Parts items in each group is presented in Figure 38. It appears that the total purchasing cost increases as the total number of items purchased increases.

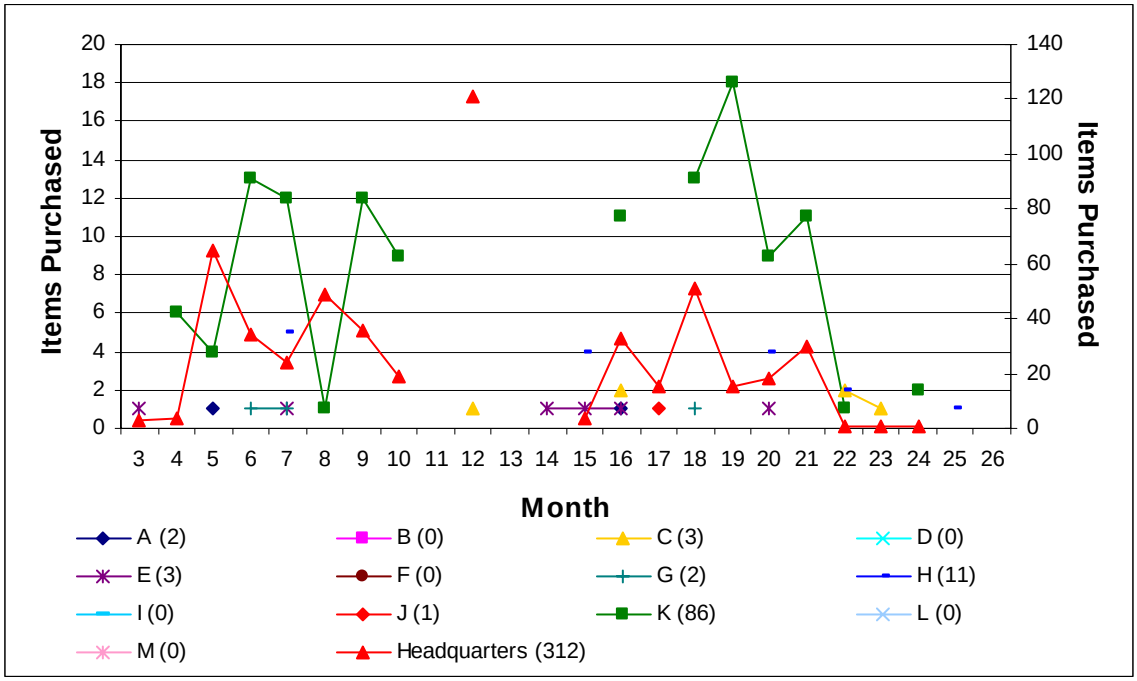

Figure 37. Equipment/Parts: Monthly Items Purchased

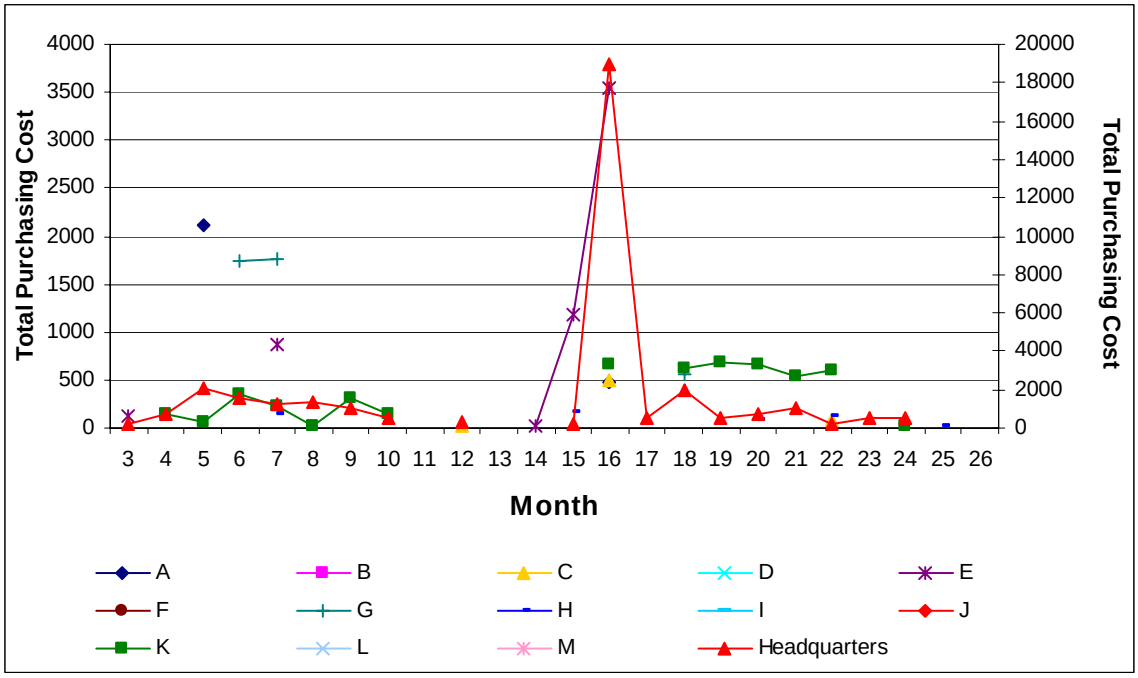

Figure 38. Equipment/Parts: Total Purchasing Cost

Fertilizer (Frt)

A total of 49 Fertilizer items were purchased with a total purchase cost of $14,822,287. Meanwhile, 54 Fertilizer items were sold. Total purchasing cost of Fertilizer items was the highest among the purchasing cost of other groups. Comparing the number of Fertilizer items purchased with the number of Fertilizer items sold in each branch shows that there was no significant difference in the number of Fertilizer items purchased and sold. This fact implies that a majority of the branches fulfilled their demand through purchasing. Further investigation on the transference of Fertilizer items (discussed in the next section) found this argument to be true. Figures 39 and 40 depict the number of Fertilizer items purchased and the total purchasing cost of these items. The Headquarters purchased the highest number of Fertilizer items and the total

purchasing costs increased as the number of items purchased increased. In general, every branch purchased Fertilizer items continuously, and the largest number of items purchased occurred in September (Month 9 and Month 21) for both years.

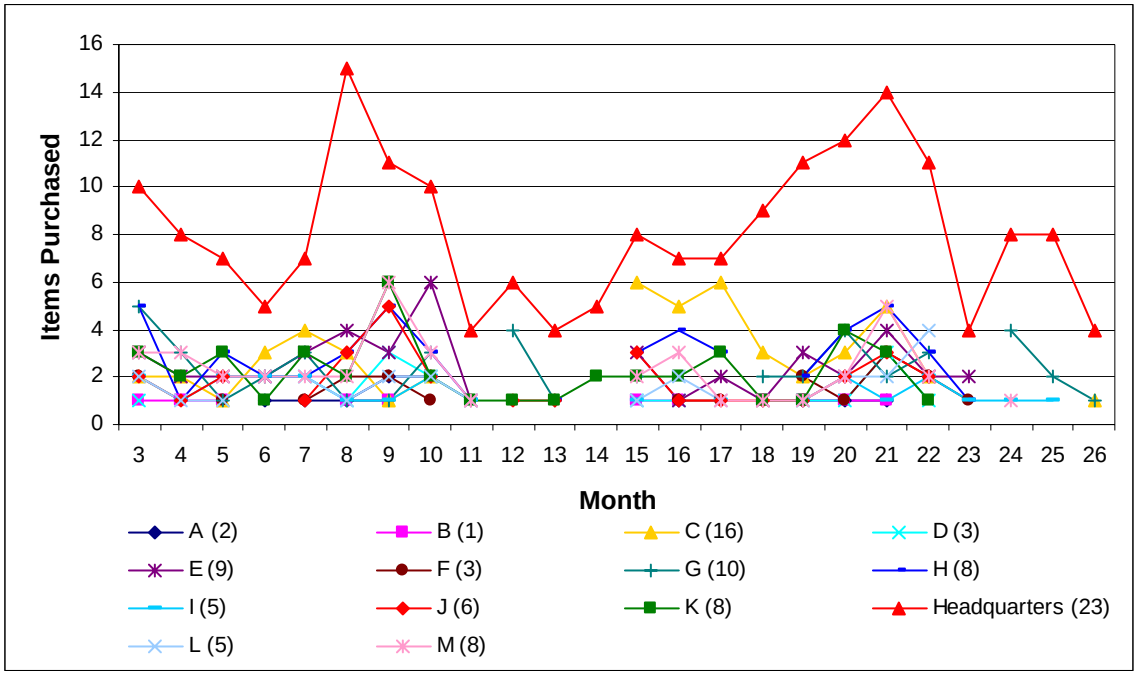

Figure 39. Fertilizer: Monthly Items Purchased

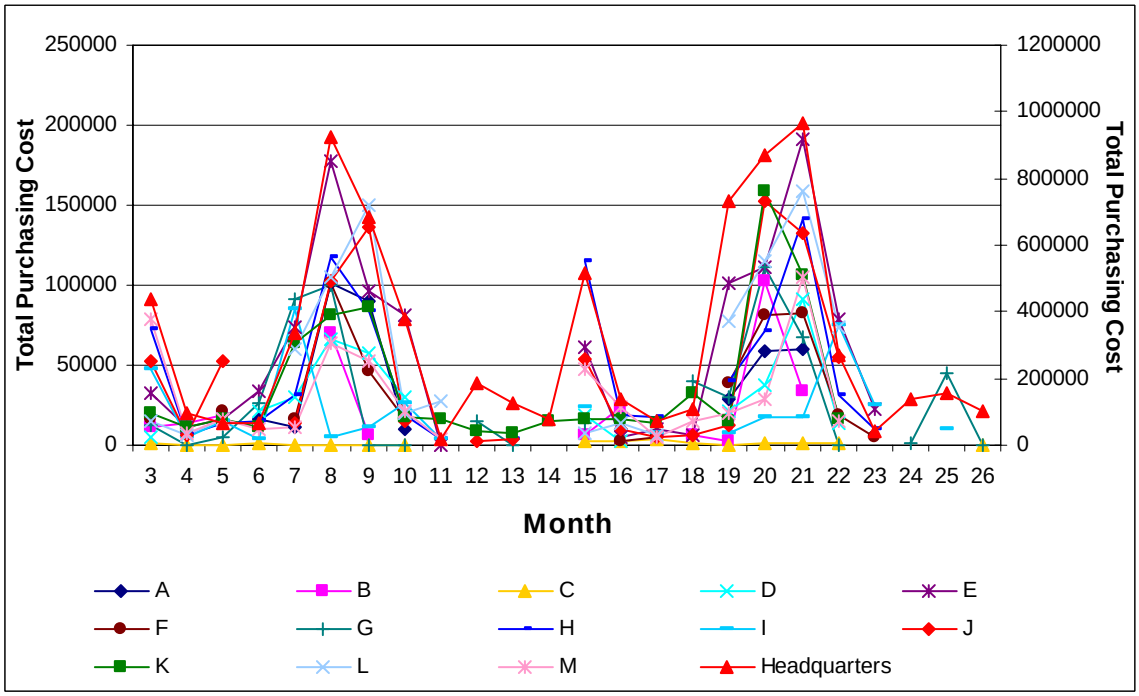

Figure 40. Fertilizer: Total Purchasing Cost

Animal Health (AH)

The total number of Animal Health items purchased was 14, which was the smallest number of items purchased among other group of items. However, the total number of Animal Health items purchased is not the smallest among the total purchasing cost of all groups of items. The cooperative spent $ 64,448 on purchasing this item, which is above the amount it spent on Equipment/Parts items and Hardware items. All branches except branch J sold AH items, while only 6 of the branches purchased Animal Health items. Branch G sold and purchased the most Animal Health items. Figures 41 and 42 depict the total number of Animal Health items purchased and the total purchasing cost of these items, respectively. It appears that all branches, except for branch G, purchased one item, irregularly.

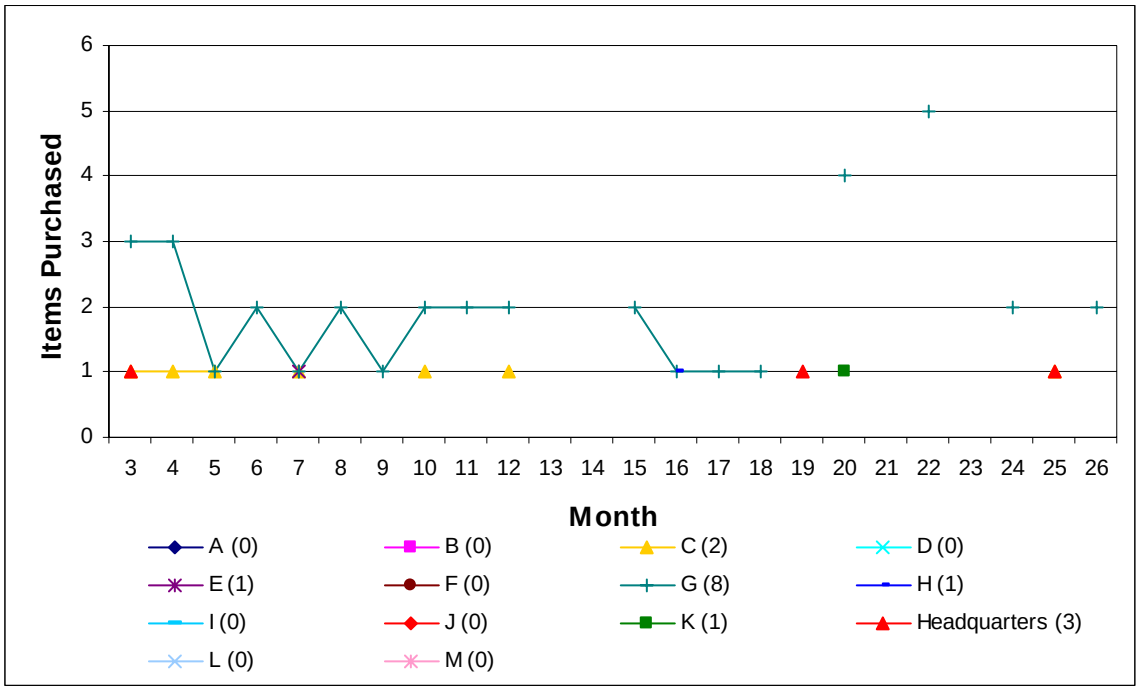

Figure 41. Animal Health: Monthly Items Purchased

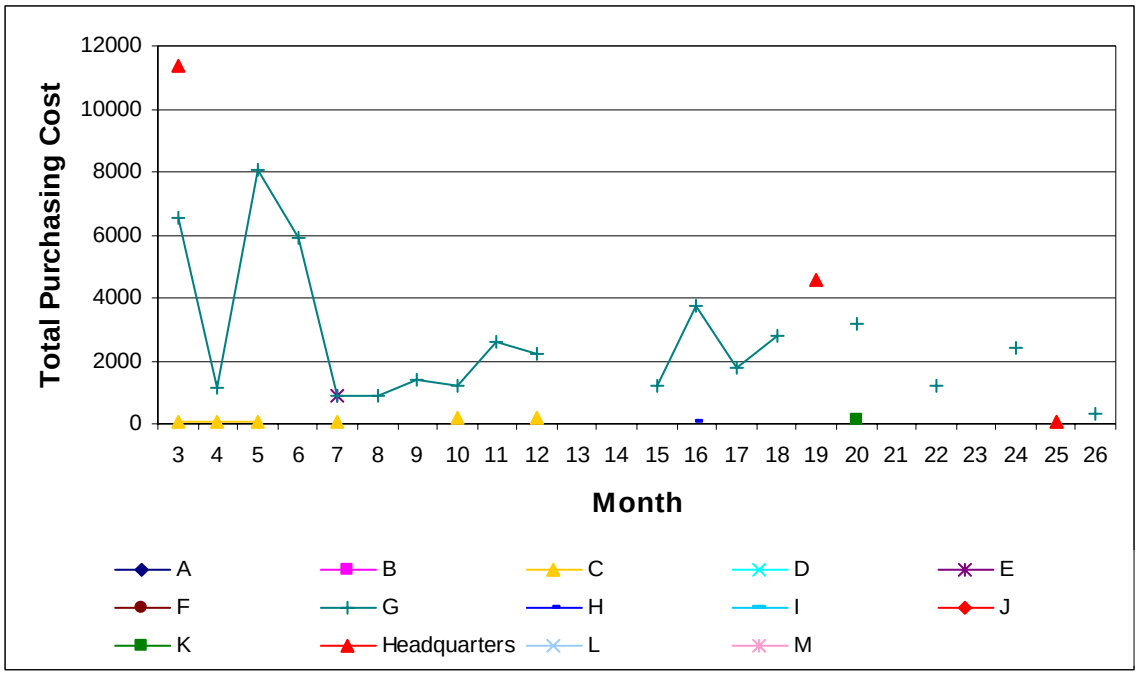

Figure 42. Animal Health: Total Purchasing Cost

Miscellaneous Items (MI)

A total of 92 Miscellaneous Items were purchased with the total cost of $ 235,739. When the total number of MI items purchased was compared with the number of Miscellaneous Items sold, it was found that the total number of items sold (117) for the entire cooperative was greater than the number of items purchased. This fact held true not only for the entire cooperative, but also for all of its branches. The fact that the number of Miscellaneous Items purchased was less than the number of items sold implies that the branches met their customer's demand either with their stocks or through transferring the items among the branches. The number of Miscellaneous Items purchased is presented in Figure 43. Branch C, E and G were branches with a higher number of Miscellaneous Items purchased. Other than the Headquarters and branch M,

which both remained relatively constant, the number of items purchased at each branch varied considerably throughout the year.

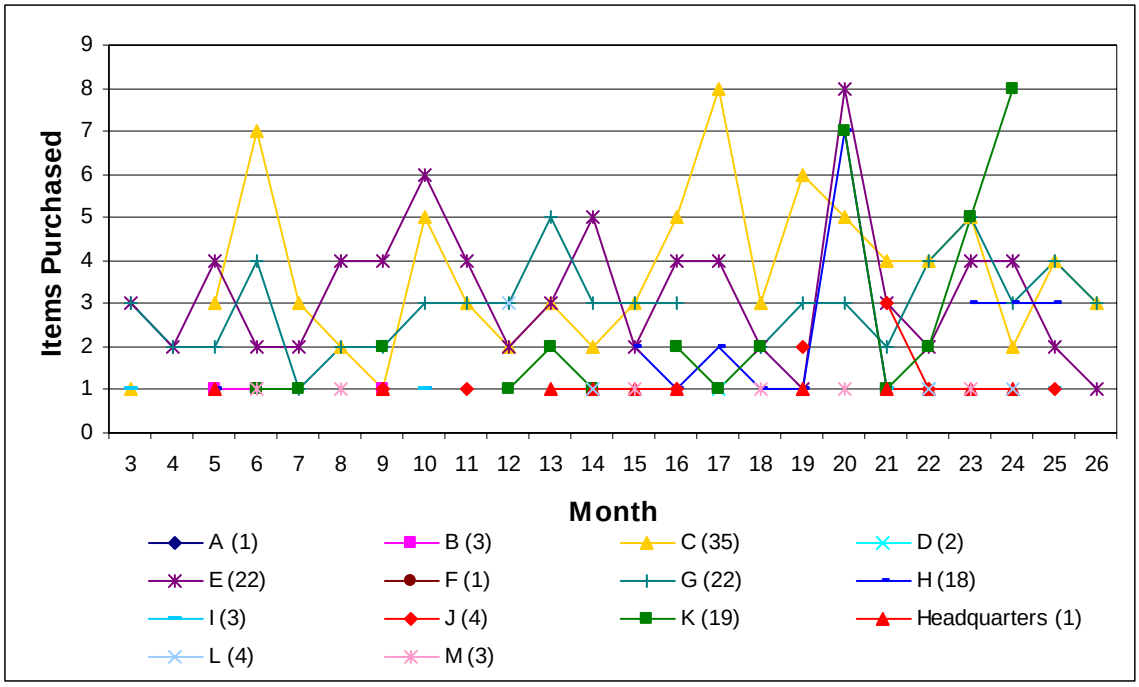

Figure 43. Miscellaneous Items: Monthly Items Purchased

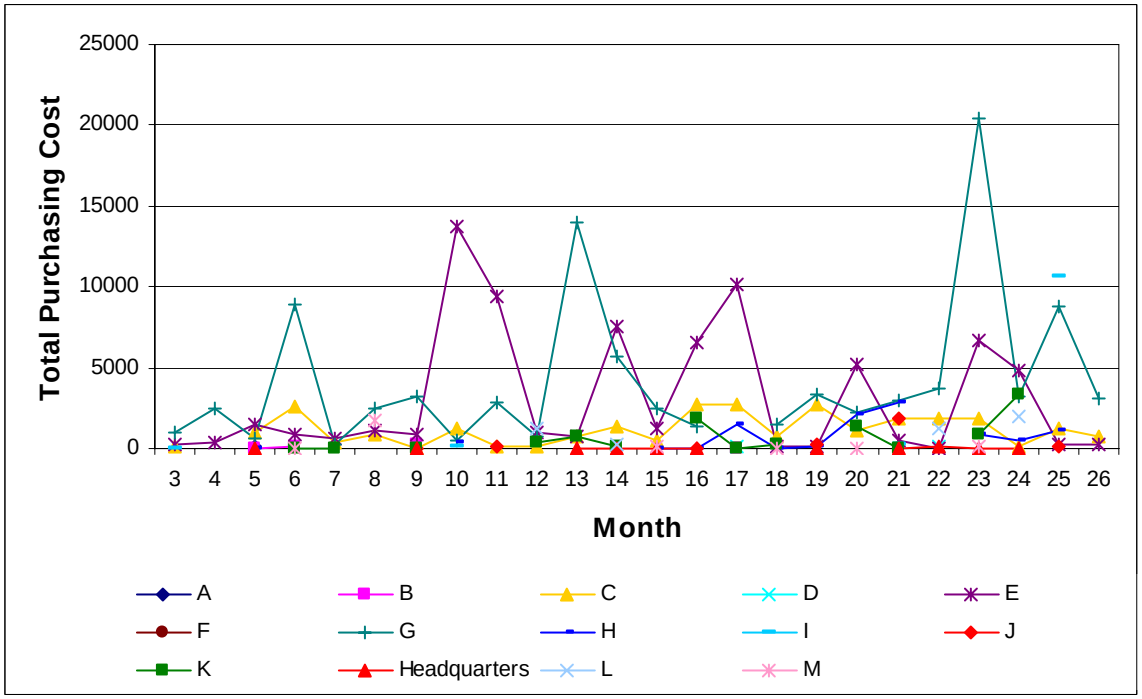

Figure 44. Miscellaneous Items: Total Purchasing Cost

The total purchasing cost of Miscellaneous Items is presented in Figure 44. This figure shows that the higher total purchasing cost accrued at branch E and G. Branch C did not spend much on Miscellaneous Items, even thought it is the branch with higher number of Miscellaneous Items purchased. The unexpectedly lower purchasing cost at branch C could be due to buying fewer quantities of each item or due to the low cost of each item purchased or due to data errors.

Transfer of Items between Branches

Transferring items between branches was another important activity. There were 719 items, constituting a total worth of $ 4,241,135 to the cooperative, transferred in and out of the branches. "Transferred in" refers to a situation when a branch receives items from another branch. Conversely, "transferred out" refers to a situation when a branch sends items to another branch. Transferred activity could happen because a branch personnel requested inventory from another branch either in order to respond to or to avoid a stock out situation. Conversely, a branch manager with excess inventory of a particular product might request that it be transferred to another branch to free warehouse space or to eliminate spoilage. Transferring items among branches may also be a result of the cooperative centralizing or partially centralizing warehousing of certain items.

Figure 45 shows the number of items transferred both in and out of the branches for each group of items. Feed items have the largest total number of items transferred and the number of Feed items transferred did not vary significantly. Conversely, the number of Herbicide/Insecticide items transferred significantly declined during the first seven months of the study, but increased and tended to vary insignificantly afterward. Other

than items in Equipment and Parts, which increase greatly in a particular month, the number of items transferred from other groups, excluding Herbicide/Insecticide, did not vary significantly.

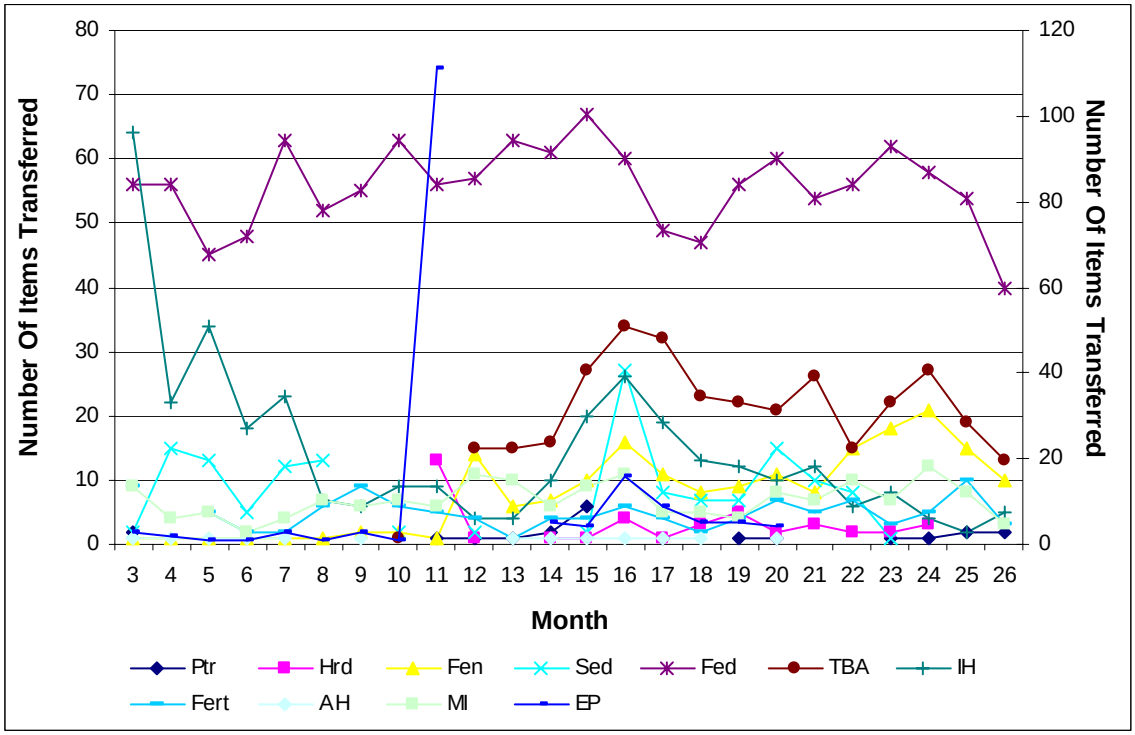

Figure 45. The Number of Items Transferred In and Out of the Branches By Group of Product

The detail on transfer activity both in and out for each group will be presented in this section.

Petroleum (Ptr)

The transfer activity of Petroleum items between branches involved nine branches transferring ten items to 11 branches. The highest transferring activity of Petroleum items occurred in the March 2005 (Month 15). Figures 46 and 47 display the number of Petroleum items transferred into and out of each branch every month.

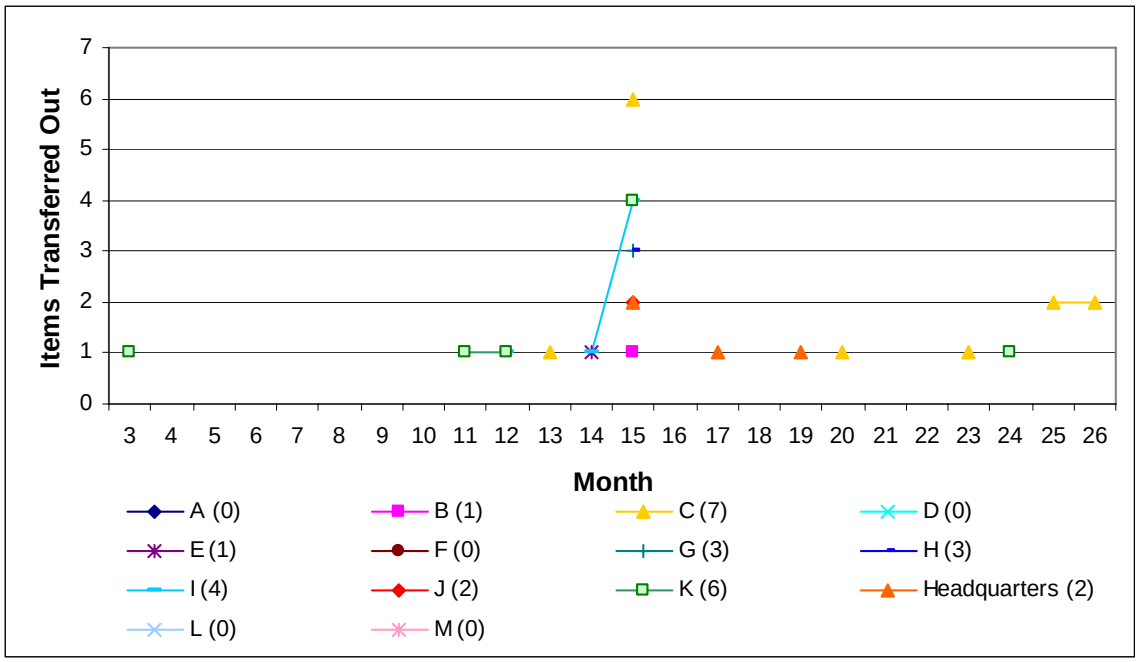

Figure 46. Petroleum: Monthly Transferred Out Items

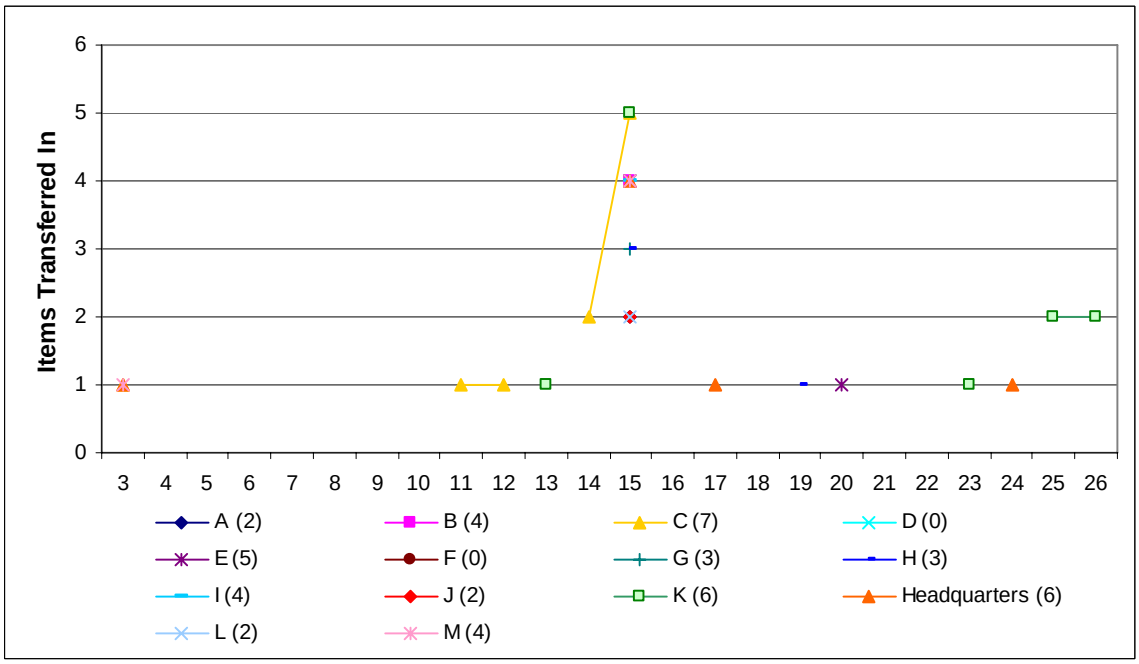

Figure 47. Petroleum: Monthly Transferred In Items

Hardware (Hrd)

Transfer activity of Hardware items did not start until December 2004. There were 13 items transferred from eight branches into 11 branches. Headquarters transferred Hardware items frequently, whereas branches K, D, and L most often received Hardware items from other branches. Figures 48 and 49 display the number of Petroleum items transferred into and out of each branch.

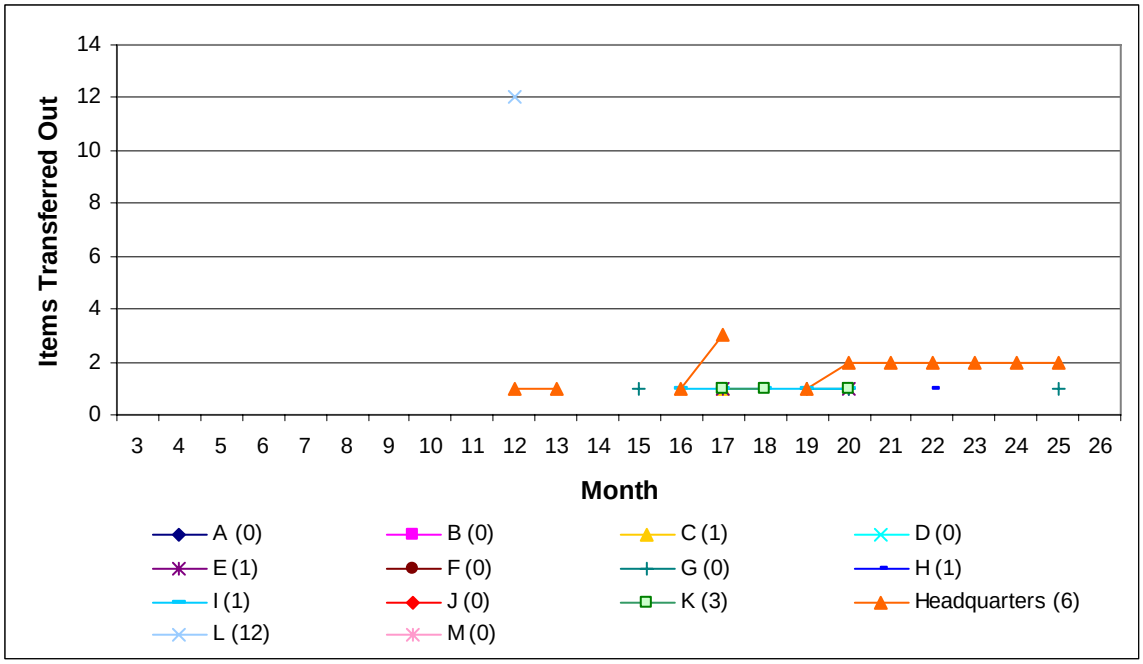

Figure 48. Hardware: Monthly Transferred Out Items

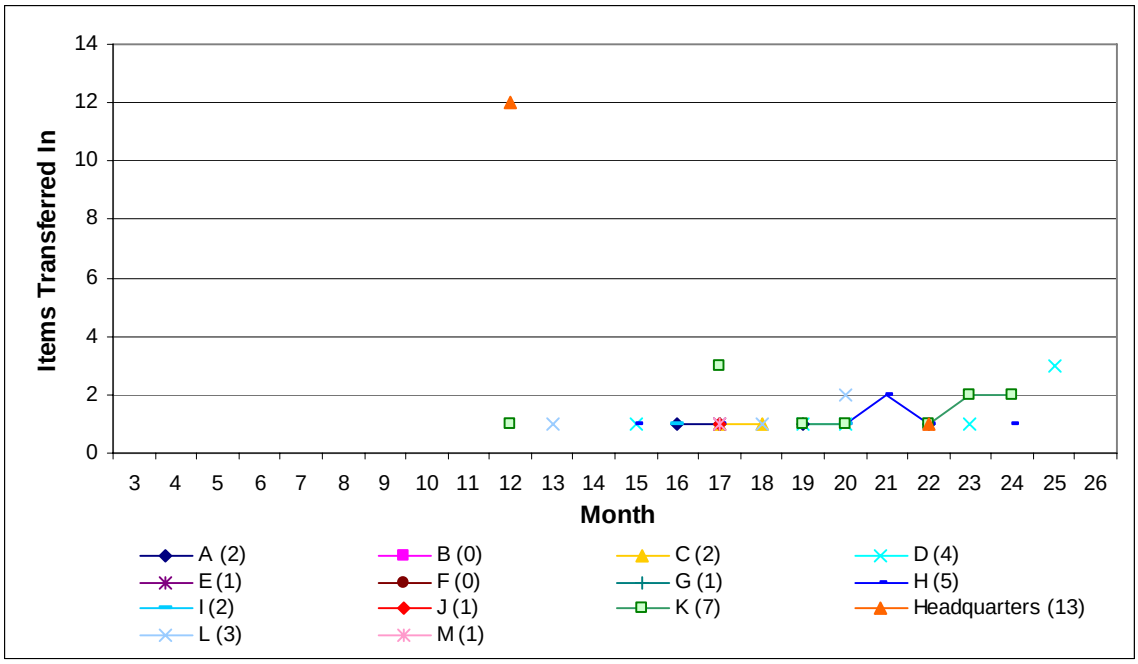

Figure 49. Hardware: Monthly Transferred In Items

Fence(Fen)

Figures 50 and 51 display the number of Fence items that transferred into and out of the branches. The total number of items involved in this transferring activity was 40. Similar to the transferring activity of Hardware items, the transferring activity of Fence items involved only a few branches and items for the first eight months of the period of data collection. The number of items transferred, either into or out of the branches, increased hereafter starting from December 2004 (Month 12). Unlike the transferring of items for Petroleum items and Hardware items, all branches were involved in transferring Fence items both into and out of their branches. The number of items transferred into and out of each branch varies as shown in Figures 50 and 51. Branches K, H, and D received a larger number of items into their inventory than other branches received,

whereas Headquarters and branch G transferred larger numbers of Fence items out of their inventory.

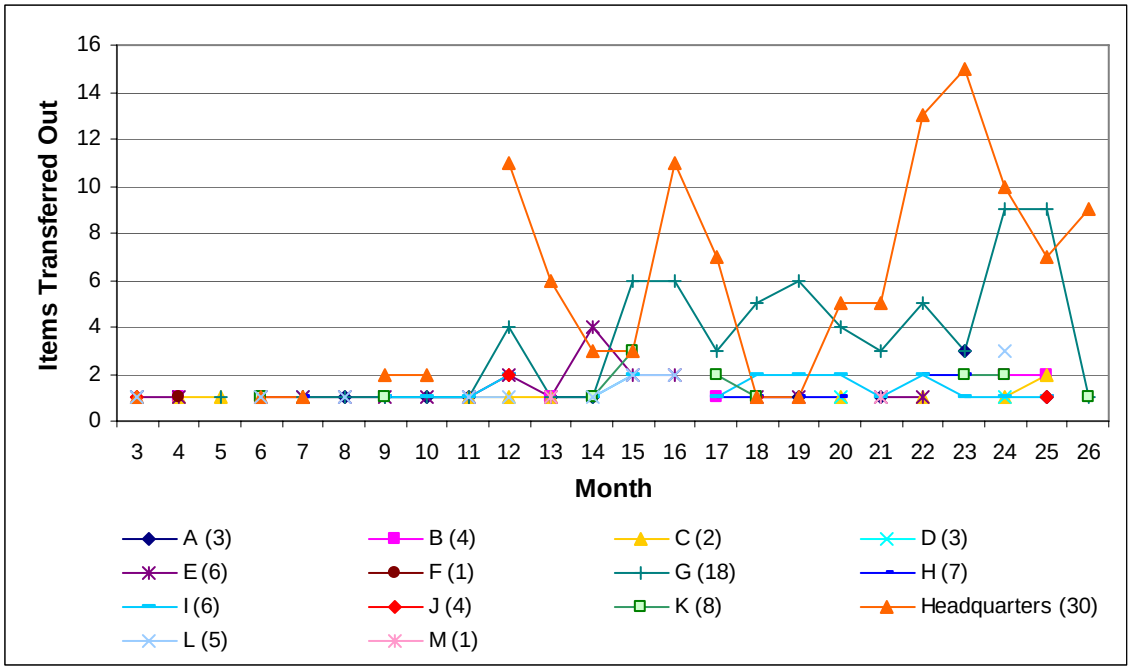

Figure 50. Fence: Monthly Transferred Out Items

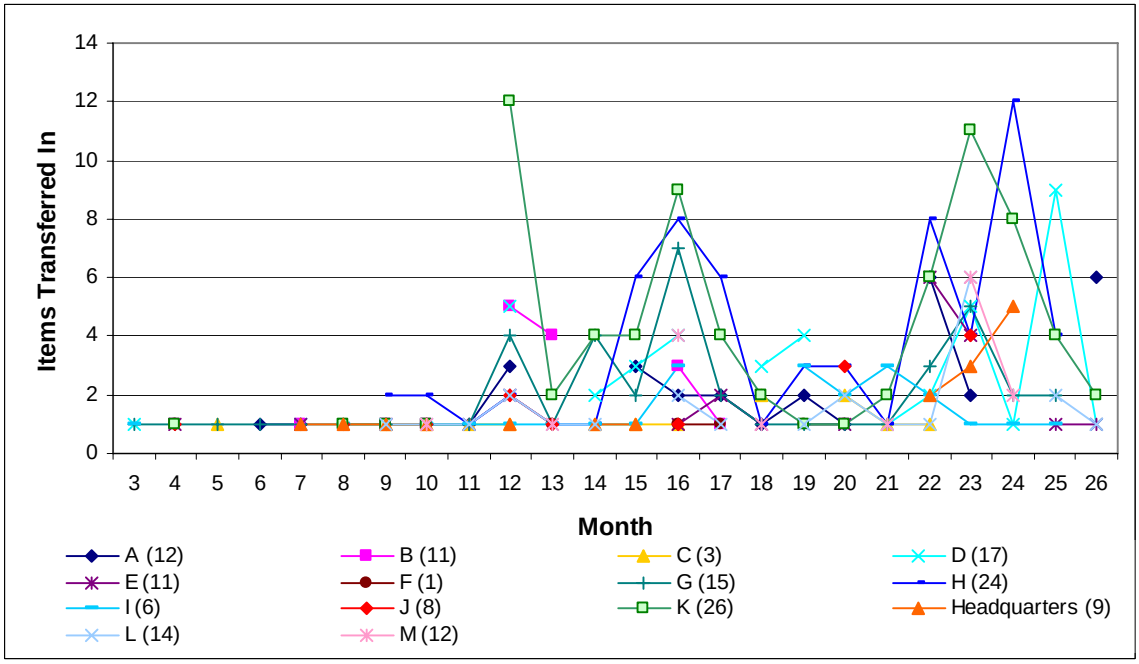

Figure 51. Fence: Monthly Transferred In Items

Feed (Fed)

Figures 52 and 53 display the number of Feed items that transferred in and out of each branch. Similar to the transfer of Fence items, all of the branches were involved in either the transferring in or out of their branches for 213 Feed items. However, unlike the transferring activity of Fence items, which for most of the branches did not occur in a continuous pattern, the transfer activity of items in Feed items at almost all of the branches was done in a continuous pattern. The number of items transferred varies between the branches. Branches C, H, K, D, and Headquarters received more items into their inventory as compared to other branches; branches E and G transferred more items out of their inventory as compared to other branches.

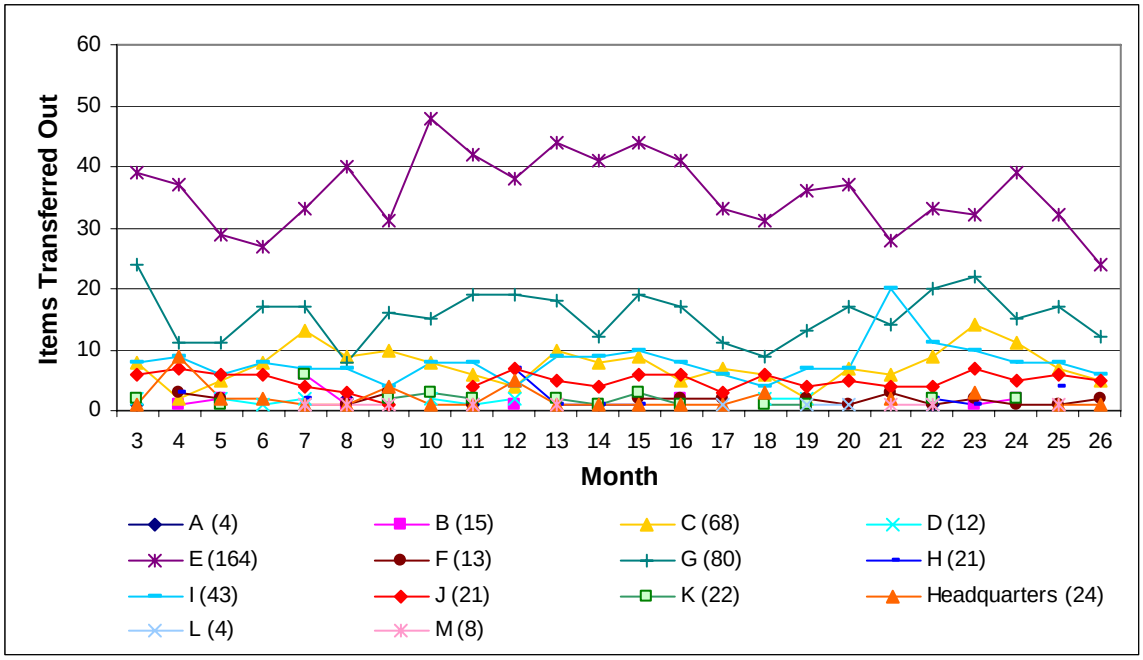

Figure 52. Feed: Monthly Transferred Out Items

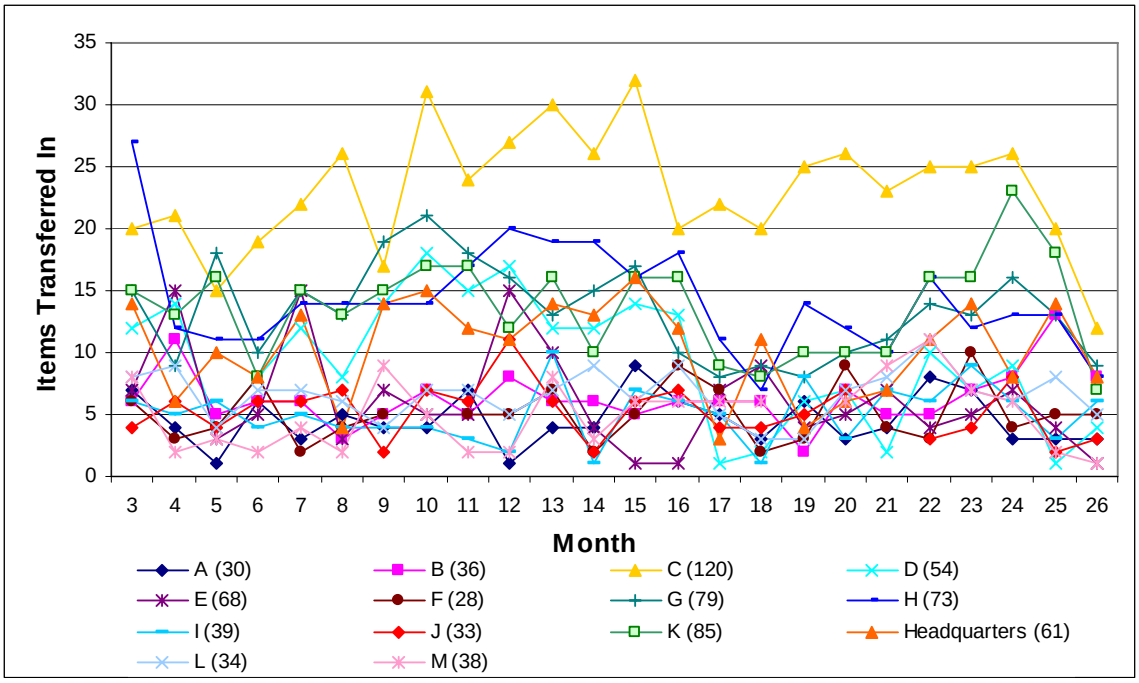

Figure 53. Feed: Monthly Transferred In Items

Seed (Sed)

The number of Seed items transferred into and out of each branch during the time frame of this study is displayed in Figures 54 and 55. Unlike Fences and Feed items, not all of the branches were involved in Seed items transfer activity. Ten branches transferred 62 items into 13 branches. Transfer was concentrated between the months of March 2004 (Month 3) and August 2004 (Month 8), and between March 2004 (Month 3) in the first year and October 2005 (Month 22) in the second year.

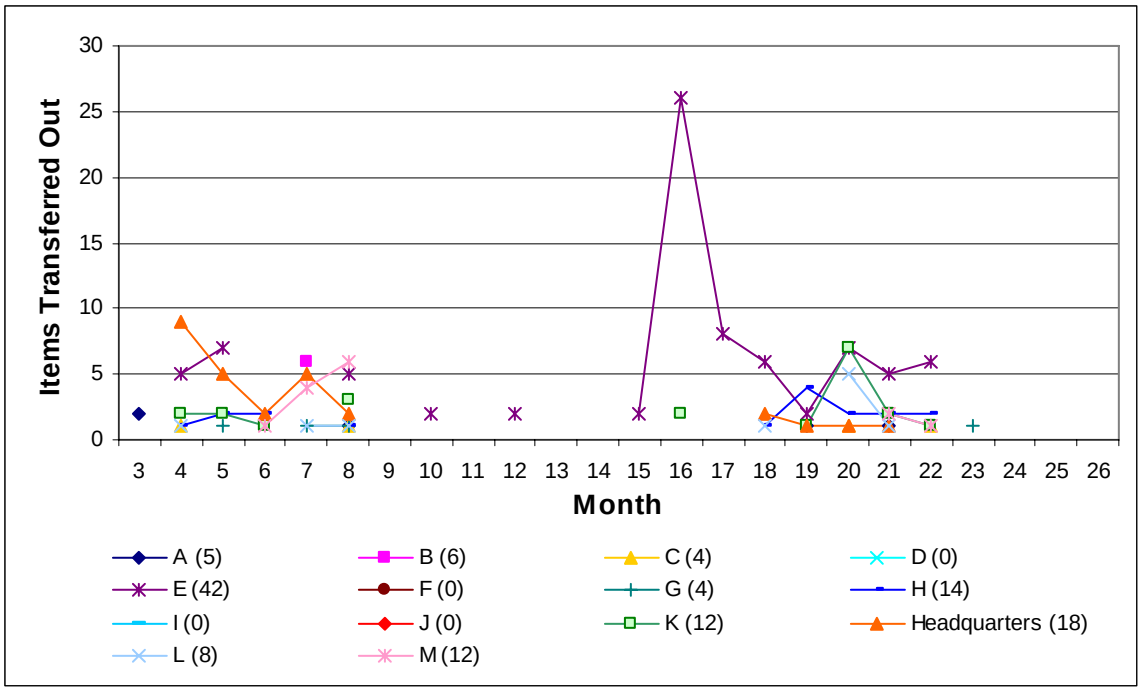

Figure 54. Seed: Monthly Transferred Out Items

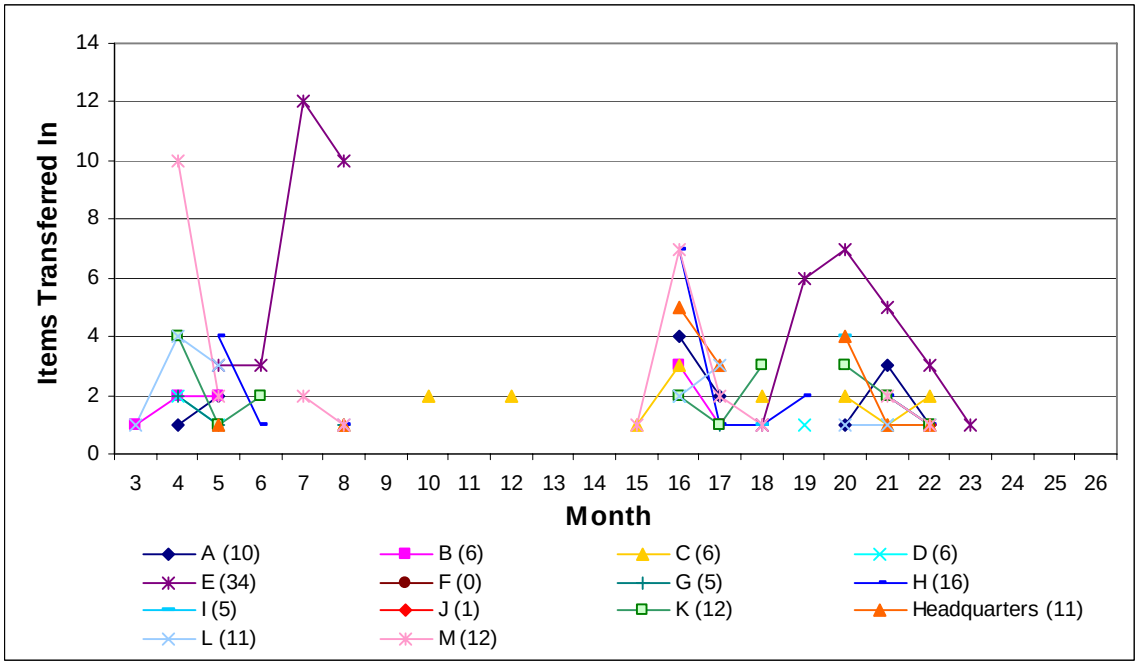

Figure 55. Seed: Monthly Transferred In Items

Tires/Batteries/Auto (TBA)

Figures 56 and 57 show the number of Tires/Batteries/Auto items that were transferred in and out of the branches. Similar to the transferring activity of Hardware items, almost all Tires/Batteries/Auto items were transferred among the branches after November 2004 (Month 11). There were 80 items transferred in and out of 13 branches. Headquarters, branches I, and E transferred out Tires/Batteries/Auto items to other branches. The number of Tires/Batteries/Auto items transferred into the branches varies each month.

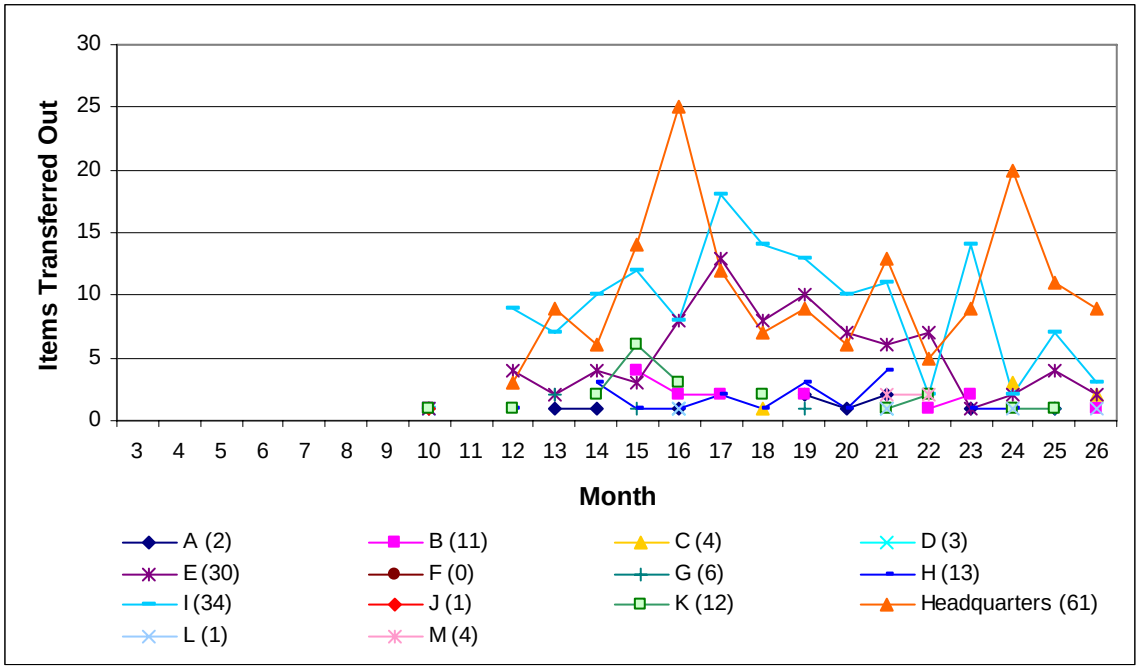

Figure 56. Tires/Batteries/Auto: Monthly Transferred Out Items

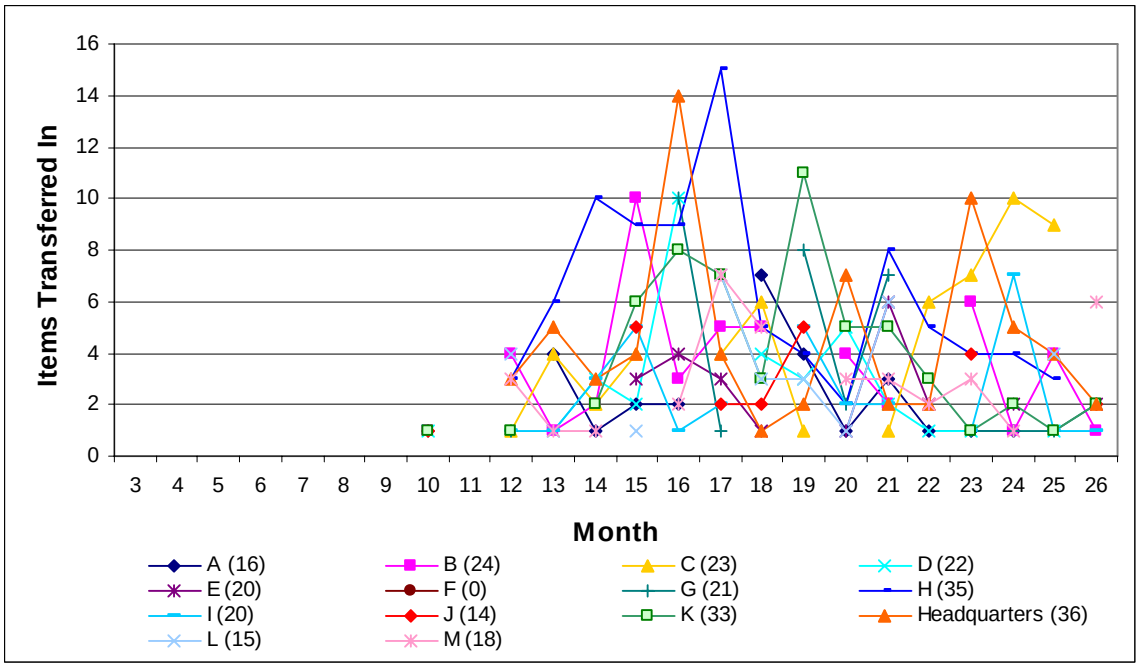

Figure 57. Tires/Batteries/Auto: Transferred In Items

Insecticide/Herbicide (IH)

Thirteen branches were involved in transferring 103 Insecticide/Herbicide items into 14 branches. Figures 58 and 59 display the number of Insecticide/Herbicide items transferred monthly from and into the branches during the 24 periods of data collection. In general, the Headquarters and branch K are two branches that were actively transferring large numbers of items in this group both in and out of their inventory.

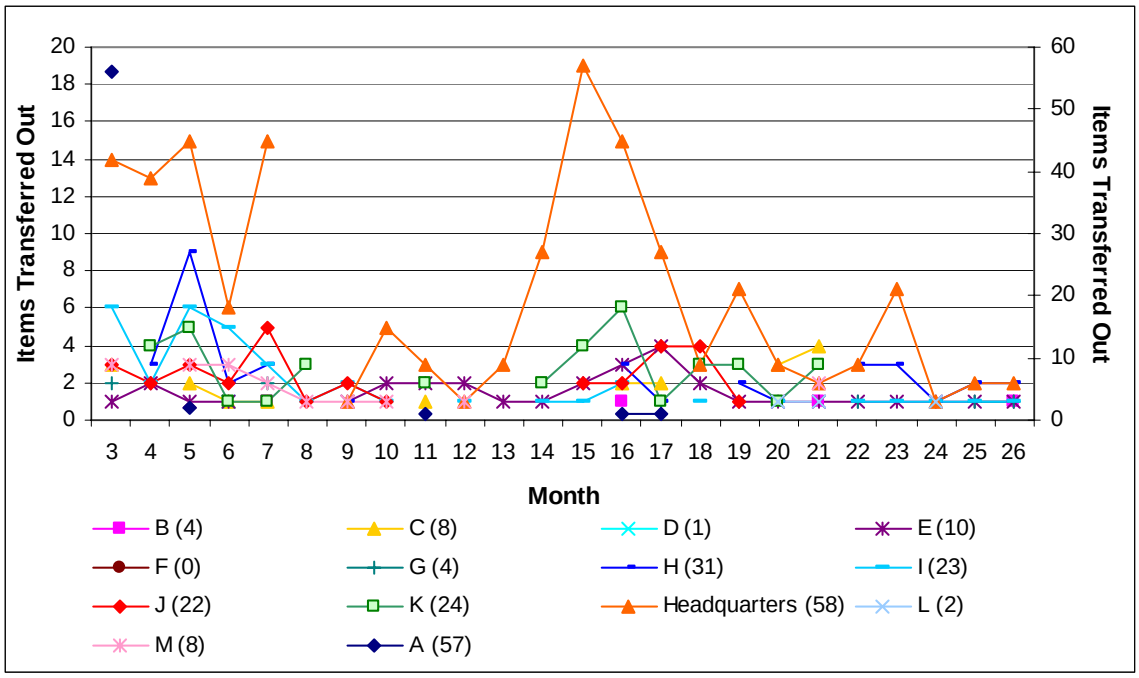

Figure 58. Insecticide/Herbicide: Monthly Transferred Out Items

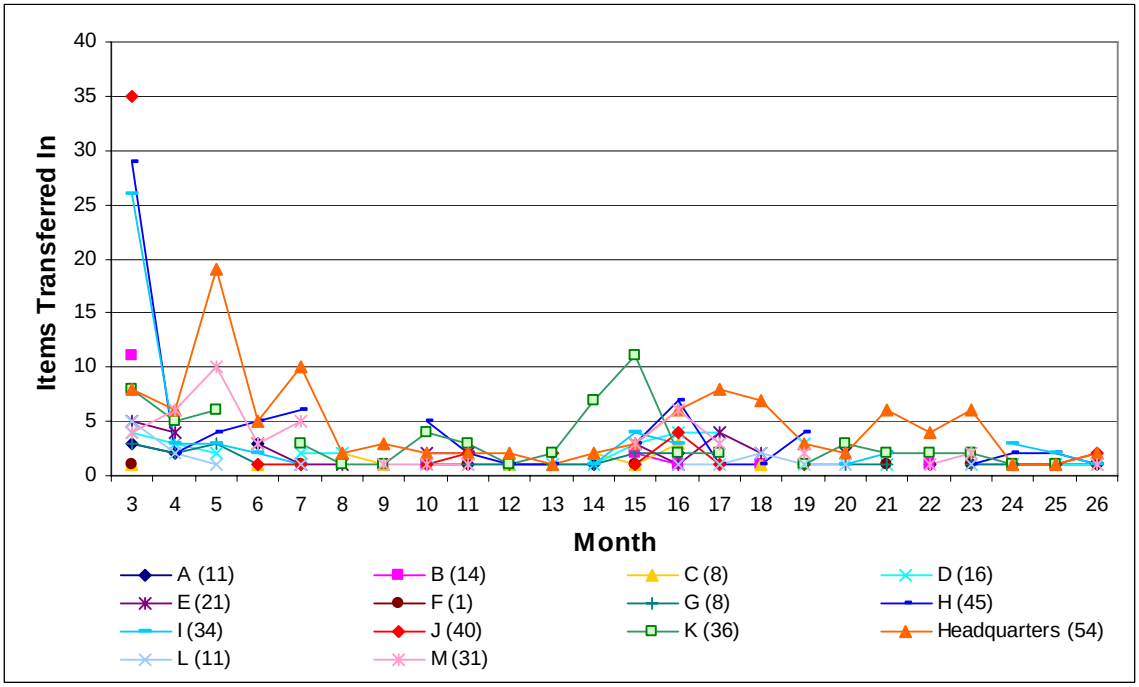

Figure 59. Insecticide/Herbicide: Monthly Transferred In Items

Equipment and Parts (EP)

Figures 60 and 61 display the number of EP items transferred monthly in and out of the branches. There were eight branches involved in transferring 135 items into 13 branches. Except for the December 2004, where the EP items transferred numbered more than 100 items, the EP items transferred at each branch were generally less than 10 items per month. Moreover, with the exception of the transfer activity on December 2004 of this study, the transfer activity in the two years of data was concentrated in the months of March through October.

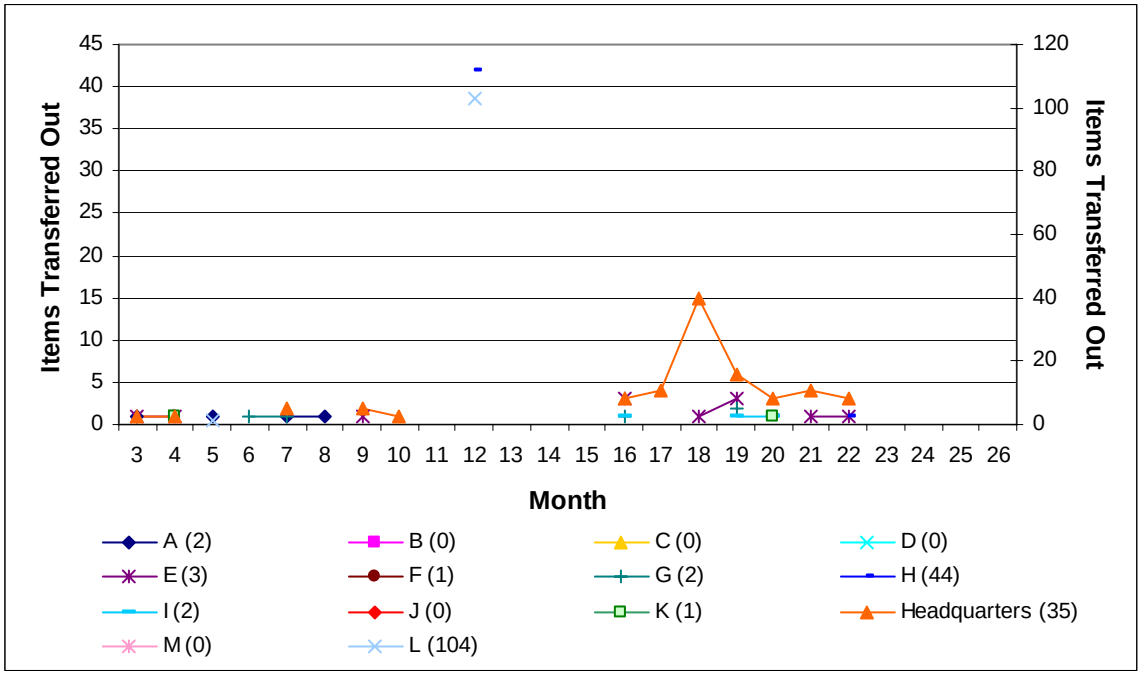

Figure 60. Equipment/Part: Monthly Transferred Out Items

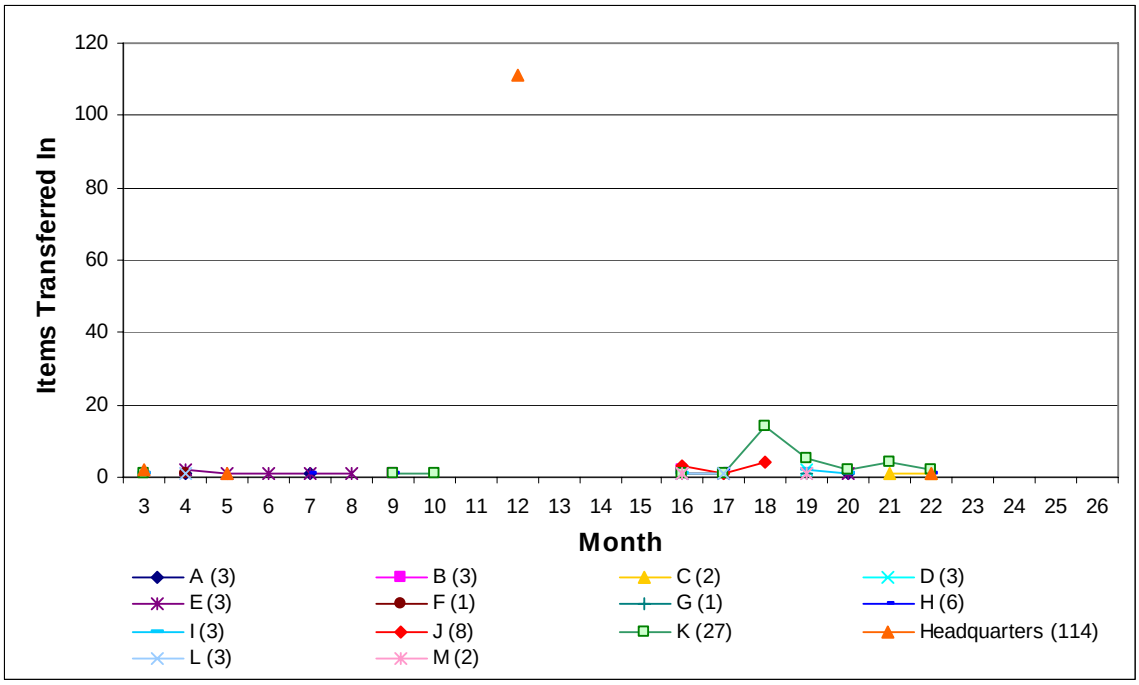

Figure 61. Equipment/Part: Monthly Transferred In Items

Fertilizer (Frt)

Figures 62 and 63 show the number of Fertilizer items transferred monthly in and out of the branches. All of the branches in this cooperative were involved in transferring 20 Fertilizer items. Headquarters transferred the most Fertilizer items in and out. Although there were 20 Fertilizer items transferred among the branches, the average number of items transferred in each branch, excluding the Headquarters, was three.

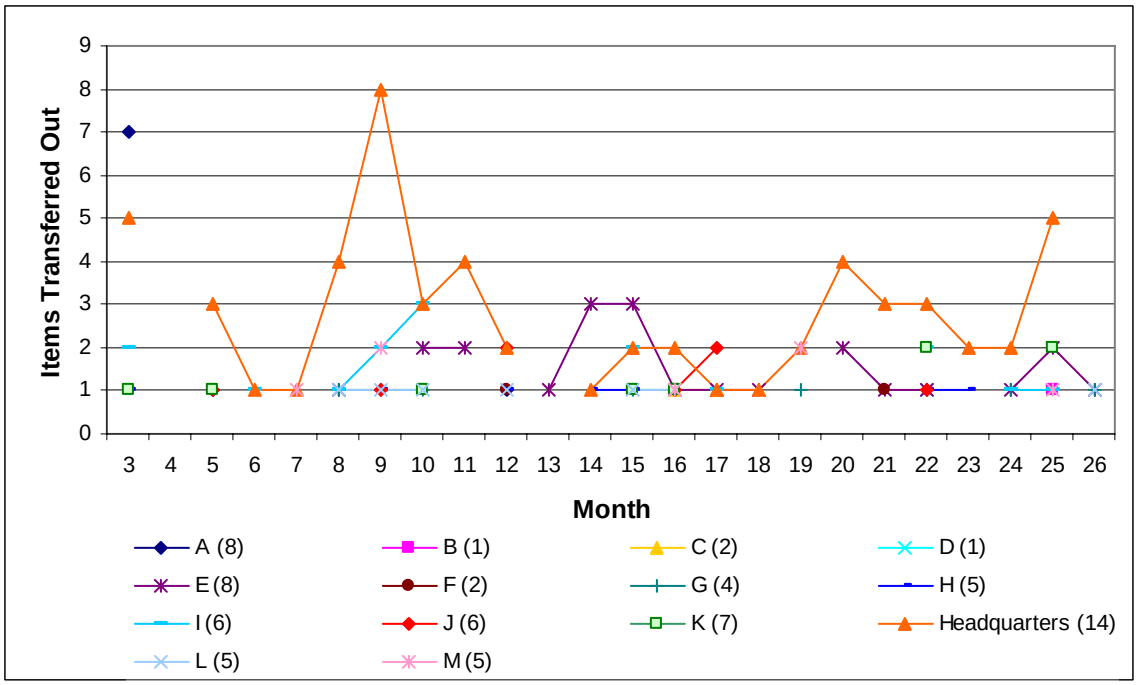

Figure 62. Fertilizer: Monthly Transferred Out Items

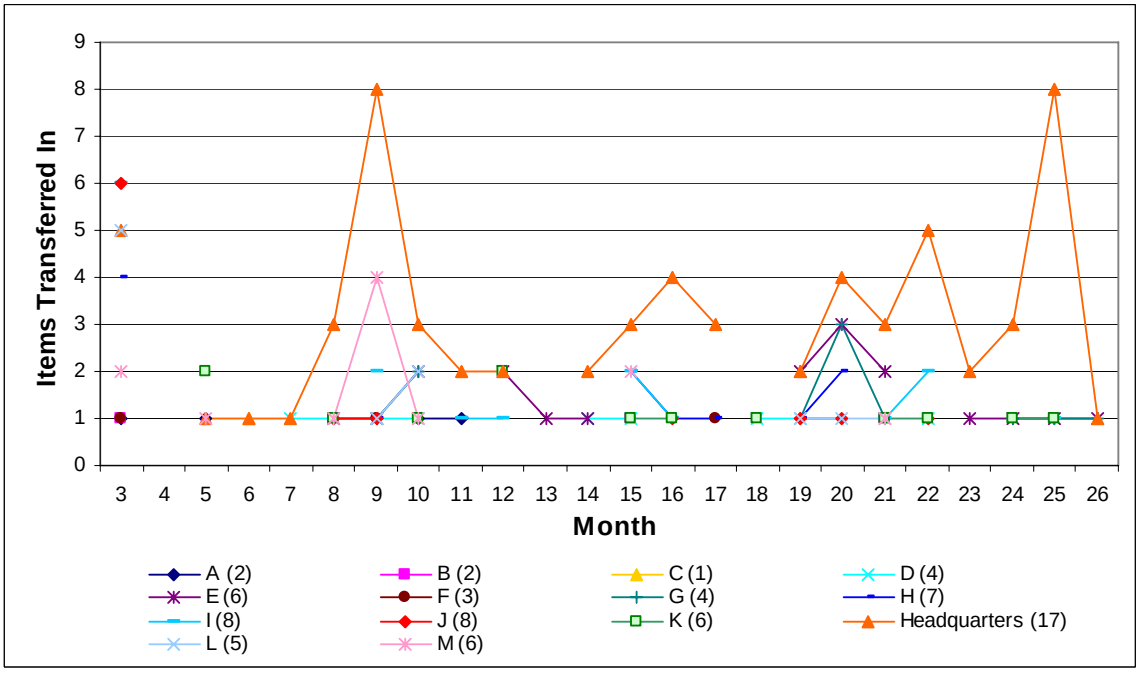

Figure 63. Fertilizer: Monthly Transferred In Items

Animal Health (AH)

As shown in Figures 64 and 65, the number of AH items that were transferred between branches was one. There were six branches involved in transferring out two items in Animal Health into 12 branches. Transfer activity occurred mainly during the months of March (Month 3 and Month 15) through August (Month 8 and Month 20).

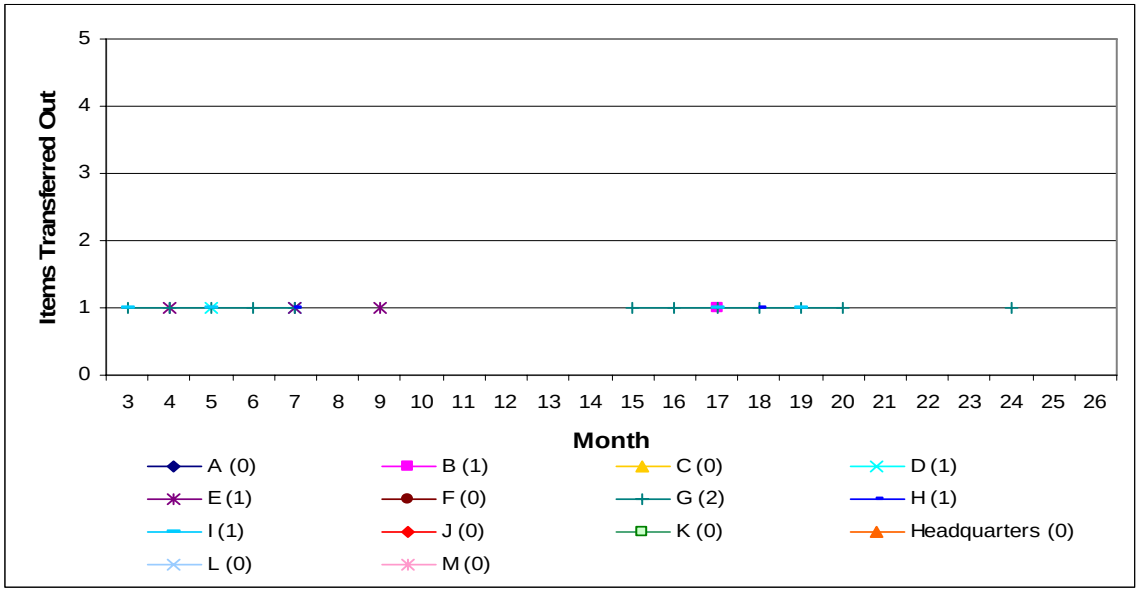

Figure 64. Animal Health: Monthly Transferred Out Items

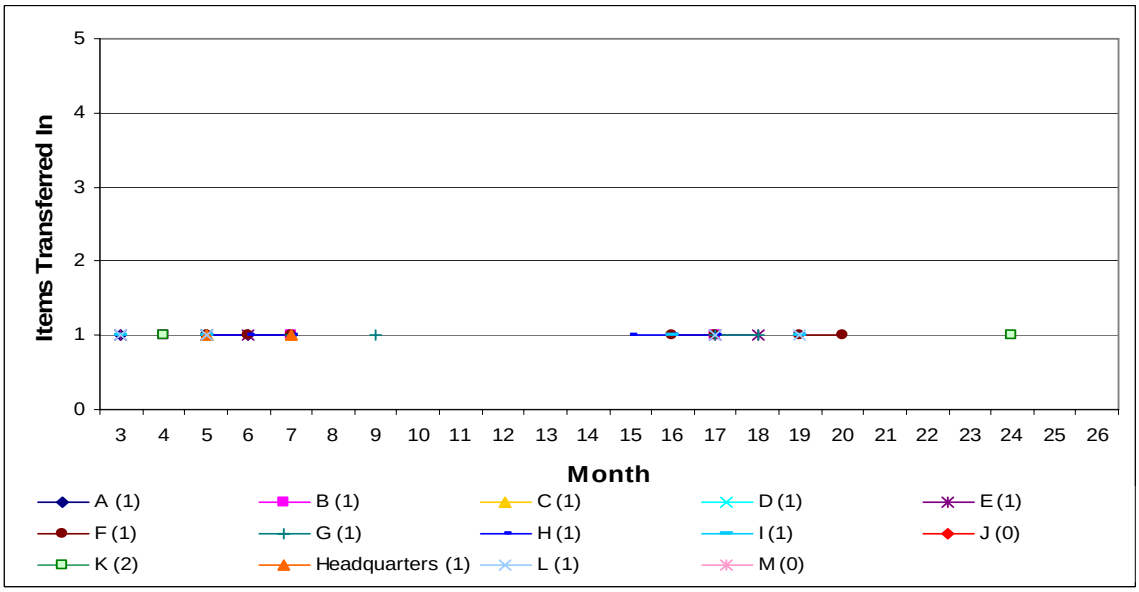

Figure 65. Animal Health: Monthly Transferred In Items

Miscellaneous Items (MI)

Figures 66 and 67 display the number of MI items traded monthly in and out of the inventory of each branch. Branches G, H, and K received larger numbers of MI items, while branches E, C, and G transferred larger numbers of MI items out of their inventory. There were 13 branches involved in transferring 38 items out of their inventory into 14 branches.

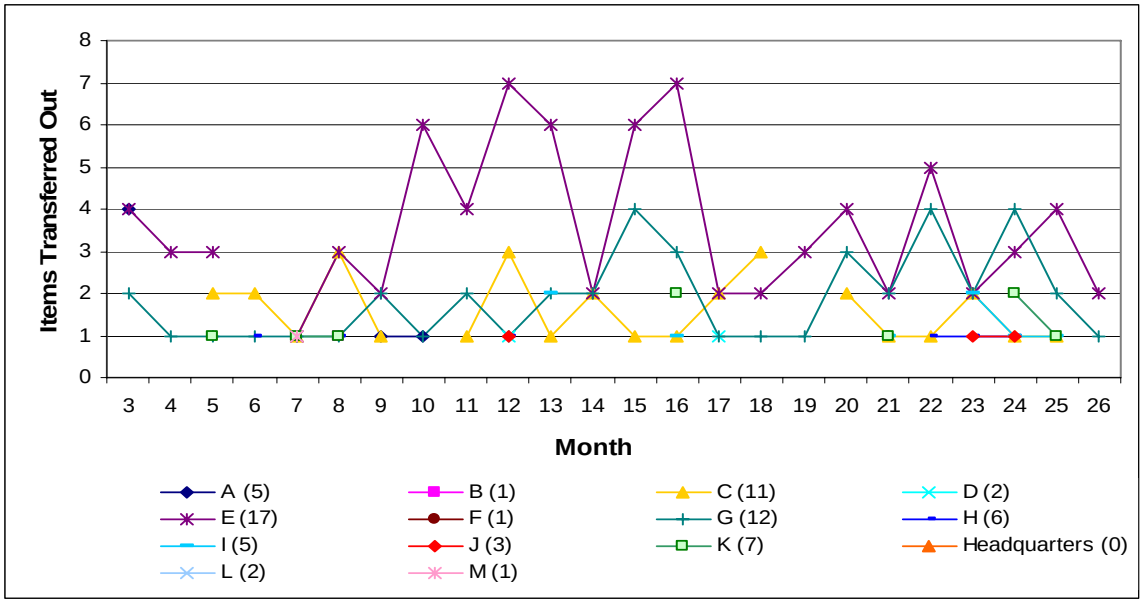

Figure 66. Miscellaneous Items: Monthly Transferred Out Items

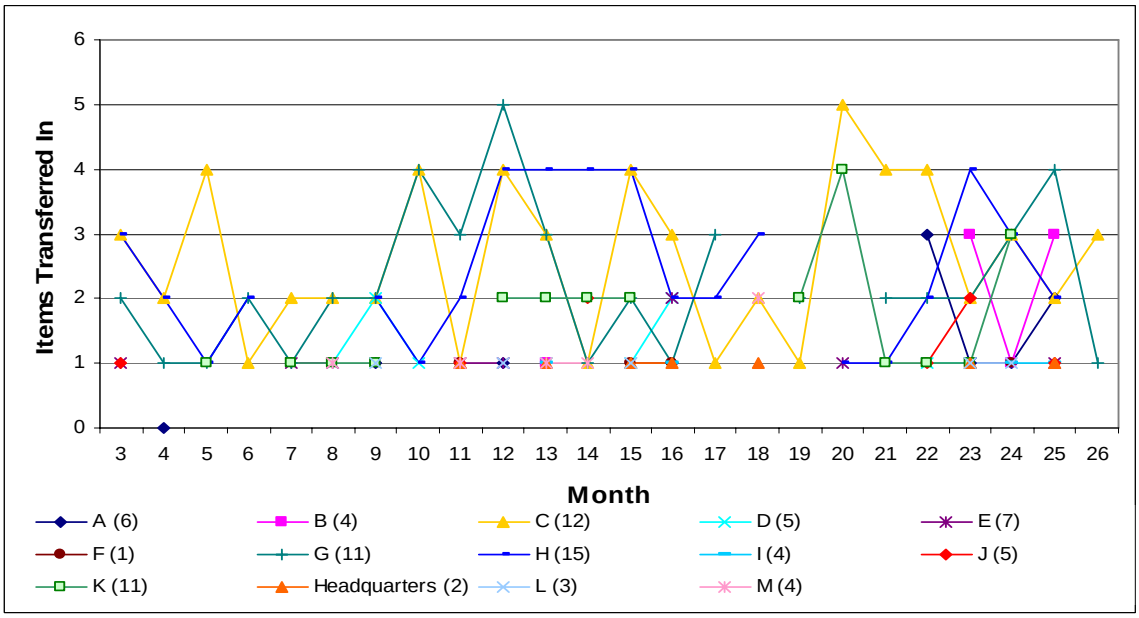

Figure 67. Miscellaneous Items: Monthly Transferred In Items

Inventory Holding Cost

Inventory is costly. Two main costs related with inventory cost are inventory holding costs and inventory ordering costs. Inventory holding cost (also known as carrying cost or inventory maintenance cost) in general is accumulated through four components: capital costs, space costs, inventory risk costs and the inventory service costs. Inventory ordering costs included the costs to place an order (such as cost of order forms, postage, and telephone calls) as well as the wage of employee who is responsible for this work. While both costs are important to study, this section is devoted to discuss exclusively the inventory holding cost of groups of items.

As a general rule of thumb, inventory holding cost consists of 20 percent of the inventory cost value per year. However, for bulky products such as petroleum and fertilizer, the rule of thumb for inventory holding cost is ten percent. Table 11 presents the holding costs as a percentage of gross margin in both year while Figure 68 displays total inventory holding costs for 11 groups of item in this cooperative.

Table 11. Gross margin and Inventory Costs

	Year 1	Year 2
Gross Margin	$ 1,068,855	$ 1,922,435
Average Inventory	$ 3,556,039	$ 7,189,268
Holding Costs	$ 3,614,668	$ 5,232,343
Holding cost as a percentage of gross margin	338 %	272%

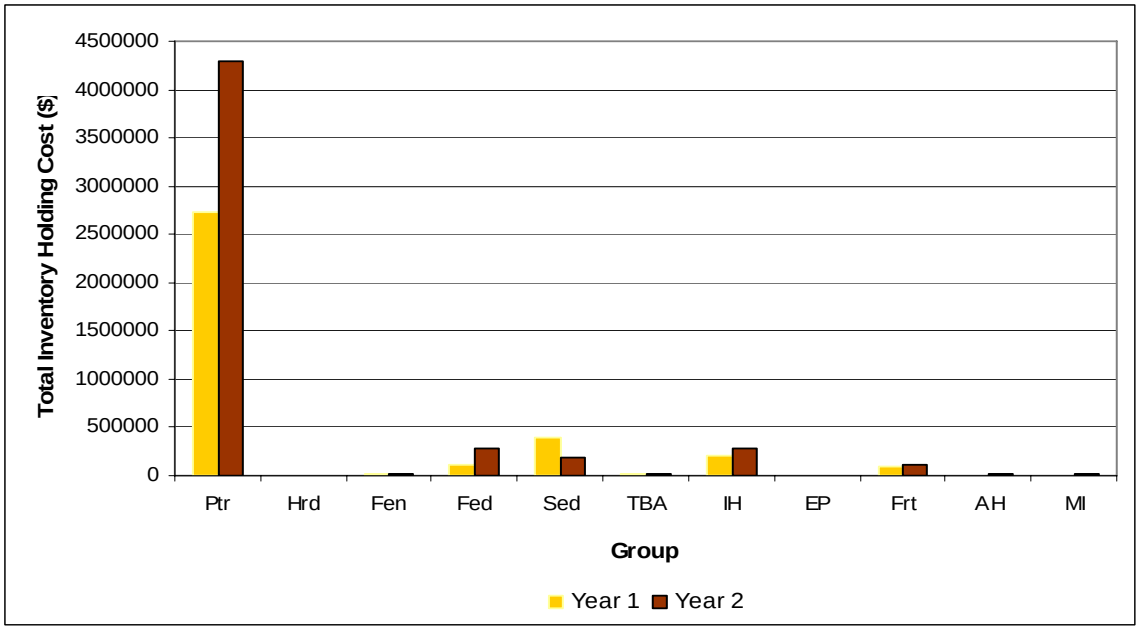

Figure 68. Total Inventory Holding Cost by Group of Items

As expected, the total inventory holding cost varies across the group of items as well as within the group of items. This variation is demonstrated by the standard deviations (Table 12) calculated for each group. The standard deviations of items in Hardware, Tires/Batteries/Auto, and EP groups implies that the inventory holding cost of items in these groups did not vary considerably. Conversely, the standard deviation of items in Petroleum, Feed, Seed, and Fertilizer groups shows that there was a significant difference in total holding inventory cost among items in these groups. However, further investigation on items with highest inventory holding cost in each group of items clarified that these few items contributed greatly to the variation of the inventory holding costs inventory within items in each group. Eliminating items with highest inventory holding cost from all group of items (Table 13) proved to significantly decrease the standard deviation of each group of items.

Table 12. Statistics of Total Inventory Holding Cost by Group of Items

Group	Year	Average	Total	Standard0 Deviation	Maximum	Item
Ptr	1	136,800	2,736,007	608,557	2,722,269	GASOLINE
Ptr	2	214,199	4,283,988	948,654	4,244,527	GASOLINE
Hrd	1	8	1,196	43	408	BALER TWINE 140
Hrd	2	16	2,336	83	715	7 X 8 WOOD CREO POSTS
Fen	1	223	15,147	433	2,631	6' T-POSTS
Fen	2	232	15,802	404	1,806	6' T-POSTS
Fed	1	381	120,876	1,795	26,535	GRASS-NATIVE-FORB MIX
Fed	2	878	278,459	9,616	170,186	GRASS-NATIVE-FORB MIX
Sed	1	4,503	396,296	31,125	289,635	MISCELLANEOUS SEED SALES
Sed	2	2,147	188,956	12,182	112,060	MISCELLANEOUS SEED SALES
TBA	1	99	18,918	307	3,080	NAVIGUARD 55GAL
TBA	2	103	19,750	250	2,063	NAVIGUARD 55GAL
IH	1	1,401	204,525	3,712	29,522	WHOLESALE CHEMICALS
IH	2	1,990	290,537	5,576	43,899	WHOLESALE CHEMICALS
EP	1	17	6,195	119	2,094	BALER WIRE CFI
EP	2	17	6,306	91	1,004	NET WRAP 64"
Frt	1	1,951	101,475	5,333	25,116	46-0-0
Frt	2	2,324	120,846	7,003	38,984	82-0-0
AH	1	378	5,673	638	1,977	VITAMIN A D E
AH	2	762	11,433	1,926	7,572	VITAMIN A D E
MI	1	82	8,360	201	1,243	WHEAT CLEANINGS
MI	2	137	13,930	387	2,746	WHEAT CLEANINGS

With the exclusion of Seed items, all groups experienced an increase in total inventory holding cost from the first year to the second year. The increase in total inventory holding cost from the first to the second year ranges from 4-100 percent. Animal Health (AH) items experienced the highest percentage increase in total holding cost among other groups of items. This increase in inventory holding cost was due to the lower sales on a particular Animal Health item, VITAMIN A D E, which has the highest inventory holding cost among other items in this group. Therefore, eliminating this item from the calculation of total inventory holding cost resulted in only a four percent increasing in total inventory holding cost of Animal Health group. This phenomenon occurred in the majority of groups of items. Table 13 presents the change in the average inventory holding cost, the total inventory holding cost, as well as the standard deviations of each group as the results of removing items with highest inventory holding costs.

Table 13. Statistics of Total Inventory Holding Cost by Group of Items Excluding Outliers with Excessively High Holding Costs

Group	Year	Average	Total	Maximum	Standard Deviation
Ptr	1	723	13,738	4,408	1,252
Ptr	2	2,077	39,461	21,199	5,180
Hrd	1	4	525	168	18
Hrd	2	7	1,051	353	37
Fen	1	187	12,516	1,648	319
Fen	2	209	3,996	1,645	357
Fed	1	299	94,341	12,535	1,026
Fed	2	343	108,273	13,188	1,214
Sed	1	1,226	106,660	29,598	4,880
Sed	2	884	76,896	17,723	2,833
TBA	1	83	15,838	1,858	217
TBA	2	93	17,687	1,788	206
IH	1	1,207	175,004	16,904	2,888
IH	2	1,701	246,638	33,280	4,362
EP	1	9	3,523	630	41
EP	2	12	4,486	816	63
Frt	1	1,064	53,206	18,017	2,945
Frt	2	1,079	53,960	16,269	2,946
AH	1	264	3,696	1,652	477
AH	2	276	3,860	1,105	417
MI	1	70	7,117	857	165
MI	2	111	11,184	2,158	288

Petroleum items had the highest average inventory holding cost as well as the highest total inventory holding cost among all groups of items. Nonetheless, as with the standard deviations, the large portion of the average and total inventory holding cost was accrued by only a few items for a majority of groups of items. Therefore, there was a significant reduction, as shown Figure 69, in both average inventory holding cost and total inventory holding cost when these items were excluded from the calculations. In fact, eliminating gasoline from the calculation resulted in Petroleum no longer being the group with the highest total inventory holding cost.

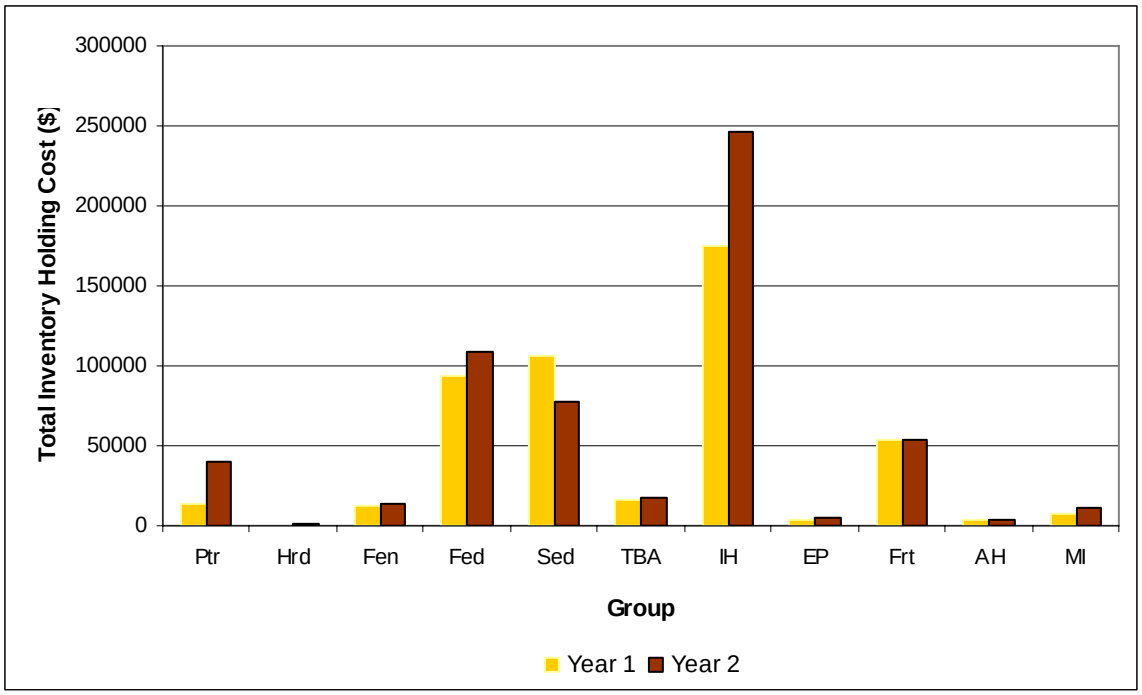

Figure 69. Total Inventory Holding Cost By Group of Items Excluding Items With Maximum Costs

Table 14 represents the percentage of holding costs to gross margin. The holding costs in this Table are the holding costs after eliminating items with excessive holding costs. Petroleum, Fertilizer and Miscellaneous Items were groups with relatively small percentage of holding costs to the gross margin. Hardware, Seed, Insecticide/Herbicide, and Animal Health had a negative percentage either in one year or both years.

Table 14. Holding Costs as a Percentage of Gross Margin

Group	Year	Gross Margin ($)	Holding Cost ($)	Percentage (%)
Ptr	1	352,443	13,738	3.90
Ptr	2	752,814	39,461	5.24
Hrd	1	(552)	525	-95.06
Hrd	2	7,095	1,051	14.81
Fen	1	11,915	12,516	105.04
Fen	2	32,285	3,996	12.38
Fed	1	118,699	94,341	79.48
Fed	2	83,935	108,273	129.00
Sed	1	27,188	106,660	392.30
Sed	2	(273,374)	76,896	-28.13
TBA	1	19,004	15,838	83.34
TBA	2	57,883	17,687	30.56
IH	1	152,721	175,004	114.59
IH	2	143,718	246,638	171.61
EP	1	6,567	3,523	53.65
EP	2	23,129	4,486	19.40
Frt	1	1,410,650	53,206	3.77
Frt	2	1,255,601	53,960	4.30
AH	1	(3,054)	3,696	-121.02
AH	2	(6,020)	3,860	-64.12
MI	1	341,023	7,117	2.09
MI	2	390,447	11,184	2.86

Inventory Performance

The performance of the inventory management system of this cooperative during the time frame of this study is discussed in this section. Two common measurements for inventory performance, the inventory turnover ratio (ITR), and the inventory management index (IMI) are used.

Considering the large number of items and branches involved in this inventory system, the discussion of the inventory performance of this cooperative will focus on the performance of each group of items. Therefore, the discussion on the performance of the

inventory system of this cooperative with regard to either the ITR or to the IMI is conducted per group of items.

Inventory Turnover Ratio (ITR)

Eliminating items with extremely high or low ITR for better information on the average ITR of the cooperative and recalculating the ITR resulted in the average ITR of 3.58. This average is lower than the average ITR for farm supply cooperatives in the US. Therefore, it indicates the need of this cooperative to improve their inventory performance. Table 15 presents average ITR of each group of items with the exclusion of items with extreme high or low ITR. The rest of this section discusses the details of ITR of each group of items. The discussion on the ITR is conducted for the ITR with the elimination of items with extreme high or low.

Table 15. Average ITR by Group

Group	Average ITR
Ptr	9.44
Hrd	0.83
Fen	1.85
Fed	4.05
Sed	0.96
TBA	1.23
IH	4.69
EP	0.76
Frt	13.29
AH	2.54
MI	1.28

The discussion on the ITR is conducted for each group of items.

Petroleum (Ptr)

The average ITR of Petroleum for the entire cooperative throughout the time frame of this study was 9.44, whereas the ITR guidelines for products commonly carried by farm supply cooperatives indicate the average ITR for petroleum items is 7-10. As for the branches, the average ITR o f Petroleum items ranges from 0.31 to 22.53. The statistics of the ITR of Petroleum items at each branch is presented in Table 16. Branches A, B, C, J, L and M had lower turnovers on Petroleum items than the industry average. The rest of the branches had higher turnover than the average. The high inventory turnover generally serves as an indication of efficient inventory management. The case study cooperative was located close to a wholesale delivery point for petroleum, therefore in this case the high turnover suggests that the cooperative took advantage of these logistics in minimizing petroleum inventories.

Furthermore, even though on average the ITR of this group of items is greater than the industry average, the minimum ITR of almost all branches shows the ITR of zero. The ITR of zero implies that all branches carried items that did not sell during the study period. Therefore, the improvement of inventory management systems for those items remains worthy of consideration. In addition, considering the lowest ITR of some branches the cooperative should reconsider offering petroleum products at some branches.

Table 16. Statistics of ITR of Petroleum Items by Branch

Branch	Average	Standard Deviation
A	1.02	0.82
B	0.31	0.61
C	2.78	4.23
D	20.52	23.81
E	7.22	16.03
G	11.36	18.20
H	15.65	43.00
I	11.47	21.36
J	3.85	3.18
K	8.98	30.34
Headquarters	22.53	73.29
L	1.14	0.70
M	4.45	6.53

Hardware (Hrd)

The average ITR of Hardware for the entire cooperative was 0.83, which is below the ITR guidelines for Hardware products (2-3). The average ITR of Hardware items, as shown in Table 17, shows that only two of the branches had higher average ITR than the ITR guidelines for Hardware items. For this reason, an improvement in the inventory management systems of items in this group is recommended.

Table 17. Statistics of ITR of Hardware Items by Branch

Branch	Average	Standard Deviation
A	1.06	1.33
B	0.89	1.26
C	1.19	2.05
D	1.47	2.53
E	1.28	1.81
G	0.60	0.76
H	3.84	6.67
I	0.31	0.36
J	0.77	0.90
K	2.09	4.28
Headquarters	0.62	0.86
L	0.20	1.03
M	1.52	2.14

Fence (Fen)

The average ITR of Fence for the entire cooperative throughout the time frame of this study was 1.85. There are no specific guidelines for the ITR of Fence items; however, the guidelines of miscellaneous items and also the overall ITR of farm supply cooperatives is 7-10. Assuming this range is appropriate for the Fence items in this cooperative, the overall performance for Fence items in this cooperative during the time frame of this study was below the standard. As for the branches (Table 18), only one branch's average ITR is within the standard, while the rest of the branches' average ITR are below the standard. This finding indicates the need for improvement in inventory management system of Fence items in this cooperative.

Table 18. Statistics of ITR of Fence Items by Branch

Branch	Average	Standard Deviation
A	1.17	2.21
B	0.48	0.84
C	0.46	0.70
D	1.08	1.36
E	0.97	1.38
F	0.64	0.91
G	0.98	1.69
H	8.42	55.00
I	0.48	0.78
J	1.02	1.86
K	1.38	1.75
Headquarters	0.72	1.31
L	0.44	0.86
M	3.57	13.31

Feed items (Feed)

The average ITR of Feed items in the entire cooperative was 4.05, whereas the ITR guideline for feed items is 10-12. The lower of ITR of Feed items in this cooperative

compared to the guideline ITR indicates the need of improvement in inventory management system of Feed items in the cooperative as a whole. The improvement is especially needed for branches with lowest ITR such as E and I. The ITR of these branches, which is slightly above zero, indicates the Feed items in these branches moved very slowly during this study time. Feed items appear to turnover relatively rapidly at Headquarters and branch L. Other branches, however, performed poorly. This indicates that the cooperative may want to reconsider stocking feed at all branch locations.

Table 19. Statistics of ITR of Feed Items by Branch

Branch	Average	Standard Deviation
A	2.66	5.24
B	2.76	4.79
C	2.45	6.21
D	3.51	7.20
E	0.62	1.86
F	2.97	6.99
G	2.87	8.22
H	6.01	42.19
I	0.70	2.09
J	3.74	8.60
K	3.57	11.10
Headquarters	19.49	193.12
L	10.49	40.48
M	3.45	13.48

Seed (Sed)

The average ITR of Seed in the entire cooperative was 0.96. As for Fence items, there are no specific guidelines for the ITR of Seed items. Therefore, the guideline of miscellaneous items, which is 7-10, is used to appraise the inventory performance of Seed items during the study time. Assuming this standard to be suitable for the Seed items in this cooperative, the overall performance of seed items was significantly below

the standard for this group. Furthermore, the minimum ITR of Seed items in all branches were zero indicating all branches carried items that did not sell during the time frame of this study. Therefore, the cooperative is recommended to pursue an improvement in inventory management system of Seed items and reconsider maintaining seed inventories at some branches.

Table 20. Statistics of ITR of Seed Items by Branch

Branch	Average	Standard Deviation
A	0.59	1.43
B	1.66	4.15
C	2.03	6.73
D	1.17	2.61
E	0.30	1.01
G	0.81	2.08
H	0.69	3.59
I	0.31	0.73
J	0.73	2.07
K	3.80	11.76
Headquarters	0.49	2.48
L	0.38	1.14
M	0.13	0.48

Tires/Batteries/Auto (TBA)

The average ITR of Tires/Batteries/Auto for the entire cooperative throughout the time frame of this study was 1.23, whereas the ITR guideline for Tires/Batteries/Auto items is 3-4. Therefore, an improvement of inventory management performance practiced by the cooperative during the time of this study is needed to enhance the inventory performance of this group of item.

As for the branches, the average ITR of Tires/Batteries/Auto ranges between 0.55-2.18. Only two of the branches', the Headquarters and M, ITR were within the range of

the standard ITR; the rest of the branches' were lower than the standard ITR. In addition, the minimum ITR in all branches was zero. This implies that the majority of the branches carried items that not only did not sell throughout the study period but also items with negative sales. This finding indicates the need for improvement in inventory management system of this group of items in all branches and that the cooperative should reconsider offering Tires/Batteries/Auto items at some branches.

Table 21. Statistics of ITR of Tires/Batteries/Auto Items by Branch

Branch	Average	Standard Deviation
A	1.49	3.34
B	1.19	2.35
C	0.97	1.93
D	0.64	1.14
E	0.93	1.74
G	1.16	2.52
H	1.53	2.63
I	0.52	1.34
J	1.20	1.90
K	1.21	1.81
Headquarters	1.55	3.34
L	0.90	1.22
M	2.18	8.60

Insecticide/Herbicide (IH)

The average ITR of Insecticide/Herbicide items in the entire cooperative throughout the time frame of this study was 4.69. As for Fence and Seed items, there are no specific guidelines for the ITR of Insecticide/Herbicide items. Therefore, the guideline of miscellaneous items, which is 7-10, is used to appraise the inventory performance of Insecticide/Herbicide items. Assuming this range to be appropriate for

Insecticide/Herbicide items in this cooperative, the overall inventory performance of this group of items in this cooperative is below the industry standard.

As for the branches, the average ITR of most branches were below the industry standard. It is possible that the cooperative provides some low performing insecticide/herbicide items as a service to their member/owners. The relatively low inventory performance of this group suggests that the cooperative should re-examine the items offered and determine if the availability of all of the under-performing items is actually important to the membership.

Table 22. Statistics of ITR of Insecticide/Herbicide Items by Branch

Branch	Average	Standard Deviation
A	0.64	2.90
B	29.52	185.41
C	0.77	1.63
D	3.56	8.90
E	13.41	106.49
F	1.87	1.31
G	2.42	5.27
H	8.61	60.87
I	2.14	8.20
J	1.99	6.06
K	4.66	12.14
Headquarters	3.65	10.09
L	1.05	3.32
M	3.05	7.06

Equipment /Parts (EP)

The average ITR of Equipment/Parts in the entire cooperative was 0.69. There are no specific guidelines for the ITR of Equipment/Parts items. Therefore, as with the groups of items with no specific ITR guidelines, the guideline of miscellaneous items, which is 7-10, is used to appraise the inventory performance of Equipment/Parts items.

Assuming this standard to be suitable for the Equipment/Parts items, the overall performance of Equipment/Parts items in this cooperative was significantly below the standard ITR for this group of item. This may indicate a need for improvement in inventory management system for Equipment/Parts in the cooperative. However, it should be noted that as user owned firms, it is sometimes appropriate for a cooperative to carry items with substandard inventory performance if their members consider availability of the item to be an important service. This is a possible explanation for the poor inventory performance of some items in the Equipment/Parts group. If this is the case the cooperative should be carefully consider the costs and benefits of maintaining these items.

Table 23. Statistics of ITR of Equipment/Parts Items by Branch

Branch	Average	Standard Deviation
A	3.27	6.50
B	4.67	9.96
C	0.43	0.89
D	1.19	2.18
E	0.78	1.45
F	0.00	0.00
G	0.46	0.81
H	0.25	0.79
I	0.59	0.95
J	1.00	1.03
K	1.03	3.30
Headquarters	0.82	1.28
L	0.04	0.43
M	0.84	1.10

Fertilizer (Frt)

The average ITR of Petroleum for the entire cooperative throughout the time frame of this study was 13.29, which is higher than the ITR guidelines of 2-3. The case study

cooperative was located relatively close to a major fertilizer manufacturing/distribution outlet. The cooperative's favorable fertilizer turnover indicates that the firm has taken advantage of these logistics to minimize fertilizer inventory. The cooperative should reconsider maintaining fertilizer inventories at the under-performing branches. This disparity between fertilizer turnover between branches may also explain the high incident of transfers of fertilizer items between the branches.

Table 24. Statistics of ITR of Fertilizer Items by Branch

Branch	Average	Standard Deviation
A	1.83	4.33
B	0.47	0.69
C	2.38	6.91
D	13.71	13.68
E	12.86	28.13
F	6.43	9.04
G	3.05	4.60
H	9.05	13.42
I	1.85	2.53
J	26.19	91.15
K	5.81	9.15
Headquarters	46.73	212.48
L	10.09	12.92
M	4.67	7.30

Animal Health (AH)

The average ITR of Animal Health in the entire cooperative was 2.54. There are no specific guidelines for the ITR of Animal Health items. Therefore, as with the groups of items with no specific ITR guidelines, the guideline of miscellaneous items, which is 7-10, is used to appraise the inventory performance of Seed items in this cooperative during the study time. Assuming this standard to be suitable for the Animal/Health items in this

cooperative, the overall performance of items in this cooperative was significantly below the industry average.

Animal Health products appear to turn rapidly at one branch location while having low turnover at all other sales points. Differences in marketing efforts and retail presentation between branches, local competition for these items and/or regional differences in farm characteristics are all possible explanation for this disparity. The cooperative may also perceive some animal health items as important to the membership and be willing to accept lower inventory performance. The low performance of this group suggests that the cooperative may want to more closely examine this group of items.

Table 25. Statistics of ITR of Animal Health Items by Branch

Branch	Average	Standard Deviation
A	2.78	3.94
B	0.00	0.00
C	0.81	1.04
D	0.93	1.32
E	1.36	1.27
F	15.74	28.72
G	1.59	2.40
H	3.11	6.98
I	1.39	1.96
K	0.86	0.93
Headquarters	1.01	1.38
L	1.78	1.13

Miscellaneous Items (MI)

The overall average of ITR of Miscellaneous Items in this cooperative was 1.29, whereas the ITR guideline for miscellaneous items is 7-10. Since the average of ITR was below the bottom level of the industry average, a need for improvement in this inventory

management is indicated. Furthermore, Table 26 shows that the average ITR of Miscellaneous Items in all branches was below the industry average and the minimum ITR of items in all branches were zero. It should be noted that this group represents less than one percent of the cooperative's total sales. This fact, combined with the disparity of items in this classification may limit the time that can be invested in improving the performance of this group.

Table 26. Statistics of ITR of Miscellaneous Items by Branch

Branch	Average	Standard Deviation
A	1.80	7.88
B	0.72	0.99
C	1.50	3.63
D	1.71	4.91
E	0.34	0.99
F	0.84	0.83
G	1.65	4.26
H	1.79	3.84
I	0.29	0.65
J	0.70	1.15
K	1.28	2.38
Headquarters	2.11	4.13
L	0.51	0.78
M	0.96	2.99

Inventory Management Index (IMI)

The IMI is used to determine the profitability of the items in the inventory because it relates the turnover with the gross margin. An IMI greater than one indicates a favorable inventory performance of an item or a group of items. Table 27 summarizes the IMI statistics for each group of items. The overall average IMI for this cooperative during the time frame of this study was 0.46. This number indicates that most of the items traded did not perform well and that the cooperative need to improve both its gross

margins and inventory turnover. However, careful investigation of performance for each item with group is needed due to high variation within the group. Examining performance of each item should assist with reaching a conclusion about the inventory management system of the cooperative as a whole. For this reason, the rest of this section is devoted to discuss the details on performance of each group of items.

Table 27. Average IMI of Group of Items

Group	Average
Ptr	1.13
Hrd	0.05
Fen	0.50
Fed	0.36
Sed	-0.48
TBA	0.42
IH	0.42
EP	0.27
Frt	2.25
AH	-0.48
MI	1.11

Petroleum (Ptr)

The average IMI for Petroleum items was 1.05. This average indicates that overall items in Petroleum had a favorable overall inventory performance. The ITR for this group was 9.44, which was above the average of turnover ratio of petroleum items. The gross margin percentage was 0.12. Careful investigation of the IMI of Petroleum items (Table 28), however, shows that not every branch had an average IMI above one. Branches A, B, C, E, F, J, L, and M had average IMI lower than one. Investigating the ITR of Petroleum at these branches showed that all branches but branch E had lower average ITR. Therefore, the lower IMI of Petroleum in these branches caused by the lower turnover, hence the cooperative need to work on improving the turnover of Petroleum items. In the case of branch E, since the ITR of Petroleum items in this

branches was above the industry average, the lower IMI of this items at branch E was likely caused by lower gross margin percentage. Therefore, the cooperative should concentrate on improving its pricing system, thus increasing the gross margin.

In addition, every branch carried items with IMI equal to one. There are two possible explanations for items to have a zero IMI. Firstly, the ITR is equal to zero and secondly, the gross margin is equal to zero. In this study, however, it is believed that most of items have zero IMI as a result of having ITR equal to zero. The ITR of zero indicates that the items did not sell during this time period. Therefore, the cooperative should consider effort to increase its turnover and further, it may also reconsider offering items that have not moved for a long time.

Table 28. Statistics of IMI of Petroleum Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Traded	IMI=0
A	0.12	0.30	0.00	0.11	3	1
B	0.03	0.18	0.00	0.06	6	2
C	0.35	2.43	0.00	0.57	18	4
D	2.44	6.32	0.24	2.69	3	0
E	0.69	4.81	0.00	1.45	5	3
F	0.00	0.00	0.00	0.00	0	0
G	1.41	8.79	0.00	2.50	6	2
H	1.64	15.75	0.00	4.00	8	5
I	1.21	6.96	0.00	2.02	7	3
J	0.50	1.44	0.08	0.51	3	1
K	1.17	25.12	0.00	4.45	16	6
Headquarters	2.37	33.55	0.00	7.39	12	5
L	0.14	0.30	0.06	0.10	3	1
M	0.41	1.48	0.00	0.59	7	3

Hardware (Hrd)

Overall average IMI for this cooperative is 0.05, which indicates that Hardware items during this time period were not making a good return to the cooperative. This low value of IMI caused by not only the low turnover, ITR of Hardware was 0.05, but also by lower gross margin percentage (0.06 percent). In other words, although, on average, Hardware items generated positive gross margins these margins may have been insufficient to cover all of inventory holding cost while leaving sufficient residual return to justify handling these items. Consequently, the net profit from Hardware items was expected to be low.

There are two things that the cooperative can do to improve IMI: improving the gross margin and/or improving the frequency of its inventory turnover. The total gross margin of Hardware items in the whole cooperative was $6,543 per item, which was the lowest total gross margin among all groups. While the complete analysis on improving the gross margin is beyond the scope of this study, it is found that the cooperative should improve its pricing strategy to achieve higher gross margin. Investigation on the average IMI of Hardware items in each branch showed that the minimum average inventory in almost all branches was negative. Negative average IMI shows that the cooperative experienced loses from their sales. Furthermore, the cooperative should reconsider offering Hardware items at branch L since 18 out of 21 hardware items traded in this branch did not sell over the study time (Table 29).

Turnover ratio of Hardware items was lower than the industry average. Since the average IMI of Hardware items was positive and that the average ITR of this items was

below the industry average, hence improving the turnover frequency is also needed to enhance the IMI of Hardware items.

Table 29. Statistics of IMI of Hardware Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Traded	IMI=0
A	0.22	0.76	-0.06	0.34	3	0
B	0.21	0.42	0.00	0.30	1	0
C	0.26	1.22	-0.05	0.50	3	1
D	0.26	1.97	-0.23	0.63	5	1
E	0.30	0.60	0.00	0.43	1	0
F	0.00	0.00	0.00	0.00	0	0
G	0.11	0.39	-0.06	0.20	3	1
H	0.69	6.41	-0.65	1.65	8	1
I	0.07	0.16	0.00	0.09	2	0
J	0.03	0.32	-0.20	0.22	2	0
K	0.28	5.51	-0.86	1.04	16	3
Headquarters	0.04	1.67	-0.81	0.19	165	36
L	0.05	1.52	-0.02	0.24	21	18
M	0.36	0.71	0.00	0.51	1	0

Fence (Fen)

The average IMI of Fence items was 0.56, which indicates an overall need to improve the inventory system of Fence items. The ITR of Fence was 1.85 that is significantly below the industry average of 7 with gross margin percent of 0.27. Similar to the argument expressed for the Hardware items, the lower ITR than industry average as well as the items with zero IMI, there is an urgent need for the cooperative to improve the turnover of Fence items for improving its IMI. Table 30 presents the statistics of the average IMI of Fence items.

Table 30. Statistics of IMI of Fence Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI=0
A	0.27	1.91	0.00	0.47	22	6
B	0.10	0.89	0.00	0.17	26	8
C	0.10	0.52	0.00	0.16	13	6
D	0.25	1.25	0.00	0.30	29	5
E	0.22	1.40	0.00	0.29	28	8
F	0.21	0.43	0.00	0.30	1	0
G	0.23	1.94	0.00	0.39	29	4
H	1.70	97.30	0.00	10.98	39	13
I	0.12	0.67	0.00	0.19	10	2
J	0.22	2.11	0.00	0.37	22	3
K	0.33	1.79	0.00	0.40	36	6
Headquarters	0.17	1.80	0.00	0.34	42	9
L	0.10	0.74	0.00	0.19	30	13
M	0.73	13.99	0.00	2.65	14	6

Feed (Fed)

As with the average IMI for Hardware and Fence items, the average IMI for Feed items was 0.36. The lower IMI indicates that the overall performance of Feed items was below the standard for a profitable inventory item. The low average of IMI caused by low turnover, the average ITR of Feed was 4.05, compare to the industry average of 10-12, as well as low margin percentage, 0.09. Therefore, the cooperative should improve both the turnover and gross margin to enhance the IMI of feed. An improvement in frequency of turnover is particularly needed in branches that carried many items that did not sell over the study period, i.e. items with IMI equal to zero (Table 31)

Although almost all branches had average IMI less than one, the average IMI of Feed items at the Headquarters and branch L show that these two locations had managed Feed items in their inventory well. This argument, however, does not imply that the

improvement in the inventory management strategies of these branches is no longer needed. In fact, despite of the higher average IMI than one that these branches had achieved, they did carry items with IMI of zero or less. Therefore, the improvement of both gross margin and ITR are still needed at these branches for achieving better average IMI.

Table 31. Statistics of IMI of Feed Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI = 0
A	0.22	2.00	0.00	0.43	39	18
B	0.24	2.51	0.00	0.46	45	10
C	0.21	5.49	0.00	0.53	259	63
D	0.31	5.03	0.00	0.63	67	15
E	0.05	1.37	0.00	0.17	196	105
F	0.25	5.76	0.00	0.67	41	7
G	0.25	7.90	0.00	0.71	136	37
H	0.57	60.97	0.00	4.34	98	26
I	0.06	1.54	0.00	0.20	58	28
J	0.30	3.31	0.00	0.66	40	9
K	0.33	13.16	0.00	1.10	104	28
Headquarters	1.97	256.46	0.00	19.94	82	21
L	0.93	27.51	0.00	3.67	41	11
M	0.30	13.86	0.00	1.36	54	9

Seed (Sed)

Unlike the groups discussed previously, Seed items had a negative average IMI in almost all branches. The average IMI of Seed group in the entire cooperative was –0.48. The negative IMI of Seed item was resulted from negative gross margin percent of –0.5. Therefore, this indicates that the cooperative need to improve its pricing system hence increase the gross margin of Seed. Particular attention is needed for improving the gross margin of Seed items with the minimum average IMI that were far below zero in each

branch. Improvement in the gross margin of items with the IMI that are far below zero is likely to improve the inventory performance of Seed items in the branches considerably. This will improve the performance of the Seed items in the entire cooperative. An improvement in the ITR is needed by this group of items especially when considering the large number of items with an IMI of zero (Table 32).

Table 32. Statistics of IMI of Seed Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI = 0
A	-0.11	2.25	-4.58	1.03	17	13
B	0.10	6.50	-4.06	1.78	12	5
C	-1.45	5.44	-54.25	8.52	21	10
D	-0.19	3.53	-3.71	1.50	9	4
E	-0.28	2.03	-10.35	1.19	82	55
F	0.00	0.00	0.00	0.00	0	0
G	-0.86	0.47	-11.16	2.81	8	5
H	-0.79	0.66	-35.57	4.80	28	20
I	-0.14	0.66	-2.31	0.71	6	3
J	0.02	2.38	-1.86	0.91	6	3
K	-2.58	26.19	-42.48	9.72	30	11
Headquarters	-0.46	0.60	-26.91	3.31	34	23
L	0.08	1.88	-1.11	0.44	14	11
M	-0.15	0.23	-3.84	0.63	29	24

Tires/Batteries/Auto (TBA)

The average IMI of Tires/Batteries/Auto for the whole cooperative was 0.42. This indicates that Tires/Batteries/Auto items had a positive gross margin percent (0.34), however, the turnover of most items was low (the average ITR of TBA was 1.23). Therefore, an improvement in ITR of Tires/Batteries/Auto is needed to boost the IMI of this group.

Table 33. Statistics of IMI of Seed Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI = 0
A	0.34	3.98	0.00	0.65	23	5
B	0.29	3.66	0.00	0.50	58	16
C	0.28	3.08	0.00	0.45	45	22
D	0.16	1.43	0.00	0.26	42	15
E	0.21	2.78	0.00	0.36	69	15
F	0.00	0.00	0.00	0.00	0	0
G	0.28	3.72	0.00	0.52	46	23
H	0.35	3.25	0.00	0.53	84	24
I	0.12	1.83	0.00	0.29	42	13
J	0.27	1.73	0.00	0.38	19	1
K	0.29	2.35	0.00	0.37	81	22
Headquarters	0.37	7.81	0.00	0.67	148	35
L	0.22	0.98	0.00	0.29	23	3
M	0.48	12.78	0.00	1.66	30	7

Insecticide/Herbicide (IH)

The overall average IMI of Insecticide/Herbicide in this cooperative was 0.42. The average ITR of Insecticide/Herbicide was 4.69, which is lower than the industry average, with gross margin percent of 0.09. This finding indicates that the cooperative should consider improvement both in the turnover ratio as well as the gross margin. Investigation on the average IMI of Insecticide/Herbicide show that branch B and E had managed their Insecticide/Herbicide inventories well. Conversely, branches A and C had not. Moreover, 85 percent of items at branch A had zero IMI, suggesting the cooperative to reconsider offering Insecticide/Herbicide in this location. On the contrary, only 8 percent of Insecticide/Herbicide items traded at branch C had zero IMI. The rest of the items had IMI greater than zero, indicating that the lower IMI was likely caused by the lower gross margin percentage, hence an improvement in pricing system is needed in this branch. Statistics of IMI of Insecticide/Herbicide are presented in Table 34.

Table 34. Statistics of IMI of Insecticide/Herbicide Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI = 0
A	0.05	2.35	0.00	0.23	65	51
B	2.37	100.02	0.00	14.73	22	9
C	0.07	1.03	0.00	0.14	61	5
D	0.32	4.23	0.00	0.77	31	8
E	1.09	74.80	0.00	8.46	39	13
F	0.17	0.33	0.00	0.13	2	1
G	0.23	3.41	0.00	0.56	21	5
H	0.76	58.17	0.00	4.88	73	34
I	0.19	4.56	0.00	0.66	48	21
J	0.20	4.11	0.00	0.62	50	25
K	0.45	12.93	0.00	1.27	62	12
Headquarters	0.36	10.54	0.00	1.08	141	40
L	0.10	1.57	0.00	0.29	23	15
M	0.31	5.54	0.00	0.76	63	19

Equipment/Parts (EP)

The overall average IMI of 0.27, calculated by multiplying the average ITR of 076 and the gross margin percent of 0.36. This finding shows an indication of Equipment/Parts items had unfavorable inventory performance. This is held true for all branches except for branches A and B that had an average IMI greater than one. However, an average IMI greater than one that the branch B had mainly due to this branch having only three items traded during the time period of this study. Therefore, an improvement for both the ITR and the gross margin of Equipment/Parts is needed for achieving higher number of profitable items in this group of items. Furthermore, 98 percent of Equipment/Parts traded at branch L did not move during the study period. This finding clearly suggest that the cooperative need to reconsider offering this group of items in branch L. The statistics of IMI of Equipment/Parts Items by Branch is presented in Table 35.

Table 35. Statistics of IMI of Equipment/Parts Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI=0
A	1.08	6.54	0.00	2.08	5	2
B	1.79	9.70	0.00	3.90	3	1
C	0.16	1.13	0.00	0.35	6	4
D	0.47	2.12	0.00	0.85	3	1
E	0.30	1.77	0.00	0.57	5	2
F	0.00	0.00	0.00	0.00	1	1
G	0.15	0.64	0.00	0.26	3	2
H	0.09	1.80	0.00	0.29	64	51
I	0.23	0.88	0.00	0.37	4	1
J	0.36	2.14	0.00	0.39	40	8
K	0.38	24.49	0.00	1.29	198	35
Headquarters	0.29	6.12	0.00	0.46	424	130
L	0.02	2.26	0.00	0.17	107	105
M	0.33	0.91	0.00	0.43	2	0

Fertilizer (Frt)

As the group that earned the highest gross margin among all group of items, it is not surprising that the average IMI of Fertilizer for the whole branch was the highest, 2.25. The ITR of Fertilizer group (13.29) was significantly higher than the industry average (2-3). The gross margin percent of Fertilizer group was 0.17.

Further investigation on the average IMI of Fertilizer items at each branch showed that not every branch had IMI greater than one and that every branch carried items with an IMI equal to zero. Therefore, an improvement in inventory turnover is still needed for the cooperative to enhance the IMI. The cooperative should also reconsider offering Fertilizer items at branch A since seven out of nine Fertilizer items traded had an IMI equal to zero.

Table 36. Statistics of IMI of Fertilizer Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI=0
A	0.33	3.15	0.00	0.79	9	7
B	0.07	0.19	0.00	0.10	1	0
C	0.38	5.60	0.00	1.07	25	7
D	2.37	6.00	0.00	2.29	4	0
E	2.29	20.92	0.00	5.14	9	2
F	1.13	5.36	0.00	1.66	5	0
G	0.52	2.97	0.00	0.78	11	2
H	1.62	8.93	0.00	2.49	11	3
I	0.33	1.85	0.00	0.47	9	2
J	4.91	73.84	0.00	17.24	8	1
K	1.04	7.32	0.00	1.72	8	0
Headquarters	8.63	272.75	0.00	40.17	20	3
L	1.83	6.85	0.00	2.43	6	1
M	0.84	6.14	0.00	1.37	11	3

Animal Health (AH)

The overall average IMI of Animal Health was -0.48. Negative IMI indicates that the gross margin percent of Animal Health was negative (-0.19), thus indicating the cooperative experienced losses in trading this items. Furthermore, although the average ITR of this item was 2.54, the cooperative need to reconsider trading Animal Health items, particularly at branch F. Statistics of IMI for Animal Health is presented in Table 37.

Table 37. Statistics of IMI of Animal Health Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI=0
A	-0.28	0.00	-0.56	0.39	1	0
B	0.00	0.00	0.00	0.00	1	1
C	-0.15	0.00	-0.50	0.21	5	3
D	-0.09	0.00	-0.19	0.13	1	0
E	-0.30	0.00	-0.94	0.38	3	2
F	-3.76	0.00	-20.34	8.16	2	0
G	-0.28	0.00	-1.04	0.30	9	0
H	-0.33	0.00	-2.03	0.69	4	3
I	-0.39	0.00	-0.78	0.55	1	0
J	0.00	0.00	0.00	0.00	0	0
K	-0.18	0.00	-0.56	0.23	4	2
Headquarters	-0.22	0.00	-1.17	0.38	5	2
L	-0.32	-0.07	-0.56	0.20	2	1
M	0.00	0.00	0.00	0.00	0	0

Miscellaneous Items (MI)

The overall average IMI of Miscellaneous Items in this cooperative during the time frame of this study was 1.11. This indicates that most of Miscellaneous Items had favorable inventory performance during the time period of this study. With the average ITR of 1.28 and gross margin percentage of 0.87, it can be concluded that the favorable IMI of this group was caused by higher gross margin percent. Therefore, an improvement in ITR is needed to enhance the IMI of this group. Statistics of IMI for Animal Health is presented in Table 38.

Table 38. Statistics of IMI of Miscellaneous Items by Branch

Branch	Average	Max	Min	Std Dev	Number of Item	
					Item Traded	IMI=0
A	1.51	34.76	0.00	6.54	14	11
B	0.61	2.95	0.00	0.83	8	2
C	1.31	22.20	0.00	3.27	57	13
D	1.45	21.05	0.00	4.08	13	6
E	0.30	5.14	0.00	0.87	29	17
F	0.73	1.82	0.00	0.72	7	3
G	1.41	23.41	0.00	3.63	36	11
H	1.54	21.78	0.00	3.38	31	13
I	0.25	1.69	0.00	0.57	8	7
J	0.59	3.81	0.00	0.97	14	7
K	1.11	13.79	0.00	2.11	33	12
Headquarters	1.85	12.55	0.00	3.71	6	4
L	0.44	1.85	0.00	0.66	8	3
M	0.87	12.15	0.00	2.72	10	6

Improved Inventory Control Strategies

One of the objectives of this study is to identify improved inventory control strategies that may help the cooperative perform better in managing their inventory system. Three major activities –sale, purchase, and transfer– that relate to inventory management were carefully examined to see the potential improvement that can be implemented. These potential improvements would address the inventory problems detected. This section is devoted to discussing the improved inventory control strategy developed in this study for each activity (sale, purchase, and transfer).

Sale

In his study to develop the inventory management strategies for local farm supply cooperatives, Wadsworth recommended ten fundamental strategies that need to be implemented for local farm supply cooperatives to have an effective inventory management system. Three of those strategies are: attaining proper inventory mix; understanding pricing, mark-up, and margin concept; and merchandise and coinciding merchandising and promotion with sale activity. For the purpose of this study, however, emphasis will be given to the first strategy: attaining proper inventory mix. Basically what Wadsworth means by "attain proper inventory mix" is that the cooperative needs to continuously analyze its inventory items and remove items that are unprofitable, no longer serve the needs of patrons, and face declining demand in the future market.
In explaining this strategy, Wadsworth provides no details on how to implement this strategy in day-to-day practice. Therefore, this study develops simple tools to help the manager implement this strategy. The impact of applying this strategy on the data available for this study is determined by the change in IMI performance before and after implementing the strategy as well as the change in the inventory residual income (IRI).

Change in IMI Performance

Using the information on how profitable (by IMI standard) the items are to the cooperative, a tool is developed to help the manager decide which of the items needs to be removed from the inventory list. The result of applying this process, the hierarchy of the process is explained in Figure 7, to the data available is presented in Table 39. The threshold used in this process is 3, 5, 7, and 10 percent.

Table 39. The Paired T-Test Comparison of the Average IMI before and after Implementing the Proper Inventory Mix Strategy with 3, 5, 7, and 10 Percent Thresholds.

Group	t-Value				Pr > |t|			
	3	5	7	10	3	5	7	10
Ptr	-1	-1.2	-1.2	-1.2	0.337	0.255	0.255	0.255
Hrd	-1.01	-1.09	-1.09	-1.09	0.3313	0.2968	0.2966	0.2963
Fen	-2.25	-2.55	-2.64	-2.79	0.0241**	0.0244**	0.0206**	0.0152**
Fed	-2.12	-2.31	-2.34	-2.4	0.0535*	0.0382**	0.0358**	0.0319**
Sed	-2.21	-2.22	-2.21	-2.23	0.0472**	0.0468**	0.047**	0.0458**
TBA	2.22	-2.5	-2.72	-3.22	0.0463**	0.0281**	0.0187**	0.0074**
IH	-1.35	-1.48	-1.42	-1.42	0.1993	0.162	0.1791	0.1798
EP	-1.09	-1.1	-1.35	-1.39	0.294	0.2902	0.2005	0.1892
Frt	-1.04	-1.04	-1.04	-1.04	0.3156	0.3156	0.3156	0.3156
AH	-1.46	-1.46	-1.46	-1.46	0.1717	0.1716	0.1716	0.1716
MI	-1.08	-1.13	-1.13	-1.16	0.2998	0.2801	0.2774	0.2661

** Significant at = 0.05 and = 0.1

* Significant at = 0.1

The null hypothesis that is tested when using the paired t-test comparison in this case is that the average IMI of the items in the inventory before applying the strategy of proper inventory mix is equal to the average IMI of the items after implying this strategy using the thresholds of 3, 5, 7 and 10 percent. Using this test, it can be concluded that there is no difference in the average IMI for groups of items such as Petroleum, Hardware, Insecticide/Herbicide, Equipment/Parts, Fertilizer, Animal Health, and Miscellaneous Items before and after applying this strategy. On the contrary, for Fence items, Feed items, Seed Items, and Tires/Auto/Batteries, it can be concluded that there is significant evidence that the average IMI's of these groups of items are different before and after implementing this strategy.

The reason the average IMI of groups such as Petroleum, Insecticide/Herbicide, Fertilizer items, were not different before and after implementing the strategy was due to the significantly large variation between the IMI of items within this group. The highest IMI of Petroleum items was extremely large that eliminating items in this group will not

change the average IMI for this group significantly. As for the groups such as Hardware, and Equipment/Parts, the average IMI of these groups was not differ before and after implementing the strategy because none of the items of these groups were included in the ten percent of the lowest items in the cooperative.

Although the first approach has identified changes that could improve the inventory performance of some groups of items, the assumption –that every item is equally important– is somewhat unrealistic. There are items which although they are not performing well by the IMI standard, may be considered important for meeting patrons' needs, or they may have increasing demand in the future. Therefore, removing them from the list of items in the inventory system may cause problems not only in the present time but also in the future. Hence, the second tool developed in this study incorporates the importance of items to the cooperative in the process of implementing the proper inventory mix strategy. There are two categories of importance: important and not important.

The result of applying this process on the data available is presented in Table 40. Similar to the first process, the threshold used in this process is 3, 5, 7, and 10 percent of the total inventory items in each branch. With the use of the significance level of 0.1 and 0.05, the paired t-test comparison shows the average IMI before and after implementing the proper inventory mix strategy with the inclusion of the importance of the items to the cooperative that are statistically different for some groups. The groups in which the difference occurs in the first method are the same groups as in the second method.

Table 40. The Paired T-Test Comparison of the Average IMI before and after Implementing the Proper Inventory Mix Strategy with 3, 5, 7, and 10 percent Thresholds and the Inclusion of the Importance of the Items to the Cooperative.

Group	t-Value				Pr > |t|			
	3	5	7	10	3	5	7	10
Ptr	-1	-0.99	-0.99	-0.97	0.337	0.3438	0.3438	0.3517
Hrd	-1.09	-1.09	-1.09	-1.1	0.297	0.2968	0.2968	0.2923
Fen	-1.69	-2.03	-2.23	-2.56	0.1139	0.0635*)	0.0444**)	0.0237**)
Fed	-1.83	-1.85	-1.8	-1.8	0.0897*)	0.0877*)	0.0952*)	0.0956*)
Sed	-1.78	-1.78	-1.79	-1.79	0.0996*)	0.0998*)	0.0983*)	0.0989*)
TBA	-2.12	-2.27	-2.51	-2.98	0.0552*)	0.0422**)	0.0272**)	0.0114**)
IH	-1	-1.14	-1.15	-1.46	0.3356	0.273	0.2693	0.1675
EP	-1.03	-1.17	-1.49	-1.53	0.3196	0.2624	0.1599	0.1509
Frt	-1	-1	-1	-1	0.3356	0.3356	0.3356	0.3356
AH	-1	-1	-1	-1	0.3388	0.3388	0.3388	0.3383
MI	-1.04	-1.05	-1.06	-1.1	0.3182	0.314	0.3092	0.2927

** Significant at = 0.05 and = 0.1

* Significant at = 0.1

The paired t-test comparison results in this second approach of implementing the "proper inventory mix" strategy are different, as expected, to some extent, with the first approach. For instance, using the first approach, the average IMI of items in Fence items was statistically different starting at a 3 percent threshold, whereas, using the second approach, the average IMI in this group does not start to show a difference until the 5 percent threshold. In addition, the level of significance when the conclusion is being made is also different. Take the conclusion made for Seed items for example: using the first approach, it can be concluded with a 0.05 confidence level that the average IMI of the items in this group is significantly different when applying a 3, 5, 7, and 10 percent threshold; whereas, using the second approach with the same level of threshold, the conclusion that the average IMI is different before and after implementing the strategy can only be made at a 0.1 confidence level.

This phenomenon verifies that the inclusion of the importance of the items to the cooperative may cause less significant improvement in inventory management when emphasizing the improvement solely on the average IMI of the group. For practical application, however, the second approach is more realistic to implement.

Change in Inventory Residual Income (IRI)

Table 41 presents the change in IRI before and after implementing the proper inventory mix strategy. Eliminating only three percent of items with lowest IMI proved to increase the IRI significantly. Conversely, for almost all group of items, eliminating more items (more than three percent threshold) does not shows significant improvement in the ITR. Therefore, the manager needs to consider implementing this strategy to improve the inventory performance of the cooperative.

Table 41. Inventory Residual Income before and after implementing the Proper Inventory Mix Strategy with 3, 5, 7, and Percent Thresholds.

Group	0 Percent ($)	3 Percent ($)	5 Percent ($)	7 Percent ($)	10 Percent ($)
Ptr	(650,112,767)	(4,133,087)	(4,131,718)	(4,131,631)	(4,131,631)
Hrd	2,999	4,941	4,961	4,962	4,962
Fen	12,040	12,256	12,336	12,553	13,067
Fed	(628,830)	(115,541)	163,753	184,134	211,301
Sed	(797,990)	(47,567)	(46,804)	(38,489)	(37,742)
TBA	42,182	67,435	67,584	67,761	68,120
IH	(612,571)	23,036	178,989	194,347	201,405
EP	18,574	19,061	21,732	21,815	21,832
Frt	(1,595,562)	2,282,182	2,455,072	2,455,072	2,455,077
AH	(27,625)	3,457	8,865	8,865	8,865
MI	707,107	719,676	728,412	728,490	729,185

Purchase

To minimize the inventory cost, two important decisions in purchasing activity "how much to order" and "when to order" are being used in an attempt to respond to the inventory data. This section discusses the results of applying the inventory data of this cooperative into the methods explain in Chapter IV, *Data Sources and Procedures*. The discussion is conducted in groups of products, and the emphasis is given on comparing the actual purchasing strategy practiced and the purchasing strategy proposed. The comparison is incorporated in the following: the difference in the number of items purchased as well as the number of purchasing transactions of those items; the change in the number of inventory on hand items under these two different practices; the difference the inventory holding cost and ordering cost accrued by both the practiced inventory control by the cooperative and the proposed inventory control.

Ordering Items

Applying the inventory data of all group of items into the EOQ methods and the replenishment model developed in this study, it is found that (with the exception of Animal Health items) the average monthly number of items purchased using the improved purchasing strategy is less than that of the actual purchasing practice (Table 42). The decrease in the average of number of items purchased monthly range from 7.8 percent (in Petroleum) to 49.75 percent (in Equipment /Parts), whereas the average number of items in Animal Health purchased monthly increases by two percent.

Table 42. The average Number of Items Purchased and The Number of Purchasing Transactions

Group	Average Number Of Items Purchased Per Month			Average Number Of Purchasing Transactions Per Month		
	Actual Practice	Improved Strategy	Percent Change	Actual Practice	Improved Strategy	Percent Change
1	8.12	7.48	-7.88	38.04	26.67	-29.90
2	12.44	5.28	-57.56	15.52	6.25	-59.73
3	12.04	7.48	-37.87	28.67	14.55	-49.24
4	79.44	56.76	-28.55	237.08	93.71	-60.47
5	11.6	8.92	-23.10	20.67	28.43	37.59
6	33.92	18.36	-45.87	91.41	38.50	-57.88
7	33.12	24.64	-25.60	79.46	75.08	-5.51
8	23.72	11.92	-49.75	40.47	14.26	-64.77
9	13.6	11.32	-16.76	65.54	72.25	10.24
10	2	2.04	2.00	4.40	3.13	-28.98
11	12.04	8.84	-26.58	24.33	13.91	-42.82

The change in the average number of items purchased per month could be a sign of improvement in the inventory management system as a result of applying the improved purchase strategy developed. However, the change of the number of items purchased per month does not necessarily reflect the change in the ordering cost. This is true for this study because of the assumptions used when developing the improved purchasing strategy. It is assumed that the ordering cost is fixed for each time an order is placed, and this cost is the same for all items in this inventory system. There is no limit on the purchasing transactions, i.e.: order can be placed as many times as needed in a month. Therefore, the number of purchasing transactions per month will be a better indicator whether the ordering cost has increased or decreased due to the implementation of the improved purchase strategy.

With the exception of Seed items and Fertilizer items, the average number of purchasing transactions of all other groups of items per month decreases when employing the improved purchasing strategy on the inventory data (Table 42). The decrease in the average number of purchasing transactions ranges from 5.51 (Insecticide/Herbicide) to

64.77 (Equipment/Parts) percent. Holding the assumptions discussed above to be true, the decrease in the average number of purchasing transactions indicates a decrease in the ordering cost of these groups of items. The bigger the percentage change in this case the bigger the reduction in the ordering cost. On the other hand, the increase in the average number of purchasing transactions indicates an increase in the ordering cost. Therefore, implementing the improved purchasing strategy increases the ordering cost of Feed items and Fertilizer items, and decreases the ordering cost of all other groups.

Despite the change in ordering cost, either increasing or decreasing, since total inventory cost consists of not only ordering cost but also holding cost, the total inventory cost does not necessarily increase or decrease as the result of the increase or decrease in the ordering cost. Thus, even if there is an increase in the ordering cost, the total inventory cost could be lower because of a holding cost decrease which is large enough to compensate the increased ordering cost. In this case, it is believed that even if the ordering cost of Seed items and Fertilizer items is increasing, the total inventory cost of these groups of items is decreasing by applying the improved purchasing strategy.

Inventory On Hand

Holding costs increase when the quantity of inventory on hand increases, and conversely decrease when inventory on hand more closely matches demand. This study is interested in comparing the inventory on hand calculated from the actual trading data as well as the inventory on hand as the result of employing the improved purchased strategy into sales and transfer data. When analyzing the difference in the number of inventory items on hand, the Wilcoxon statistical test is employed due to the non-normality condition of the data. The null hypothesis that there is no difference in the

inventory on hand with these two purchasing practices is tested against the alternative hypothesis that the average inventory on hand of the actual purchasing practice is greater than the inventory on hand of the purchasing practice suggested.

The result of the Wilcoxon test on the inventory on hand data of all the groups of items shows that, except for Hardware, there is significant evidence to reject the null hypothesis with (the level of confidence) equal to 0.01. Therefore, it can be concluded that the average inventory on hand of items in all groups (but Hardware items) decreases when using the improved purchasing strategy developed in this study. As a result of the decrease in the average inventory on hand, the holding inventory cost of these groups of items also decreases.

For Hardware items, it was found (using the Wilcoxon test) that its average inventory on hand, when applying the improved purchase strategy was the same or greater than that of the average inventory on hand by the actual purchasing practice. This is not a sign of failure in the improved inventory purchase strategy of this particular group of items. Further investigation on how this conclusion can be an indication of the ineffectiveness of the improved purchase strategy for this group of items led to a better understanding of how the EOQ model balances the holding inventory cost and the ordering cost.

Nonetheless, holding more inventories on hand is more economically beneficial to the cooperative than placing more orders when the holding cost is relatively low as compared to the ordering cost. In this study, this concept was found to be true for the inventory control of Hardware items. Due to the assumptions used in this study, particularly the assumption that the ordering cost for each item is the same for all items

traded in this cooperative, holding more inventories on hand in Hardware items case was found to decrease the total inventory cost of this group of items by 48 percent. The details on the change in inventory costs of all groups of items as a result of employing the improved purchasing strategy is discussed in the next section.

Inventory Costs

Inventory on hand quantity before and after implementing the improved purchasing strategy developed in this study were calculated. It was found that the inventory on hand decreases for 59 percent of the items, 23 percent of the items increases and 18 percent of the items stays the same. Similarly, the number of orders increases for 20 percent of the items, decreases for 29 percent of the items and stays the same for the rest of the items. The decrease in the quantity of on hand inventory as well as the decrease in the number of orders reflects the decrease in the inventory holding and ordering cost. Figure 70 depicts the percentage decrease in both holding cost and ordering cost.

With the exclusion of the ordering cost for Animal Health items, both holding and ordering cost decrease for all groups of items. The percentage decrease in the inventory costs not only varies among the groups of items but also varies within the group of items.

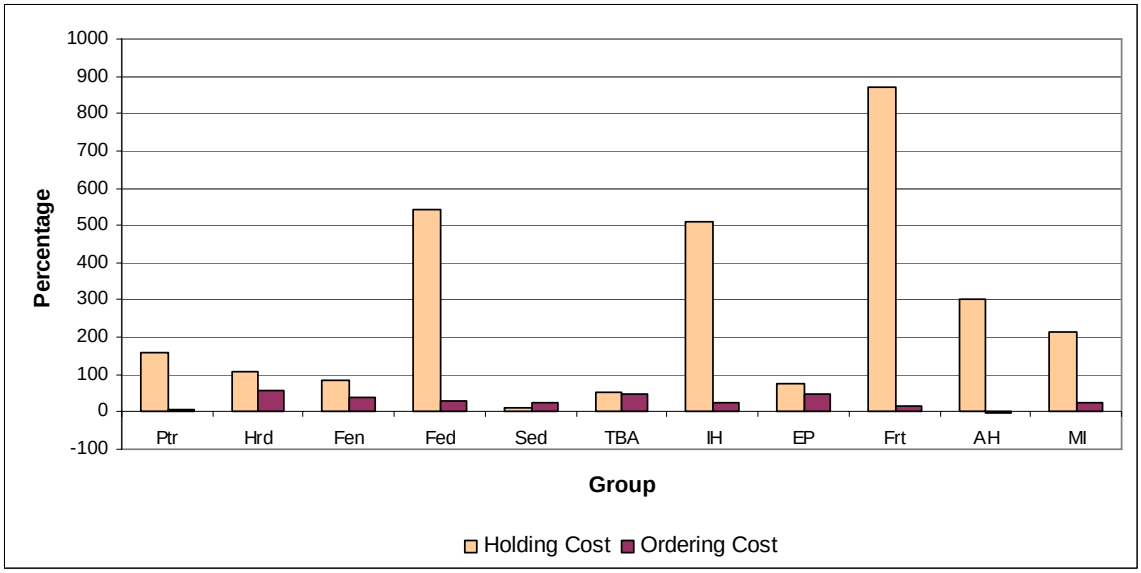

Figure 70. Percentage Decrease in Inventory Holding and Ordering Cost by Group of Items

Higher decreases in the inventory holding cost for some groups of items such as Petroleum, Feed, Insecticide/Herbicide, Fertilizer, Animal Health, and Miscellaneous items indicates that the quantity purchased for these groups were higher compared to the optimal quantity purchased in the EOQ model. Relatively larger decreases in the ordering cost, such as in Hardware and Equipment/Parts, signifies the number of orders for these groups of items is more than required to fulfill the demand throughout the time frame of this study. Moreover, the difference in the percentage of holding cost and ordering cost in each group of items identifies (indirectly) the common purchasing problems that the cooperatives faced for each group of items. For instance, the cooperative had more problems in determining the quantity to purchase of Seed items than the frequency of ordering. Conversely, it had more issues in determining the frequency to order than the quantity to order of Animal Health items. Table 43 presents the total holding cost for each group of items accrued from the actual purchasing strategy

practiced by the cooperative as well as the total inventory holding cost as a result of employing the improved purchasing strategy.

Table 43. Total Inventory Holding Cost

Group	Total Inventory Holding Cost ($)	
	Actual Practiced	Improved Purchasing Strategy
Ptr	3,479,038	1,342,851
Hrd	1,743	845
Fen	15,461	8,405
Fed	196,516	30,538
Sed	296,772	265,302
TBA	19,318	12,677
IH	245,811	40,366
EP	6,248	3,539
Frt	110,773	11,403
AH	8,437	2,097
MI	11,033	3,518
Total	4,391,152	1,721,542

Transfer of Items between the Branches

Coordinating of inventory between multiple branches of the cooperative is a typical problem. It requires good communication among branches in all trading activities such as sale and purchase. Managing a multiple locations inventory system is a complex process and the complexity increases when dealing with multiple items. Centralized stocking locations, however, has been shown in many studies to be capable of improving the inventory performance of the organizations being studied. Therefore, this study aimed to investigate the apparent efficiency or in-efficiencies from inter branch transfers and centralized warehousing.

In general, transfer of items between branches occurs because one the branches can not meet the demand from its stock of items. Consequently, efficient transfer of items should be from the branch with lower turnover to the one with higher turnover. Transfer

of items activity is believed to be efficient when the quantity of items being transferred is lower than the quantity sold: although, this may not always be the case. Also, a transfer of items activity is argued to be efficient when it is only for meeting the customers need and not for transferring to the other branch. These criteria are used when discussing the efficiency or in-efficiency in each group of item.

The comparison between the actual transfer activity and the scenario with one stocking location is based on the difference in the transfer costs accrued by both scenarios. Using the transportation model explained in Chapter IV, it is found that Headquarters is the location which has the smallest distance to all of the branches. (Hence the Headquarters serves as the stocking location in this study).

Comparing the quantity transferred into the branches with the quantity sold, it was found that most branches transferred more from all item groups than they sold. Indicating quantity being transferred being the holding stock for the receiver branches. Although the number of items transferred into as well as out of the branches varies among the group, the majority of branches: indicating the quantity transferred were higher than quantity sold. These findings could be a sign of in-efficiency in transfer activity in the cooperative. Furthermore, comparing the turnover (ITR) with the pattern of the transfer activity, the flows of the transfer activity were not always out of the branches with low turnover to the higher turnover. Detail on the transfer activity of each group of items in each branch is presented in Table 44, available in Appendix B.

Investigation on the number of items transfer out from branches in each group showed that some branches had acted as stocking locations for others. Headquarters, for instance, transferred significantly high number of Hardware items out of its inventory

compare to other branches. Similarly, branch E transferred out most of items transferred Feed items, indicating branch E could be the stocking locations of Feed items for others. Comparing the transfer costs accrued by the stocking locations scenario in this study than that of the actual practice, it is found that the transfer costs of this study was lower than the actual transfer activity. However, this did not held true for all branches. Some branches experienced increased in transfer costs as a result of applying the data on the scenario developed in this study. This finding indicated the need of having more than one stocking location to minimize the transfer cost. The details on the change in the transportation cost are presented in Table 45, Available in Appendix B.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Farm supply cooperatives serve their members/patrons not only by selling products and providing services that their members need but also by managing the cooperative effectively to give the optimal return to them. A typical farm supply cooperative has a large investment in inventory; hence the ability to manage its inventory efficiently is required to be successful in this business. Managing an efficient inventory requires planning with clear goal. The goal could be broad such as effective service or efficiency in inventory control, or a performance goal, such as higher sales and turnover, fine strategies could be employed for reaching the goal. It is a continuous process in the sense that it needs to be reviewed periodically to evaluate whether or not the strategies being implemented are achieving the goal. Therefore, this study endeavored in examining the inventory policy implemented in the particular farm supply cooperative throughout the time frame of this study as well as developing potential strategies that can be used for improving the inventory control of farm supply cooperatives.

The data for achieving the objectives of this research were obtained from farm supply cooperative in Oklahoma. This farm supply cooperative has 14 branches and traded 1,871 items in total. These items were grouped into 11 categories of items that are commonly carried by farm supply cooperatives: Petroleum, Hardware, Fence, Feed, Seed, Tires/Batteries/Auto, Insecticide/Herbicide, Equipment/Parts, Fertilizer, Animal

Health, and Miscellaneous Items. The number of items traded as well as the type of items varied among the branches. The data of the trading activity–sales, purchases, and transfers of items among the branches– of all items at each branch were collected from March 2004 to February 2006. The data were used to examine how well the inventory management system of study the farm supply cooperative performed, throughout the time frame of this study. The development of potential improved inventory control strategies for farm supply cooperatives was also researched.

Examining the trading data collected indicated an overall increase in the trading activity as well as the dollar value for these activities from the first to the second year. Similarly, overall total gross margin earned by the branches from all groups of items was increased during the time frame of this study. The increase in the trading activity and gross margin varied across branches and groups of items.

The number of items sold in this cooperative varied between the branches as well as groups of items. Some groups of items, such as Petroleum and Feed, were sold continuously with little variation in the number of items sold per month at almost all branches that sold them. Other groups, such as Insecticide/Herbicide, were also sold continuously but experienced peaks in the number of items sold in certain months during the study period. Furthermore, Animal Health items were sold sporadically throughout the time frame of the study. The trend of the sale of items was found to be vary not only among the groups of items but also among the branches.

Similar to the number of items sold, the number of items purchased varied across groups of items as well as across the branches. However, the number of items purchased for almost all group of items in all branches was found to be less than the number of

items sold. Therefore, it was concluded that the cooperative met their demand not only from purchasing the items but also from their stock of items and/or from transferring the items from other branches. The purchasing activity took place differently among the groups and the branches throughout the time of this study. Petroleum and Feed, for instance, were purchased continuously throughout the time frame of this study. Conversely, Hardware and Equipment/Part were purchased sporadically during this time period.

The number of items and the branches that were involved in transferring items varied across item groups. The branches that transferred the most items in a particular group of items were found to be the branches that purchased the most items in that group. In general, the transferring activity in each group of items involved almost all branches. Therefore, it is concluded that a local stocking strategy was employed during this time period. In addition to the difference in the number of items transferred, the time when the transferring of items took place was also different. Feed items, for instance, were transferred between the branches continuously. Conversely, Petroleum, Hardware, and Seed items were transferred occasionally.

Managing the three trading activities mentioned above is a must to achieve an efficient inventory management system. An efficient inventory management system is one that is capable of minimizing the inventory costs while still meeting customer demand. A periodic review of inventory performance is one of the strategies to achieve an efficient inventory management. For that reason, the first objective of this study was to examine the inventory management performance of this cooperative throughout the time period of this study. Two (2) well-known inventory performance measurements

were employed for this purpose: Inventory Turnover Ratio (ITR) and Inventory Management Index (IMI).

ITR was used to examine the liquidity of each item in the cooperative's inventory. The average ITR for each group was calculated to examine the performance of each group of items during the time frame of the study. The calculated ITR of each group of items was compared to the average ITR of that group across farm supply cooperatives to examine the performance of each group of items. The study found the overall average ITR of the cooperative to be 3.58, which was lower than the average ITR of farm supply cooperatives in the US. This finding indicated that the overall inventory performance of the cooperative was lower than that of the average farm supply cooperative in the US. It was suspected that the lower overall average ITR in this cooperative was due to the fact that the ITR of 1,051 items in this cooperative were equal to zero. The ITR equal to zero means that those 1,051 items were not sold during the time period of this study.

However, further assessment on each group of items indicated that not all of the groups performed lower than the industry averages. Moreover, the variation in the ITR of items within the groups was found to be significantly large hence even if the average ITR of the group was found to be lower than the industry average, some items performed above the average industry. Petroleum and Fertilizer were found to be the only groups with average ITR above the industry averages. The average ITR above the industry average indicates that the cooperative managed the inventory control of these two groups of items efficiently. Overall, it is concluded that the cooperative needs to improve its inventory control strategies to increase its average ITR and improvement is needed especially for the items with zero ITR.

While the ITR indicates the liquidity of an item to the cooperative, it does not measure how efficiently the cooperative produces earnings and whether it has done a good job selecting, merchandising, and pricing the "right" products for their customer in generating sales. Therefore, another measurement of inventory performance called the Inventory Management Index (IMI) was employed relating to the inventory turn over of items with the sales those items generated throughout the time of this study. Although there is no exact standard for the IMI, Wadsworth argued that the cooperative should strive for IMI greater than one. A minimum index of one is required for the managers to be able to cover all inventory cost and generate sufficient profits to cover their non-inventory investments in their retail operation.

The overall average IMI for this cooperative during the time frame of this study was 0.46. This number indicates that most of the items traded during this time period did not perform well and that the cooperative need to improve both its gross margins and inventory turnover. This finding was clarified by investigating the IMI of each item traded in this cooperative. It was found that 73 items had negative IMI, 1,068 items had zero IMI, 457 items had IMI greater than zero but less than one, and only 347 items had IMI greater than one.

A manager can do two things to improve IMI: increase the gross margin and/or improve the ITR. Priority improvement in gross margin is needed for items with IMI less than zero, whereas the priority improvement in turnover ratio is needed for items with IMI equal to zero. Items with IMI greater than zero but less than one improvement in either gross margin and/or turnover ratio is needed to boost the IMI. Considering a high

number of items with IMI equal to zero, it can be concluded that the priority improvement needs to be conducted to improve the inventory turnover in the cooperative.

The improved inventory control strategies in this study were developed to address the improvement in three major activities in this particular cooperative: sales, purchase, and transfer of items between branches. These strategies were developed based on the inventory management strategies for local farm supply cooperatives proposed by Wadsworth as explained in Chapter II.

A strategy called “proper inventory mix” was implemented to the sale activity. This strategy requires the cooperative to continuously analyze its inventory items and remove items when they are unprofitable, do not serve the needs of patrons, and face declining demand. Removing unprofitable items from the list of inventory items will reduce the costs that are tied with the inventories. Two scenarios: eliminating items based on the average IMI only and eliminating items based on the combination of the average IMI and the importance of the items to the cooperative, with four thresholds: 3, 5, 7, and 10 percent were studied for this purpose. Further analysis was conducted on the change in the average profit and average IMI in each group of items before and after implementing the strategy.

Utilizing this simple strategy to the inventory data available, showed that the effect of eliminating items on the average IMI differed from one group to the other. Some groups which had items with extremely low IMI experienced significant difference in the IMI before and after implementing the strategy. Conversely, groups that did not carry items with extremely low IMI did not experience significant differences. As expected, the inclusion of the importance of the items to the cooperative caused less significant

improvement in average IMI before and after implementing the strategy. Investigating the change in the inventory residual income (IRI) as a result of implementing this strategy showed that the (IRI) was significantly improved by only eliminating three percent of items with the lowest IMI. Therefore, the manager is suggested to consider using this strategy in the day-to-day management practice.

A strategy to make an efficient order by balancing the holding and ordering costs was developed for purchasing activity. The strategy employed the Economic Order Quantity model and Dynamic Economic Lot-size model to solve for the optimum quantity to order and the time to place such an order. To examine the effectiveness of this strategy, the outcome of this strategy was compared with the actual purchasing strategy practiced by this cooperative during the time frame of the study. In this dissertation, the emphasis was on comparing the difference in the number of purchasing transactions of items traded in each group of items and the change in the number of inventory on hand as the result of implementing the improved purchasing strategy developed in this study.

With the exception of Seeds and Fertilizer, the average number of purchasing transactions of all other groups per month decreased when employing the improved purchasing strategy into the inventory data during the time frame of this study. The decrease in the average number of purchasing transactions ranged from 5.51 percent (Insecticide/Herbicide) to 64.77 (Equipment and Parts). The decrease in the average number of purchasing transactions indicates a decrease in the ordering cost of these groups of items and the larger the percentage change in this case, the larger the reduction in the ordering cost. Conversely, the increase in the average number of purchasing

transactions translates into an increase in the ordering cost. The increase in the ordering cost however, does not signify the failure of this strategy for those particular groups. The models that were used to build this strategy minimize the inventory costs by balancing the holding cost and ordering cost and thus it can be safely argued that the problem of higher ordering cost is offset by the saving in the holding cost. Furthermore, the total inventory cost, which is the sum of ordering and holding costs, as the result of implementing this strategy will be significantly lower than the actual practice. This idea was found to be true when further examination on the inventory holding cost was conducted.

When examining the difference in the inventory on hand as a result of implementing the purchasing strategy in this study, it is found that all groups, with the exclusion of Hardware, experienced a decrease in inventories on hand. The increase in inventory on hand of Hardware could be explained by the assumptions used in this study, particularly the assumption that the ordering cost for each item is the same for all items traded. In the case where the holding cost is relatively low compared to the ordering cost, holding more inventories on hand are more beneficial, economically, to the cooperative than placing more orders.

The potential cost savings from implementing the improved inventory control strategy was evaluated. The evaluation on the improvement on two major inventory costs, holding and ordering, was conducted for each item as well as each group of products. When calculating the holding cost in the two situations, before and after implementing the improved inventory control strategy, it was found that the holding cost of 59 percent of the items decreased, 23 percent increased and 18 percent of the items

stayed the same. However, the ordering cost increased for 20 percent of the items, decreased for 29 percent of the items and stayed the same for the rest of the items. With the exclusion of the ordering cost for Animal Health, the average cost for both holding and ordering cost decreased for all groups of items. However, overall the average inventory costs of all groups of items decreased as the result of implementing the improved inventory control strategy.

Lastly, investigations on the apparent efficiency or in-efficiencies from inter branch transfers and centralized warehousing was conducted. An efficient inter branch transfers was defined to be one that transferred with quantity lower than the quantity sold; one that flow from branch with low turnover to higher turnover; as well as only for materializing the demand and not transferring to another branch. Utilizing this concept on the data available, it is found that in general the transferring activity among the branches was not efficient. Many research have shown that centralized stocking location was a better alternative compare to decentralized stocking locations. Therefore, a scenario of placing one optimal centralized stocking location was developed and Headquarters was found to be the branch with the lowest distance to the 14 branches. Calculating the transfer cost under the Headquarters as the stocking location, it was found that in average the transfer cost of this scenario was lower than the actual transferred activity by the cooperative. However, not every branch had lower transportation under the Headquarters as stocking locations. Therefore, multiple stocking locations should be considered.

Limitations and Suggestions for Further Research

This study developed inventory control strategies for farm supply cooperatives that can improve the inventory control strategies that were practiced when this was conducted. While the results show that the inventory control strategies developed in this study are better, in terms of the inventory costs that accrue by implementing these strategies, than that of the actual strategies practiced, many assumptions used in this study appear to be far removed from reality. In calculating the EOQ for instance, it is assumed that the demand is deterministic, the order quantity is fixed with no restriction in the size of order, the spontaneous replenishment, and the costs factors are fixed. If any of these assumptions are relaxed, although it is believed that improvement will still take place, the results may change. Therefore, to make the developed inventory control strategy to be more suitable for actual practice purpose, further work on relaxing the assumptions mentioned above is needed.

Because of the limited available data to do demand forecasting, this study assumed the demand to be known. Several case studies have attempted to improve the inventory management system of different firms in various industries. These studies have proved that slight improvement in demand forecasting could save the firm significant amounts. Muscatello and Coccari, for instance, applied a simple forecasting technique into a job shop manufacturer that specializes in replacement parts and found that utilization of the demand forecasting technique could have saved a significant amount over two years on just one product. Another work in using inventory models to manage seed-corn supply at Syngenta Seeds, Inc, by Jones et al has benefited the company by reducing inventory cost while still meeting customer needs. For this reason,

after the data become available, immediate work is needed to relax the assumption of demand being known.

Several other assumptions in building the strategy for purchase activity could also be relaxed. A lead -time of zero assumption is not realistic. In real life the uncertainty of the lead-time has been a challenge for many industries. This is particularly true for retailers, including farm supply cooperatives, who depend on supply of their products from many suppliers. The inventory control strategy built in this study does not put constraints on the quantity to be ordered or the capacity of the storage sites. In real practice, these two constraints have influenced decision making of the purchasing management. Furthermore, according to Wadsworth many farm supply cooperatives take into consideration the quantity discount offer by the supplier when making the decision on how much to order. This aspect is not a part of this study could be beneficial for a more suitable model for farm supply cooperatives.

Finally, the inventory control strategy develop in this study is built to be implemented for all items in farm supply cooperatives. Nonetheless, there is no single "ideal" inventory control system that can be applied to every item hence further research is needed to ascertain a better inventory control system for individual item or group of items.

REFERENCES

Adams, C.C., K.C. DeVille, J.E. Penn, and E.E. Eversull. *Farmer Cooperative Statistics, 2002*. Washington DC: U.S. Department of Agriculture, Rural Business-Cooperative Service, Research Report 62, June 2004.

Aggarwal, A. and J.K. Park. "Improved Algorithms for Economic Lot-Size Problems. *Operation Research* 41 (1991): 549-571.

Arnold, J. R.T., and S. N. Chapman. *Introduction to Material Management*, 5th ed. New Jersey: Prentice-Hall, 2004.

Attamturk, A. and M. W. P. Savelsbergh. "Integer-Programming Software Systems." *Annals of Operations Research* 140 (2005): 67-124.

Ballou, R.H and A. Burnetas. "Planning Multiple Location Inventories." *Journal of Business Logistics* 24 (2003): 65-89.

Bierlen, R., B.L. Ahrendsen, and B.L. Dixon. "Impacts of Financial Characteristics and the Boom-Bust Cycle on the Farm Inventory-Cash Flow Relationship." *Journal of Agricultural and Applied Economics* 30(1998): 363-377.

Cardos, M. and J.P. Garcia-Sabater. "Designing a Consumer Products Retail Chain Inventory Replenishment Policy with the Consideration of Transportation Costs." *International Journal Production Economics* 104 (2005): 525-535.

Chavas, J.P., P. M. Despins, and T. R. Fortenbery. "Inventory Dynamics under Transaction Costs." *American Journal of Agricultural Economics* 82(2000): 260-273.

Chen, F.Y. "Fractional Programming Approach to Two Stochastic Inventory Problems." *European Journal of Operational Research* 160 (2005): 63-71.

Christensen, P.O., G.A. Feltham, and M.G.H. Wu. "Cost of Capital in Residual Income for Performance Evaluation" *The Accounting Review* 77 (2002): 1-23.

Coffey, J.D. “Implications for Farm Supply Cooperatives of the Industrialization of Agriculture.” *American Journal of Agricultural Economics* 75(1993): 1132-1136.

Das, C., and R. Tyagi. “Effect of Correlated Demands on Safety Stock Centralization: Patterns of Correlation Versus Degree of Centralization.” *Journal of Business Logistics* 20 (1999): 205-213.

David, I., and A. Mehrez. “An Inventory Model with Exogenous Failures.” *Operations Research* 43 (1995): 902-903.

Edelman, M. P. “Use of the Inventory Turnover Measurement.” *Hospital Materiel Management Quarterly* 12 (1990): 50-56.

Evers, P.T., and F. J. Beier. “Operational Aspects of Inventory Consolidation Decision Making.” *Journal of Business Logistics* 19 (1998): 173-189.

Eynan, A. And D.H. Kroop. “Effective and Simple EOQ-Like Solutions for Stochastics Demand Period Review Systems.” *European Journal of Operational Research* 180 (2007): 1135-1143.

Federgruen and Tzur. “A Simple Forward Algorithm to Solve General Dynamic Lot-Sizing models with n periods in *O (n log n)* or *O(n)* Time. *Management Science,* 37: 909-925.

Gaur, V., M.L. Fisher and A. Raman. “An Econometric Analysis of Inventory Turnover Performance in Retail Services.” *Management Science* 51 (2005): 181-194

Goyal S.K., and B.C. Giri. “Recent Trend in Modeling of Deterioration Inventory.” *European Journal of Operational Research* 134 (2001): 1-16.

Gray, T.W., and C.A. Kraenzle. *Problems and Issues Facing Farmer Cooperatives*. Washington DC: U.S. Department of Agriculture, Rural Business-Cooperative Service, Research Report 192, September 2002.

Hamilton, S.F., and T. L. Kastens. “Does Market Timing Contribute to the Cattle Cycle?” *American Journal of Agricultural Economics* 82(2000): 82-96.

Hariga, M.A, A. Al-hamari and A. A. Mohammed. “A Joint Optimization for Inventory Replenishment, Product Assortment, Shelf Space and Display Area Allocation Decisions.” *European Journal of Operation Research* 181 (2007): 239-251.

Hariga, MA. “Setup Cost Reduction in (Q,R) Policy with Lot Size, Setup Time and Lead-Time Interactions.” *Journal of the Operational Research Society* 51 (2000); 1340-1345.

Hojati, M. “Bridging the Gap between Probabilistic and Fuzzy-Parameter EOQ models.” *International Journal of Production Economics* 91(2004): 215-221.

Hsu, N.H. “An Economic Lot Size Model for Perishable Products with Age-Dependent Inventory and Backorder Costs.” *IIE Transactions* 35 (2003): 775-780.

Johnson, D.D., and R.P. King. “Optimal Pricing and Inventory Control for A Country Grain Elevator.” Dept. Agr. and App. Econ. Staff Paper 88-22, University of Minnesota, 1988.

Johnson, F.R., J.E. Boylen, and E.A. Shale. “An Examination of the Size of Orders from Customers, Their Characterization and the Implications for Inventory Control of Slow Moving Items.” *Journal of the Operational Research Society* 54(2003): 833-837.

Jones, P. C., G. Kegler, T. J. Lowe, R. D. Traub. “Managing the Seed-Corn Supply Chain at Syngenta.” *Interfaces* 33 (2003): 80-90

Kanet, J.J., and A. R. Cannon. “Implementing Supply Chain Management Lessons Learned at Becton Dickinson.” *Production and Inventory Management Journal* 41 (2000):33-40.

Karlof, J.K. *Integer Programming: Theory and Practice*, Taylor & Francis Group, 2006.

Krupp, J.A. “Safety Stock Management”. Production and Inventory Management Journal 38 (1997): 11-17

Levy, M. and C.A. Ingene. “Residual Income Analysis: A Method of Inventory Investment Allocation and Evaluation.” *Journal of Marketing* 48 (1984): 93-104.

Li, C.L, V.N. Hsu, and W.Q. Xiao. “Dynamic Lot Sizing with Batch Ordering and Truckload Discount.” *Operation Research* 52(2004): 639-654.

Lowe, T.J. and L.B. Schwarz. “Parameter Estimation for the EOQ Lot-Size Model. Minimax and Expected Value Choices.” *Naval Research Logistics Quarterly* 30 (1983): 367-376.

Meller, R.D. “The Impact of Multiple Stocking Points on System Profitability.” *International Journal of Production Economics* 38 (1995):209-214.

Menkhaus, D.J., O. R. Phillips, C.T. Bastian, and L.B. Gittings. “Matching and Inventory Loss Risks as Facilitators of Market Power in Private Negotiation Spot Trading.” Paper presented at AAEA annual meeting, Denver Colorado, 1-4 August 2004.

Miller, E.S. “Seasonality and Stock Adjustment Models of Retail Food Store Inventory Food Behavior.” *American Journal of Agricultural Economics* 72(1990): 1018-1027.

Moon, I., B.C. Giri, and B. Ko. “Economic Order Quantity Models for Ameliorating/Deteriorating Items under Inflation and Time Discounting.” *European Journal of Operational Research* 162(2005): 773-785.

Moon, I.K. and B.C. Cha. “The Joint Replenishment Problem with Resource Restriction.” *European Journal of Operational Research* 173 (2006): 190-198.

Mustacello, J. R. and R. L. Coccari. “Savings with a Formal Forecasting System: A Case Study”. *The Journal of Business Forecasting Methods and Systems* 19 (2000): 19-21.

Nahmias, S. *Production and Operational Analysis.* New York: McGraw-Hill Irwin, 2005.

Nemhauser, G. and L.A. Wolsey. Integer and Combinatorial Optimization, New York: John Wiley & Sons, 1988.

Ozdemir, D., E. Yucesan and Y.T. Herer. “Multilocation Transshipment Problem with Capacitated Transportation.” *European Journal of Operational Research* 175 (2006): 602-621.

Ptak, C.A. “A Comparison of Inventory Models and Carrying Cost.” *Production and Inventory Management Journal* 29(1988): 1-3.

Reynolds, D. “Inventory Turnover Analysis.” *Cornell Hotel and Restaurant Administration Quarterly* 40(1999): 54-58.

Robison, J.A. “Inventory Profile Analysis: An Aggregation Technique for Improving Customer Service while Reducing Inventory.” *Production and Inventory Management Journal* 42(2001): 8-13.

Scheider, H., and D. B. Rinks. “Empirical Study of a New Procedure for Allocating Safety Stock in a Wholesale Inventory System.” *International Journal of Production Economics* 24 (1991): 181-189.

Schwaller, R.L. “EOQ under Inspection Cost.” *Production and Inventory Management Journal* 29(1988): 22-24.

Shih. “Planning of Fuel Coal Imports Using a Mixed Itneger Programming Method.” *International Journal of Production Economics* 51 (1997): 243-249.

Silver. A.E., D.F. Pyke and R. Peterson. *Inventory Management and Production Planning and Scheduling*, John Willey & Sons, 1998.

Simpson, N.C. “Central Versus Local Multiple Stage Inventory Planning. An Analysis of Solutions.” *European Journal of Operational Research* 181 (2007): 127-138.

Solomon, David. *Divisional Performance: Measurement and Control*. Chicago. Irwin. 1965.

Stadler, H. Multilevel Lot Sizing with Setup Times and Multiple Constrained Resources Internally Rolling Schedules with Lot-Sizing Window.” *Operation Research* 51 (2003): 487-502.

Tallon, W.J. “The Impact of Inventory Centralization on Aggregate Safety Stock: The Variable Supply Lead Time Case.” *Journal of Business Logistic* 14 (1993):185-203.

Toelle, R. A., and R. J. Tersine. “Excess Inventory: Financial Asset or Operational Liability?” *Production and Inventory Management Journal* 30 (1989): 32-35.

Vergin, R.C. “An Examination of Inventory Turnover in the Fortune 500 Industrial Companies.” *Production and Inventory Management Journal* 39(1998): 51-56.

Vuvosevic, M.M., D. Petrovic and R. Petrovic. “EOQ Formula when Inventory Cost is Fuzzy.” *International Journal of Production Economics* 45 (1996): 499-504.

Wadsworth, J.J. *Inventory Management Strategies for Local Farm Supply Cooperatives*. Washington DC: U.S. Department of Agriculture, Rural Business-Cooperative Service, Research Report 41, July 1994.

Wagner, H.M. and T.M. Whitin. “Dynamic Problems in the Theory of Firm.” *Naval Research Logistic Quarterly* 5 (1958): 53-74.

Williams, M.W. *Inventory and Production Decisions*. Michigan: UMI Research Press, 1981.

Yu, G. “Robust Economic Order Quantity Models.” *European Journal of Operational Research* 100(1997): 482-493.

Zinn, W., M. Levy, and D.J. Bowersox. “Measuring the Effect of Inventory Centralization/Decentralization.” *Journal of Business Logistics* 10 (1989): 1-13

Zipkin, P.H. *Foundation of Inventory Management*, New York: Mc Graw-Hill Higher Education, 2000.

APPENDIXES

APPENDIX A--INVENTORY MODELS

A.1. Economic Order Quantity Model

A.1.1. Derivation

Considering the Ordering cost, C(Q), as:

(10) $$C(Q) = k + cQ$$

where *k* is the fixed cost to place an order and c is the variable cost to place an order. If the demand rate is , the length of each cycle is:

(11) $$T = \frac{Q}{\lambda}$$

Therefore the average ordering cost during this period of time is $\frac{C(Q)}{T}$.

If during one cycle, the inventory decreases linearly to zero then the average inventory is $\frac{Q}{2}$ .Thus the average holding cost, *H(Q)* will be:

(12) $$H(Q) = \frac{Q}{2}h$$

where *h* is the cost to hold one unit in inventory.

Suppose the objective is to minimize the total average inventory cost:

(13) $$G(Q) = \frac{k + cQ}{T} + \frac{Q}{2}h$$

Substituting *T* with $\frac{Q}{\lambda}$ and taking the derivative of *G(Q)* with respect to *Q*, the result is:

(14) $$G'(Q) = \frac{- k \lambda}{Q^2} + \frac{h}{2}$$

With the second order condition:

(15) $$G''(Q) = \frac{2k\ \lambda}{Q^3}, \quad \text{for } Q \succ 0$$

This second order condition of equation proof that *G(Q)* is a convex function of *Q*, thus the optimal value of *Q* that minimizes *G(Q)*, is:

(16) $$Q^* = \text{EOQ} = \sqrt{\frac{2k\lambda}{h}}$$

A.1.2. Sensitivity Analysis of Economic Order Quantity

Let *G (Q)* be the average annual holding and ordering cost function given by

(17) $$G(Q) = \frac{k\lambda}{Q} + \frac{Q}{2}h$$

And let G* be the optimal average annual inventory cost and *Q** as the optimal solution

(18) $$G^* = \frac{k\lambda}{Q^*} + \frac{Q^*}{2}h$$

Substituting Q* with $\sqrt{\frac{2k\lambda}{h}}$,

(19) $$G^* = \sqrt{2k\lambda h}$$

Thus for any *Q*,

(20) $$\frac{G(Q)}{G^*} = \frac{k\lambda / Q + Q/2\ h}{\sqrt{2k\lambda h}}$$

With a bit of algebra it can be shown that

(21) $$\frac{G(Q)}{G^*} = \frac{1}{2}\left[\frac{Q^*}{Q} + \frac{Q}{Q^*}\right]$$

Suppose we used the "wrong" value of Q instead of Q^* --because of errors in parameter estimates, or additional constraints not included in the model, or for any other reasons—thus the relative cost of this suboptimal policy, compared to the true optimal cost, depends only on the relative error in Q itself. This formula is entirely independent to the cost and demand parameters.

A.2. The Dynamic Economic Lot-Size (DEL) Model

The DEL described in this section is one that relates with discrete- time formulation and the goal is to determine a feasible ordering plan which minimizes the total cost over all time points. The model presented here is the same as that of Zipkin. The notation used to explain this model follows:

T = finite time horizon
t = index for time points, $t = 0, \quad ,T$
$d(t)$ = demand at time t
$x(t)$ = inventory at time t, with xo as the beginning inventory
$z(t)$ = order size at time t
$v(t)$ = binary indicator variable, $v(t)$ is 1 if we order at time t, and 0 otherwise
$k(t)$ = fixed order cost at time t
$c(t)$ = variable order cost at time t
$h(t)$ = inventory holding cost at time t
$D(t)$ = cumulative demand through time $t = \sum_{s=0}^{t} d(s)$
$D[t,u)$ = demand from time t through u-1 = $D(u\text{-}1)\text{-}D(t\text{-}1)$, $t \quad u$
$\tilde{c}[t,u)$ = variable cost to order a unit at t and hold it until $u = c(t) + \sum_{s=t+1}^{u} h(s), \quad t \le u$

These are all nonnegative variables. The model is formulated as:

Initial condition:

(22) $$x(0) = x_o$$

Dynamics condition:

(23) $$x(t+1) = x(t) + z(t) - d(t) \quad t = 0, \cdots, T$$

Constraint:

(24) $$\begin{aligned} & x(t) \geq 0 \;\; t = 0, \cdots, T \\ & v(t) \in \{0,1\} \\ & z(t) \geq D[t, T)v(t) \quad t = 1, \cdots, T-1 \end{aligned}$$

Objective:

(25) $$\text{Minimize} \sum_{t=0}^{T-1} [k(t)v(t) + c(t)z(t)] + \sum_{t=1}^{T} h(t)x(t)$$

The DEL can be expressed as linear-mixed integer programming model.

APPENDIX B-- THE TRANSFER COSTS BY BRANCH BY GROUP OF ITEMS

Table 44. Transfer Activity, ITR and Sale

Branch	Group	ITR	Transfer>Sale	Transfer In	Transfer Out	Both
A	Ptr	15.84		2		
B	Ptr	0.34	1	3		1
C	Ptr	6.44	1	2	2	5
D	Ptr	47.82				
E	Ptr	48.81	2	5	1	
G	Ptr	25.99				3
H	Ptr	32.56				3
I	Ptr	21.02				4
J	Ptr	14.35				2
K	Ptr	13.77	2	2	2	4
Headquarters	Ptr	38.99		4		2
L	Ptr	127.28		2		
M	Ptr	16.63		4		
A	Hrd	2.36	2	2		
B	Hrd	1.50				
C	Hrd	2.09	1	1		1
D	Hrd	2.10	3	4		
E	Hrd	2.16	1			1
G	Hrd	1.18		1	1	
H	Hrd	2.85	1	4		1
I	Hrd	0.38	2	1		1
J	Hrd	0.89	1	1		
K	Hrd	3.58	3	4		3
Headquarters	Hrd	1.41	9	12	5	1
L	Hrd	0.32	2	3	12	
M	Hrd	3.86	1	1		
A	Fen	2.71	10	9		3
B	Fen	0.91	9	8	1	3
C	Fen	0.94	2	2	1	1
D	Fen	2.28	13	14		3
E	Fen	1.67	6	8	3	3
F	Fen	0.17	1			1
G	Fen	2.33	4	6	9	9
H	Fen	4.28	12	17		7
I	Fen	0.91	6	3	3	3
J	Fen	1.42	4	7	3	1
K	Fen	2.48	12	20	2	6
Headquarters	Fen	1.71	2	1	22	8
L	Fen	0.92	5	12	3	2
M	Fen	7.73	8	11		1
A	Fed	3.26	17	27	1	3
B	Fed	3.55	20	23	2	13
C	Fed	3.83	60	65	13	55
D	Fed	4.62	30	42		12
E	Fed	0.93	35	10	106	58
F	Fed	3.28	14	17	2	11
G	Fed	3.27	52	23	24	56
H	Fed	5.44	42	57	5	16
I	Fed	0.76	36	11	15	28
J	Fed	4.82	23	15	3	18
K	Fed	5.24	53	63		22

Table 44. Transfer Activity, ITR and Sale (Continue)

Branch	Group	ITR	Transfer>Sale	Transfer In	Transfer Out	Both
Headquarters	Fed	4.91	37	40	3	21
L	Fed	9.48	23	30		4
M	Fed	5.66	26	30		8
A	Sed	0.37	3	7	2	3
B	Sed	1.94	2	4	4	2
C	Sed	2.48		3	1	3
D	Sed	0.99		6		
E	Sed	0.50	29	14	22	20
G	Sed	1.45	4	2	1	3
H	Sed	0.84	10	6	4	10
I	Sed	0.61	1	5		
J	Sed	1.51		1		
K	Sed	3.29	4	2	2	10
Headquarters	Sed	0.97	5	8	15	3
L	Sed	0.48	10	3		8
M	Sed	0.33	17	11	1	11
A	TBA	2.67	7	14		2
B	TBA	2.79	16	15	2	9
C	TBA	1.71	13	19		4
D	TBA	1.40	16	20	1	2
E	TBA	1.73	6	12	22	8
G	TBA	1.67	12	17	2	4
H	TBA	2.84	20	25	3	10
I	TBA	0.86	18		14	20
J	TBA	2.65	8	13		1
K	TBA	2.52	21	24	3	9
Headquarters	TBA	3.08	14	9	34	27
L	TBA	2.76	11	14		1
M	TBA	3.45	10	14		4
A	IH	0.49	3	2	48	9
B	IH	2.68	8	13	3	1
C	IH	1.24	3	7	7	1
D	IH	3.36	4	16	1	
E	IH	1.25	11	15	4	6
F	IH	1.25	1	1		
G	IH	2.60	3	4		4
H	IH	4.70	23	20	6	25
I	IH	3.40	25	19	8	15
J	IH	2.48	25	19	1	21
K	IH	4.98	10	19	7	17
Headquarters	IH	4.19	9	28	32	26
L	IH	1.07	7	9		2
M	IH	4.93	11	26	3	5
A	EP	3.00		2	1	1
B	EP	5.50	2	3		
C	EP	0.31		2		
D	EP	1.83	2	3		
E	EP	0.66	3			3
F	EP	0.00	1			1
G	EP	0.21			1	1
H	EP	0.32	1	4	42	2

Table 44. Transfer Activity, ITR and Sale (Continue)

Branch	Group	ITR	Transfer>Sale	Transfer In	Transfer Out	Both
I	EP	1.07	3	1		2
J	EP	1.10	3	8		
K	EP	1.43	7	26		1
Headquarters	EP	1.04	74	97	18	17
L	EP	0.05	2	2	103	1
M	EP	1.54	1	2		
A	Frt	1.49	1		6	2
B	Frt	1.87	1	1		1
C	Frt	4.10			1	1
D	Frt	28.54		3		1
E	Frt	6.45		1	3	5
F	Frt	5.64	1	2	1	1
G	Frt	3.88				4
H	Frt	8.48	1	3	1	4
I	Frt	1.76	3	2		6
J	Frt	4.97	3	2		6
K	Frt	8.64	2	1	2	5
Headquarters	Frt	9.24	2	4	1	13
L	Frt	22.55	1	1	1	4
M	Frt	4.65	2	1		5
A	AH	6.00		1		
B	AH	1.63	1			1
C	AH	0.56		1		
D	AH	1.00	1			1
E	AH	1.64	1			1
F	AH	19.28		1		
G	AH	1.41			1	1
H	AH	1.24	1			1
I	AH	1.50	1			1
K	AH	0.38	1	2		
Headquarters	AH	0.84	1	1		
L	AH	1.19	1	1		
A	MI	1.64	3	5	4	1
B	MI	2.57	4	4	1	
C	MI	2.23	8	4	3	8
D	MI	2.56	4	5	2	
E	MI	0.34	6	3	13	4
F	MI	0.64	1	1	1	
G	MI	2.13	9	6	7	5
H	MI	2.95	12	10	1	5
I	MI	0.11	3	1	2	3
J	MI	0.72	4	2		3
K	MI	1.56	7	8	4	3
Headquarters	MI	3.81	1	2		
L	MI	0.50	1	2	1	1
M	MI	1.46	4	4	1	

Table 45. Transfer Costs By Branch By Group of Items

Branch	Group	Transfer Transactions		Transfer Cost	Centralized Stocking Transfer Cost ($)
		In	Out		
A	Ptr	4		44.34	37.22
B	Ptr	4	1	62.20	36.4
C	Ptr	13	12	112.95	121.55
D	Ptr				
E	Ptr	6	1	61.30	31.2
G	Ptr	3		22.05	12.75
H	Ptr	4		47.80	26.8
I	Ptr	4		38.60	19.4
J	Ptr	2		34.90	21.7
K	Ptr	13	53	94.50	91
Headquarters	Ptr	8	3	51.10	0
L	Ptr	4		68.28	41.08
M	Ptr	8		58.10	65.2
A	Hrd	4		26.21	37.22
B	Hrd				
C	Hrd	2	1	21.00	18.7
D	Hrd	7		36.60	45.15
E	Hrd	2	5	13.80	10.4
G	Hrd	1	5	4.70	4.25
H	Hrd	8	1	58.30	53.6
I	Hrd	2	6	9.70	9.7
J	Hrd	1		8.35	10.85
K	Hrd	16	3	128.55	112
Headquarters	Hrd	13	29	129.94	0
L	Hrd	5	12	47.83	51.35
M	Hrd	1		8.15	8.15
A	Fen	41	6	384.13	381.505
B	Fen	18	4	181.09	163.8
C	Fen	16	15	113.45	149.6
D	Fen	49	3	284.13	316.05
E	Fen	25	84	124.65	130
F	Fen	9		87.53	21.78
G	Fen	93	136	532.06	395.25
H	Fen	103	16	801.92	690.1
I	Fen	42	25	267.86	203.7
J	Fen	15	5	169.15	162.75
K	Fen	106	22	809.77	742
Headquarters	Fen	20	246	88.48	0
L	Fen	30	16	298.44	308.1
M	Fen	17	6	146.25	138.55
A	Fed	145	4	1441.27	1349.225
B	Fed	235	20	1220.66	2138.5
C	Fed	875	240	6719.40	8181.25
D	Fed	301	24	2152.45	1941.45
E	Fed	183	2579	1051.31	951.6
F	Fed	162	38	1510.24	392.04
G	Fed	458	845	2335.23	1946.5
H	Fed	504	23	3279.33	3376.8

Table 45. Transfer Costs By Branch By Group of Items (Continue)

Branch	Group	Transfer Transactions		Transfer Cost	Centralized Stocking Transfer Cost ($)
		In	Out		
I	Fed	164	334	1251.30	795.4
J	Fed	164	187	1708.70	1779.4
K	Fed	474	46	4692.47	3318
Headquarters	Fed	362	62	1964.70	0
L	Fed	241	9	1930.19	2475.07
M	Fed	167	9	2038.46	1361.05
A	Sed	16	4	242.33	148.88
B	Sed	9	6	83.98	81.9
C	Sed	18	4	148.20	168.3
D	Sed	9		48.05	58.05
E	Sed	62	117	552.31	322.4
G	Sed	5	3	23.05	21.25
H	Sed	23	17	146.49	154.1
I	Sed	6		48.82	29.1
J	Sed	1		5.05	10.85
K	Sed	24	37	218.44	168
Headquarters	Sed	18	35	88.30	0
L	Sed	19	6	308.81	195.13
M	Sed	33	13	390.80	268.95
A	TBA	39	11	144.95	362.895
B	TBA	56	15	389.00	509.6
C	TBA	61	7	580.35	570.35
D	TBA	40	1	314.55	258
E	TBA	27	108	188.10	140.4
G	TBA	48	4	213.35	204
H	TBA	101	23	577.50	676.7
I	TBA	44	215	215.25	213.4
J	TBA	24		184.55	260.4
K	TBA	67	20	558.65	469
Headquarters	TBA	79	232	413.95	0
L	TBA	30	3	152.12	308.1
M	TBA	50	4	485.15	407.5
A	IH	21	118	123.76	195.405
B	IH	23	6	191.90	209.3
C	IH	16	16	162.65	149.6
D	IH	45	1	283.95	290.25
E	IH	35	110	200.05	182
F	IH	8		64.00	19.36
G	IH	37	10	177.75	157.25
H	IH	105	35	847.17	703.5
I	IH	68	50	290.13	329.8
J	IH	64	37	681.25	694.4
K	IH	83	40	614.77	581
Headquarters	IH	152	256	963.41	0
L	IH	16	3	174.67	164.32
M	IH	65	22	525.77	529.75
A	EP	3	4	29.63	27.915
B	EP	3		27.70	27.3
C	EP	2		15.90	18.7
D	EP	4		21.80	25.8

Table 45. Transfer Costs By Branch By Group of Items (Continue)

Branch	Group	Transfer Transactions		Transfer Cost	Centralized Stocking Transfer Cost ($)
		In	Out		
E	EP	10	16	93.37	52
F	EP	2		19.81	4.84
G	EP	1	7	4.70	4.25
H	EP	8	47	53.60	53.6
I	EP	10	4	71.10	48.5
J	EP	8		86.25	86.8
K	EP	34	2	251.05	238
Headquarters	EP	153	59	1395.32	0
L	EP	5	106	34.84	51.35
M	EP	2		21.30	16.3
A	Frt	8	25	66.44	74.44
B	Frt	5	3	31.68	45.5
C	Frt	1	2	9.35	9.35
D	Frt	16	1	105.90	103.2
E	Frt	38	31	242.51	197.6
F	Frt	5	2	12.80	12.1
G	Frt	18	9	85.94	76.5
H	Frt	23	2	197.31	154.1
I	Frt	25	23	135.86	121.25
J	Frt	18	6	209.30	195.3
K	Frt	18	10	154.54	126
Headquarters	Frt	102	120	265.30	0
L	Frt	20	10	192.00	205.4
M	Frt	16	9	130.91	130.4
A	AH	3		46.02	27.915
B	AH	3	2	31.05	27.3
C	AH	2		13.00	18.7
D	AH	1	2	4.45	6.45
E	AH	6	7	33.60	31.2
F	AH	8		77.35	19.36
G	AH	7	35	48.85	29.75
H	AH	10	4	86.95	67
I	AH	5	4	45.50	24.25
K	AH	2		14.70	14
Headquarters	AH	2		8.50	0
L	AH	5		36.55	51.35
A	MI	13	4	141.03	120.965
B	MI	9		93.27	81.9
C	MI	91	47	606.80	850.85
D	MI	13	2	89.30	83.85
E	MI	12	146	100.80	62.4
F	MI	6	1	57.81	14.52
G	MI	65	94	284.79	276.25
H	MI	70	5	644.19	469
I	MI	5	8	30.57	24.25
J	MI	10	3	101.18	108.5
K	MI	33	11	293.80	231
Headquarters	MI	9		48.60	0
L	MI	5	12	48.99	51.35
M	MI	6	1	84.50	48.9

APPENDIX C—GAMS CODE

C. 1. GAMS CODE FOR REPLENISHMENT MODEL

```
options limrow=0;
options limcol=0;
sets
t time in month /2*26/
i item
/
A
AA
AAA
AAAA
AAAB
AAAC
AAAD
AAAE
AAAF
AAAG
/
table Demand(i,t) Demand per month
          2    3    4    5    6
A         2    0    0    0    0
AA        160  0    0    0    0
AAA       0    0    0    0    0
AAAA      4    0    0    0    0
AAAB      2    0    0    0    0
AAAC      2    0    0    0    0
AAAD      10   0    0    -2   1
AAAE      4    0    0    0    0
AAAF      5    0    0    -2   0
AAAG      2    0    -2   0    0
+
          7    8    9    10   11
A         0    0    0    0    0
AA        0    0    0    0    0
AAA       0    0    0    0    0
AAAA      0    0    0    0    0
AAAB      0    0    0    0    0
AAAC      0    0    0    0    0
AAAD      0    -4   0    0    0
AAAE      0    0    0    0    0
AAAF      0    0    0    0    0
AAAG      0    0    0    0    0
+
          12   13   14   15   16
A         0    0    0    0    0
AA        -50  -3   -3   -15  -11
AAA       0    0    0    0    0
AAAA      0    0    0    0    0
AAAB      0    0    0    -1   0
AAAC      0    0    0    -1   0
AAAD      -2   0    -1   0    -3
AAAE      -3   0    0    0    0
AAAF      -3   0    0    0    0
AAAG      0    0    0    0    0
```

```
+
          17   18   19   20   21
A         0    0    0    0    0
AA        -15  -15  -3   -4   -3
AAA       0    0    0    0    0
AAAA      0    -2   -1   0    -1
AAAB      0    0    0    -1   0
AAAC      0    0    0    -1   0
AAAD      0    -2   0    0    0
AAAE      0    0    0    0    -1
AAAF      0    0    0    0    0
AAAG      0    0    0    -1   -1
+
          22   23   24   25   26
A         0    -2   0    0    0
AA        -76  -97  -59  -11  -1
AAA       0    -5   -1   -2   -1
AAAA      0    0    0    0    0
AAAB      0    0    0    0    0
AAAC      0    0    0    0    0
AAAD      0    0    0    0    0
AAAE      0    0    0    0    0
AAAF      0    0    0    0    0
AAAG      0    0    0    0    0
Parameters
EOQ(i)
/
A         0
AA        22.59839533
AAA       13.35623186
AAAA      0
AAAB      0
AAAC      0
AAAD      5.232203508
AAAE      0
AAAF      0
AAAG      4.821689175/

order(i)
/
A         0
AA        225.9839533
AAA       13.35623186
AAAA      0
AAAB      0
AAAC      0
AAAD      5.232203508
AAAE      0
AAAF      0
AAAG      4.821689175
/
```

```
Price(i)
/A        44.43000031
AA        27.65737649
AAA       3.459183296
AAAA      5.96999979
AAAB      5.49000001
AAAC      2.660000086
AAAD      7.51365006
AAAE      8.263999939
AAAF      5.409999847
AAAG      5.89835
/

variables
inventory(i,t)   inventory item i at time t
mininv         min inventory quantity
ordering(i,t) more than one monthly order
maxpur(i,t)                                ;

integer variable ordering;
positive variables inventory, miniv;

equations
obj
calcInv(i,t)
maxpura(i,t)
maxbuy(i)
monmininv(i,t);

obj..  mininv =e= sum((i,t), 0.2*price(i)*inventory(i,t)) +
sum((i,t),ordering(i,t)*13.65);


***0.2 is the holding cost and 13.65 is the ordering cost**

calcInv(i,t)..  inventory(i,t)=e= ordering(i,t)*EOQ(i)+ demand(i,t)+
inventory(i,t-1);
monmininv(i,t).. inventory(i,t) =g= 0;
maxpura(i,t)..  maxpur(i,t) =e= ordering(i,t)*EOQ(i);
maxbuy(i)..  sum((t), maxpur(i,t)) =e= order(i);

model purchase /all/;
solve purchase  using MIP minimizing mininv;

parameter Purchase1;
Purchase1(i,t) = ordering.L(i,t);
display Purchase1;

parameter HitInventory;
HitInventory(i,t)=inventory.L(i,t);

display HitInventory;
```

C.2. GAMS CODE FOR STOCKING LOCATION

```
options limrow=0;
options limcol=0;

sets
i item
/A/

t towns
/
A
D
H
I
K
Head
L
F
E
G
M
B
C
J
/


alias(t,j)
table Distance(t,j) distance from one town to the other
```

	A	B	C	D	E	G	H
A	0	19.55	42.29	39.06	33.58	33.05	25.94
B	19.55	0	47.18	31.1	18.6	24.9	8.3
C	42.29	47.18	0	13	15.9	10.1	26.3
D	39.06	31.1	13	0	18.2	8.9	25.6
E	33.58	18.6	15.9	18.2	0	9.4	11
G	33.05	24.9	10.1	8.9	9.4	0	18.1
H	25.94	8.3	26.3	25.6	11	18.1	0
I	7.6	12.8	28.4	21.3	17.2	18.2	13.1
J	25.1	3.9	36.3	34.5	20.6	27.8	10.1
K	25.73	31.1	21	7.8	22.7	14.7	27.4
Head	18.61	18.2	18.7	12.9	10.4	8.5	13.4
L	16.59	21.48	44.22	40.99	35.51	34.98	27.87
M	8.12	23	33.2	22.3	26.3	23.7	24.2
F	14.49	19.37	28.52	25.29	19.81	19.27	16.27

+

	I	J	K	Head	L	M	F
A	7.6	25.1	25.73	18.61	16.59	8.12	14.49
B	12.8	3.9	31.1	18.2	21.48	23	19.37
C	28.4	36.3	21	18.7	44.22	33.2	28.52
D	21.3	34.5	7.8	12.9	40.99	22.3	25.29
E	17.2	20.6	22.7	10.4	35.51	26.3	19.81
G	18.2	27.8	14.7	8.5	34.98	23.7	19.27
H	13.1	10.1	27.4	13.4	27.87	24.2	16.27
I	0	16.7	19.3	9.7	9.53	11.1	6.92
J	16.7	0	34.9	21.7	27.03	26.9	24.92
K	19.3	34.9	0	14	34.14	16.6	18.44
Head	9.7	21.7	14	0	20.54	16.3	4.84
L	9.53	27.03	34.14	20.54	0	25.59	16.42
M	11.1	26.9	16.6	16.3	25.59	0	23.49
Jeff	6.92	24.92	18.44	4.84	16.42	23.49	0 ;

variables
TD Total Distance
x(i,t) Zero - one variable for stock locations for item i at location i

binary variable x;

equations
obj

OnlyOneDepot(i) Only one stock location restriction;

obj.. TD =e= sum((i,t,j),x(i,t)*Distance(t,j));
OnlyOneDepot(i).. sum((t),x(i,t))=e=1;

model transport /all/;
solve transport using MIP minimizing TD;

parameter Transport1;
Transport1(i,t) = x.L(i,t);
display Transport1;

VITA

Fitryanti Pakiding

Candidate for the Degree of

Doctor of Philosophy

Thesis: IMPROVED INVENTORY CONTROL STRATEGIES FOR FARM SUPPLY COOPERATIVES

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Rantepao, Indonesia, on November 12, 1972, the daughter of Julius Pakiding Lamba and Agustina Limbong Tangdan.

Education: Graduated from Sekolah Menengah Atas Katolik Cenderawasih Ujung Pandang, Indonesia in June 1991; received Bachelor of Science Degree of Agroindustrial Technology, Bogor Agricultural Institute, Bogor, Indonesia in February 1996; received Master of Science degree in Agricultural Economics Department at Oklahoma State University in December, 2003; completed requirements for the Doctor of Philosophy degree in Agricultural Economics at Oklahoma State University in May 2007.

Experience: Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, January 2003 to May 2007; Lecturer at Papua State University, Manokwari, Indonesia, August 1998 to present.

Name : Fitryanti Pakiding Date of Degree: May, 2007

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: IMPROVED INVENTORY CONTROL STRATEGIES FOR FARM SUPPLY COOPERATIVES

Pages in Study: 175 Candidate for the Degree of Doctor of Philosophy

Major Field: Agricultural Economics

Scope and Method of Study: The general objective of this research was to examine farm supply cooperative inventory management performance and to identify improved inventory control strategies. The data were obtained from an inventory data of a farm supply cooperative in Oklahoma from March 2004 to February 2006. To examine the inventory performance of the cooperative, the Inventory Turnover Ratio (ITR) and Inventory Management Index (IMI) were employed. The major decisions in practicing an effective inventory management within this cooperative coincide with three major trading activities: sale, purchase, and transfer of items between the branches. Therefore, the improved inventory control strategies related to these three activities were developed in this study. A strategy called "proper inventory mix" was implemented to the sale activity; a strategy based on economic order quantity was applied to improve the purchasing activity; lastly the centralization storage model was applied in making a better decision in transferring items between branches activities.

Finding and Conclusions: The inventory performance of each group of items found to be varied significantly within the group and among the groups of items. The average ITR for the entire cooperative was 3.58 and the average IMI was 0.46. This finding indicates that the cooperative needs to improve its inventory turnover as well as its gross margin. The improved sales strategy was found to significantly increase the performance of some groups of items. The improved purchasing strategy was found to significantly reduce the ordering costs and the holding costs. The stocking locations strategy was found to reduce the total distance to transfer the items, hence decrease the transportation cost. Despite of all the improvement in inventory performance due to the implementation of improved inventory control strategies developed in this study, it can be concluded that there is no single "ideal" inventory control system that can be applied to every item, hence further research is needed to ascertain a better inventory control system for individual items or group of items.

Advisor's Approval: Dr. Phil Kenkel