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WAREHOUSING AGRICULTURAL INPUTS IN MICHIGAN: AN ECONOMIES OF SIZE AND LOCATION ANALYSIS

By

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ABSTRACT

WAREHOUSING AGRICULTURAL INPUTS IN MICHIGAN: AN ECONOMIES OF SIZE AND LOCATION ANALYSIS

By

Lynn Wayne Robbins

The Michigan Farm Bureau Services' Farm Supply Division predicts that demand on their warehousing system for agricultural input supplies will increase markedly over the next five years. This estimate presents the Farm Supply Division with a potential problem because their expansion possibilities are somewhat limited and they suspect that the current warehousing facilities may be approaching maximum capacity.

The Farm Bureau contracted this research to compare projected future assembly, distribution, and warehouse cost functions for the current system to those of a one-warehouse system at each of seven proposed alternative sites. They feel that these comparisons will provide them with the information necessary to decide whether to invest in a one-warehouse system, and where the ideal site for that system might be.

The research contract provided an opportunity to apply theoretical constructs to applied agribusiness problems within real-world constraints using a unique combination of research techniques. A modified lockset model was used in conjunction with an economic-engineering systems-simulation technique to discover values required to calculate internal rates of return.

Transportation costs were separated and analyzed as assembly and distribution costs. The modified lockset model was used to calculate distribution costs for the seven proposed one-warehouse locations once it could adequately duplicate the current system's behavior structure. Costs for assembling products from other than backhaul suppliers were drawn from manufacturers' freight rate schedules.

Warehouse operating costs for the one-warehouse system were synthesized by constructing a model of its expected behavioral design. Required construction parameters included storage, delays, ordering intervals, and other factors dynamic by virtue of their memory or feedback characteristics. A systems simulation model was used to estimate these parameters because of its advantage, relative to other techniques, in estimating dynamic interrelationships. The remaining exogenous parameters were obtained from Farm Bureau Management and manufacturer estimates.

The economic-engineering systems-simulator that resulted was validated when it demonstrated its capability to satisfactorily trace the costs and related behavioral characteristics exhibited by the existing warehouse system. The one-warehouse system's operations model was constructed by updating parameters in the existing system's model to reflect differences predicted for a one-warehouse facility.

Finally the transportation and warehousing analyses were evaluated together with a range of investments that would likely be required for the one-warehouse system by calculating internal rates of return. The product of this process provided Farm Bureau with information that will assist them in their decision to accept or reject the one-warehouse system.

The final investment decision should depend on how well the calculated internal rates of return compare to Farm Bureau's cost of capital. The study did show, however, a cost advantage for a one-warehouse system that provides service equivalent to that available in the existing system. This entire advantage stems from labor, inventory, and related variable cost-savings.

Transportation cost calculations exhibited an advantage for the one-warehouse system in assembling products, but demonstrated an offsetting disadvantage for distributing products to dealers. Models of the seven proposed one-warehouse locations displayed essentially equivalent transportation costs which leaves resource availability and management preference parameters with relatively more importance in site selection than would have otherwise been the case.

Limitation on current warehouse expansion was shown to be a problem. Major modifications will be required in the current system before 1980 unless the Farm Supply Division accepts substantially higher stock-out rates than they have in the past.

Despite the fact that capacity limitations will be a problem for the current system in the future, the model demonstrated a possible savings in the present for the existing system by reducing inventories. A general inventory reduction of 15 to 20 percent would reduce inventory carrying costs more than it would increase costs of lost sales.

Other findings include:

1. Despite inventory consolidation, the one-warehouse system would not assemble larger quantities of products than would be assembled in the current system, under similar demand conditions.
2. Demand predictions in dollar terms did not necessarily reflect equivalent percentage increases in volume terms.

Finally, the results give strong indications that the economic advantages of a one-warehouse system justify the required investment.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

Page

LIST OF TABLES v

LIST OF FIGURES vii

Chapter

I. INTRODUCTION 1

Problem Setting 1
General Needs Analysis 2
Expected Needs 3
Current Needs 5
General Problem Statement 8
Research Objectives 10
Nature of This Study 10

II. THEORETICAL BACKGROUND AND LITERATURE REVIEW 13

Efficiency Considerations 13
Formulation of a Theoretical Framework 15
Length of Operation, Rate of Output, and Scheduling Variables 19
Assembly and Distribution Cost Functions 23
Continuous Analysis 24
Discontinuous Analysis 29
Estimation of Plant Cost Relationships 35
Descriptive Analysis 35
Economic Engineering 37
Systems Simulation 41

III. VARIABLE TRANSPORTATION COSTS 43

Variable Distribution Costs 44
Historical Description 44
The Model 48
Model Verification 50
Results 53
1979-1980 Analysis 56
1979-1980 Results 58
Variable Assembly Costs 60
Total Variable Transportation Costs 64

Chapter		Page
IV.	VARIABLE IN-WAREHOUSE COSTS	69
	The Nature of the Simulator	69
	The Modeling Procedure	73
	Fundamental Data	75
	General Model Description	79
	Analysis Process	82
	Model Verification	87
	Results	91
	Inventory Strategy Costs	91
	Estimated Parameters	96
	The One-Warehouse System	96
	The 1979-1980 Simulator	101
	Simulator Results With Projected Demands	102
	Warehouse Size Alternatives	111
	Construction Timing	115
V.	INVESTMENT ANALYSIS	118
	Cash Flows	119
	Evaluation Interval	129
	Return on Investment	131
	Sensitivity Analysis	135
VI.	SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	139
	Summary	139
	Conclusions	144
	Recommendations	145
Appendix		
A.	DEALERSHIPS AND BACKHAUL POINTS	149
B.	EXISTING ROUTE STRUCTURES	151
C.	PRODUCTS BY PRODUCT GROUP	156
D.	WEEKLY AVERAGE SEMIANNUAL DEALER DEMAND IN CUBIC FEET	159
E.	GENERATED ROUTE CONFIGURATIONS FOR SEVEN PROPOSED ONE-WAREHOUSE LOCATIONS	160
BIBLIOGRAPHY		169

LIST OF TABLES

Table		Page
1.	Classification of Yearly Fixed and Variable Transportation Costs for the Michigan Farm Bureau	47
2.	Weekly Cost and Capacity Averages: A Comparison for Verification with 1972-73 Fiscal Year Data	52
3.	Modeled Weekly Variable Distribution Costs for 1972-1973	55
4.	Projected 1979-80 Warehouse Demands in Cost of Sales Dollars	57
5.	Modeled Weekly Variable Distribution Costs for 1979-1980	59
6.	Predicted Farm Bureau Product Demand Increases in Cubic Feet from 1972-73 to 1979-80	61
7.	Products with Variable Inbound Freight Rates	62
8.	Variable Inbound Michigan Freight Rates	63
9.	Total Variable Transportation Cost Comparison, 1972-1973	65
10.	Total Variable Transportation Cost Comparison, 1979-1980	66
11.	Initial Simulator Parameters for the 1972-1973, 1979-1980 Farm Bureau Systems' Models	76
12.	Warehouse Operating Cost Classifications for Farm Bureau's 1972-1973 System	83
13.	Monthly Inventory Levels, 1972-1973	88
14.	Desired Inventory Levels for the Jenison Warehouse, 1972-1973	89
15.	Annual Variable Cost Comparison, 1972-1973 Data	90

Table Page

16. Inventory Strategy Cost Comparison, 1972-1973 92

17. Chemical Order Size Comparison Between a One- and Two-Warehouse System Using 1972-1973 Data 100

18. Inventory Strategy Costs by Capacity and Percent of Desired Inventory Level Projected 1979-1980 103

19. Annual Warehouse Cost Comparisons Between a One- and Two-Warehouse System at Approximately Equivalent Performance Levels or Stock-Out Rates 107

20. One-Warehouse Capacity Requirements for Performance To Be Acceptable Until 1987 for Two Performance Levels and Two Demand Projections 115

21. Construction Timing for the Proposed One-Warehouse System 117

22. Warehouse Cost Comparisons Between the Current and Proposed Warehouse Systems as Predicted for 1979-1980 . . 120

23. Estimated Additions to Cost from Higher Inventory Carrying Costs in a One-Warehouse System 123

24. Estimated Savings from Lower Net Profits Lost in a One-Warehouse System 123

25. Annual Cash Flows After Taxes for a $397,600.00 Initial Investment Through 1985-1986 132

26. Internal Rate of Return and Sensitivity Calculations Through 1985-1986 for a One-Warehouse System 134

LIST OF FIGURES

Figure Page

1. Total monthly sales through the Michigan Farm Bureau warehouses for fiscal year 1972-1973 17

2. Warehousing stages 18

3. A cost surface for producing a single product by varying both rate and time of operation. 21

4. Assembly route organization and road travel 26

5. Location of impound points in supply band 1, 5,000 pounds per square mile per year density level . . . 28

6. Stollsteimer's model 30

7. A conceptual Stollsteimer approach 34

8. Michigan Farm Bureau dealerships and backhaul points . . . 45

9. Sample of lockset derived routes 54

10. The general warehouse Model 74

11. Zilwaukee strategy costs for 1972-1973 93

12. Jenison strategy costs for 1972-1973 94

13. End-to-end strategy costs for 1972-1973 95

14. Zilwaukee strategy costs and capacity requirements for 1980 104

15. Jenison strategy costs and capacity requirements for 1980 105

16. The one-warehouse system's strategy costs and capacity requirements for 1980 106

Figure | Page

17. New warehouse inventory strategy costs: predicted costs versus true values 110

18. New warehouse capacity selection 112

19. Estimated additions to cost from higher inventory carrying costs in a one-warehouse system 122

20. Estimated savings from lower net profits lost in a one-warehouse system 124

21. Net profits lost 126

CHAPTER I

INTRODUCTION

Problem Setting

The Michigan Farm Bureau Services' Farm Supply Division is a $33 million a year operation. This sales figure represents 20 percent of Michigan's input supplies market. The distribution of this $33 million is divided almost equally between Farm Bureau-owned outlets, cooperatives on management contract, and independent dealers. Similarly, the $6 million in sales of farm supplies that flow through the two Farm Bureau warehouses is equally divided between the three different outlet types.

The warehouses are located at Zilwaukee near Saginaw and at Jenison near Grand Rapids. At one time the Farm Supply Division had as many as seven warehouses, but has since found the current two-warehouse system to be more economical. The warehouses are supplied primarily from the Chicago area except for instate supplies and a few supplies such as baler twine that currently come through the St. Lawrence Seaway to Zilwaukee. Both warehouses account for 35 percent of their sales in hardware and building supplies. Feed, the next largest portion of sales, makes up 31 percent of the movement at Zilwaukee but only 24 percent at Jenison. The feed moved through the warehouses is mostly specialty feeds such as pet food and feed additives from the Battle Creek plant. Each warehouse runs one eight-hour shift per day and has a five-unit truck fleet distributing supplies to dealers three or four days of the week.

The purposes of the warehouse operation are: (1) to give basic support to dealers who cannot economically justify direct shipments from manufacturers, (2) to act as a back-up source of supply for those dealers who receive the majority of their supplies from direct shipments, and (3) to break down and reship large orders.

The Michigan Farm Bureau doubts that the two existing warehouses are sufficient to fulfill the needs that they have projected for the next five years. Because of the potential for savings in a one-warehouse system and because of restrictions upon expansion within the existing facilities, they feel an economies of size and location analysis would provide the information required to make financially sound decisions with respect to these alternatives.

Specifically, Farm Bureau Management questions whether one large warehouse would be an improvement over the current arrangement and, if so, which of their proposed locations is most desirable.

General Needs Analysis

The Michigan Farm Bureau doubts the current system's capability to fulfill the needs projected for the next five years. A detailed scrutinization of those needs will provide a more precise definition of the Farm Bureau problem. An important question relates to whose needs are being determined. Needs will, therefore, be carefully labeled as to their source.

A total distribution system is required for agricultural factors of production marketed by the Farm Supply Division of Michigan Farm Bureau. Participants in the system include farmer-consumers of Farm Bureau products, dealers, warehouse employees, central management, suppliers of commodities that are backhauled, input suppliers, and affected society.

The Farm Bureau is a cooperative structured primarily to serve member-consumers. Farmer-consumer, dealer, and central management needs are, therefore, interdependent and interrelated. For this reason, a combined analysis of these three participants' activities should lead to a discovery of what they require from the system.

Expected Needs

First, a look at expected participant activities should be instructive [20].[1] It is ironic that while agriculture in Michigan and in the nation will be shrinking in terms of total farms and land in production, never has there existed a heavier demand for farm products. Consequently, Michigan farmers are motivated to increased productivity in all enterprise areas in order to meet expanded market demand for food, and to remain competitive with agricultural products from surrounding states and countries.

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[1]The following section is taken from Farm Bureau Supply Division's "Five Year Projection--July 1, 1974 to June 30, 1979" which includes statistics and projections from Project 80 + 5.

Examples of this emphasis upon increased productivity is observed in livestock, poultry, dairy products, and crop production. There are fewer milk cows, but greater milk production; less acreage, but higher crop yields; fewer layers, but more eggs per hen. The trend toward a reduction in the total number of farms will continue, but individual farm operations will increase in size and complexity, thus requiring greater capitalization and specialization.

Currently, the Farm Bureau organization can provide better quality or lower cost marketing services to farmers than farmers could provide for themselves. As farms continue to increase their size and capitalization, comparative advantages may shift from the cooperative to the farmer and vice versa. The cooperative must recognize the possibility of such shifts and adjust to meet them. Despite these shifts in comparative advantage, the expected increased output from all farm operations will provide significant opportunities for a growth in product volume and services in all departments of the Farm Supply Division. There will be increased demands for fertilizer materials, pesticides, feed products, and building materials. In this connection, a major objective of the Farm Supply Division will be to capture a greater share of the expanding farm supply market by increasing market penetration through improvements in the cooperative's distribution system while maintaining the cooperative purpose.

The Farm Bureau's traditional means of moving farm supply inputs to farmers through local elevators will continue as the primary system of distribution. However, as individual farm operations increase in size and scope, there will be an economic and competitive necessity to serve these farmers on a direct basis with major inputs. It is expected that feed concentrates, super-concentrates, and complete feeds will move directly from the feed mill to farmers; and that farmers will be equipped to handle full truckloads of fertilizer from manufacturing sources.

Projections to 1980, therefore, indicate that the market for farm supplies will continue to expand the potential of Farm Bureau Services. As a result, Farm Bureau expects a similar increase in demand for the products and services provided through its warehousing system.

Current Needs

Requirements or needs arising out of predicted situations have been discussed. The more current needs, those reflected by the existing system, have yet to be presented.

Supplies are stocked in warehouses and dealerships or ordered as customers need them. Goods may be shipped directly to dealers either on Farm Bureau carriers or on suppliers' carriers. Goods may move to warehouses where they are later transported on Farm Bureau trucks to dealerships. Warehouse shipments are also used as backup sources of supply for those dealers who are mainly direct shippers. Finally, warehouses act as layover points where large orders are disassembled, reassembled, and reshipped.

Other Farm Bureau activities not previously discussed reveal some additional participant needs. For seasonal or infrequently purchased supplies, farmer-consumers buy inputs from Farm Bureau dealers on an order basis. Regularly required items, on the other hand, are usually on stock in stores. Farmers, therefore, expect easy accessibility to dealers, no unreasonable delays in order delivery, stocking of regularly required items, competitive prices, as well as good quality merchandise and service. Farm Bureau's role in this system is one of factor-supplier and competitor. They establish dealerships in rural areas in order to create a competitive atmosphere that hopefully will lead to reasonable prices.

Because dealers are the means used by Farm Bureau to serve their consumer-members, Farm Bureau's needs will reflect farmers' needs. Dealerships, therefore, must be distributed so as to be accessible to Farm Bureau members. They need satisfactory transportation services for assembly and distribution. They require disassembly, storage, and reassembly marketing functions as well as methods for contending with partial or nondirect shipment dealers.

Dealerships have been referred to in this discussion as if they and Farm Bureau were one and the same. Although most dealerships are vertically integrated with Farm Bureau through ownership or contract, some dealers are completely independent. These dealers would, therefore, have needs in addition to those already mentioned. They deal with Farm Bureau because of the market mechanism. They must feel that Farm Bureau can supply them with merchandise at a lower price, with better service, or with some other favorable combination. Independents, then, require a reliable source of supply. Here is a point where the participants' needs may conflict if a radical change is made in the existing system. For example, it may be that those independents who come to the current warehouse location for supplies cannot be economically included in a delivery route, should changes in warehouse locations be implemented.

Similarly, warehouse employees, backhaul suppliers, input suppliers, and affected society are participants whose needs, although overlapping to a great extent, may conflict with Farm Bureau's management should a move be required.[2]

Employees need jobs and job security which is a cost that may not be continually justifiable in the eyes of Farm Bureau. Backhaul suppliers are those firms who happen to produce goods required within the system and who happen to be located near a delivery route so that Farm Bureau carriers do not have to return empty. They could easily have needs and, therefore, policies that would conflict with the Farm Bureau System's need to backhaul rather randomly. A similar statement holds for input suppliers. Input suppliers, of which backhaul suppliers are a part, are those firms who supply Farm Bureau with commodities to market. Participants found at the interface between Farm Bureau and the rest of the system have been classified as affected society.

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[2]This is not to say that management, dealers, and consumers would not also have conflicting needs. It does imply, however, that their conflicts are likely to be less restrictive to eventual implementation of a system alternative than those of independent dealers, input suppliers, and warehouse employees.

This group includes those regions within Michigan whose needs to maintain their employment and income, conflict with Farm Bureau needs.[3]

Although a number of the needs discussed are outside the immediately researchable scope of this study, they are not to be ignored. To do so might invalidate otherwise sound system-improvement strategies. This research will model the obvious Farm Bureau needs. Border needs will, however, have a major impact in determining the constraints within which the model must work.

The heuristic nature of the needs analysis must also be stressed. As the research progresses, new needs may appear that are not at first apparent. Constantly recycling the analysis process will provide a vehicle for discovering the central issues in the crux of Farm Bureau's problem. When the crux of the problem is revealed, more appropriate solutions will naturally follow.

General Problem Statement

The problem is to discover a low cost, highly efficient technology for the assembly, storage, and distribution of agricultural inputs that will expand the throughput capacity of the existing Farm Bureau system. Total discounted costs and investments must be kept low without losing, and hopefully gaining, market share and total discounted sales volume. Simultaneously, dealer prices must remain competitive

[3]For example, the moving of a warehouse by Farm Bureau would conflict with employees' needs as well as the needs of the particular region being abandoned.

from month to month and year to year, avoiding soaring costs due to inventory mixes not being compatible with consumer tastes and preferences.

If these conditions can be met, farmers should be able to increase their productivity and remain competitive. At least Farm Bureau can keep their sector of the input supply market from contributing to a lessening of that competitive position. As a consequence of achieving this desired state, Farm Bureau should be rewarded with an improved competitive position in the Michigan agricultural input market.

It is also important to study the potential of the existing system, although this alternative does not meet the central objective of increasing the system's throughput. Indeed, if the existing system did meet the objective of increasing throughput, the problem, as it was previously described, would not exist. Because, however, the "expectation" of increased demand is the motivation behind the need for an analysis rather than a "current" felt need, it is quite possible that the existing system could exhibit increased throughput. On the other hand, it is not obvious that it would be the best alternative available. Knowledge is needed for planning future contingencies. The question might more appropriately be stated as: Is the existing system sufficient to fulfill expected needs, and if not, what superior alternatives exist?

Research Objectives

These objectives outline the major accomplishments to be achieved by this research.

1. Determine the cost of distributing supplies to the 96 dealers placing the highest demand on Farm Bureau warehouses while backhauling supplies from the 11 most active backhaul points (a) from the two existing warehouses and (b) from each of the seven proposed one-warehouse locations.
2. Compare the assembly cost structures for the existing facilities to each of the seven proposed one-warehouse locations.
3. Calculate operating cost structures (a) for the existing facilities in 1972-73 and (b) for the existing facilities as well as a one-warehouse facility in 1979-80.
4. Conduct an investment analysis comparing the current system to the proposed one-warehouse system.

Nature of This Study

Although numerous doctoral theses use a company-specific data base, few are built directly around contracted research. Although this process imposes additional restraints on the researcher, it is possible that research applied to actual business situations can result in an effective means of demonstrating the usefulness and validity of theory.

Dobson and Matthes, for example, describe university research as inadequate because it is often either too technical to be interpreted, or not timely enough to be useful. This research project is confronted by both of these problems. Results, as well as all other information communicated to managers, must be clear and straightforward. This means keeping to a minimum of mathematical formulae and disciplinary jargon. It also requires constant surveillance of legal, political, social, and physical feasibility with respect to research and social implementation. Without this surveillance, theoretically valid solutions may be proposed that are not realistically valid. It may be, for example, that the elimination of many marginal Farm Bureau dealerships would lead to cost minimization for the warehouse operation. Politically, however, this solution would be infeasible for an agricultural cooperative whose goals emphasize member service.

The importance of the timeliness factor was demonstrated by two Farm Bureau requests for relatively rough approximations rather than waiting for the final results. Such requests require schedule readjustments that allow concentration on areas that were either previously not scheduled or set for a later time.

Grayson extends Dobson and Matthes' argument for increased firm-university intimacy by relating his experience as Chairman of the Price Commission. In his opinion, "Managers and management scientists are operating as two separate cultures each with its own goals, languages and methods. Effective cooperation and even communication between the two is just about minimal" [12, p. 41]. He points out that management scientists want to help managers produce more explicit decision-making through scientific methodology. Managers, on the other hand, "make and implement decisions largely by rough rules of thumb and intuition" [12, p. 42]. These positions obviously are not compatible. Grayson discovered what he thought were the reasons for this incompatibility. When "putting together the Price Commission, [he] used absolutely none of the management science tools explicitly" [12, p. 43]. He found he couldn't use them because of shortage of time, inaccessibility of data, resistance to change, long response time, and invalidating simplifications.

It seems, therefore, that the agribusiness industry and related departments in our colleges and universities have two random sets of nearly nonoverlapping activities. This research will attempt to adjust economic, marketing, and management tools from the university to industry problems within the industry constraints. This should be possible, because, unlike firm managers, the university researcher is free to contend with technique inadequacies without interference from the firm's day-to-day responsibilities. Once implementation techniques are developed, however, managers should be able to apply them in the face of constraints such as those suggested by Grayson.

CHAPTER II

THEORETICAL BACKGROUND AND LITERATURE REVIEW

The theory and literature related to this research is presented in three parts. Because this study is concerned with Farm Bureau's assembly and distribution functions as well as their warehouse operations, the theory and literature related specifically to those functions is discussed separately. In addition to the specific operations, points of importance pertaining to the system as a whole are also reviewed. These more encompassing considerations will be presented prior to the points specifically relating to either product transportation or warehouse operations.

Efficiency Considerations

Equating marginal revenue product and marginal factor cost determines the combination of inputs that will most efficiently yield the greatest output in terms of price. Neoclassical economics often assumes that price or allocative efficiency is calculated using a production function that, within environmental constraints, will yield the greatest output for any set of inputs. The best existing production function in these terms is said to be technically efficient[4]

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[4]These efficiency definitions come from Ben French's review of agriculture production literature whose framework of approach is loosely followed in this and the next section.

[10, p. 3]. Firms failing to equate marginal revenue products and factor prices could be technically efficient, but would not be allocatively efficient. Applied economists should not forget that the objective is to discover allocative optima by using the most highly efficient production function in technical terms. It follows then that the researcher's first concern should be with definitions of production functions that are at or near technical efficiency.

Technical efficiency is of prime importance especially in the warehouse cost portion of this study. The search will be for technical as well as allocative optima.

Another Farm Bureau concern is warehouse size. French [10, p. 3] has shown that it is possible to calculate allocative optima with a nontechnically efficient production function. He also points out that it is possible to calculate allocative efficiency on technically efficient production functions for nonoptimally-sized firms. This research seeks results that will help the Michigan Farm Bureau move closer to optimums in technology, factor allocation, and size. This intention was expressed earlier as a desire to discover a low cost, highly efficient technology for the assembly, storage, and distribution of agricultural inputs that will expand the throughput capacity of the Farm Bureau system.

Although the Farm Bureau is interested in improving efficiency with operations that approach optimal size, they must do so within boundaries defined by other economic factors. Factors such as nonhomogeneity of product, quality of management and labor input, and personal preferences are not easily measurable but constrain improvement more than would initially appear to be the case.

This study is especially concerned with the assembly, storage, and distribution operations within the warehousing enterprise. Although it would seem desirable to optimize the efficiency in each of these operations separately, a systems approach may dictate differently. The systems approach "focuses on the performance of total systems, with clear recognition that the optimization process may require some trade-offs in efficiency among subsystems" [10, p. 3]. Because the assembly, distribution, and warehouse cost functions are likely to be calculated, using independent research techniques, a good deal of subjective judgment will be required to avoid excluding the important nonlinearities that may exist between them.

Formulation of a Theoretical Framework

Within the Farm Bureau organization, there are variables of importance other than input and output rates. Time, space, and form dimensions are also important and cannot be ignored. Farm Bureau transforms the products of input manufacturers into intermediate products characterized by changes in form, to some degree, but mostly by changes in location and timeliness of availability.

The Farm Bureau marketing system differs from a purely manufacturing process in that its definition of the product emphasizes time flow of inputs and outputs. The product of the Farm Bureau Warehouse, therefore, is almost entirely service. When nearly all of a product is in the form of convenience of location and availability, output becomes difficult to measure. Input-output flow is important because of the seasonality of demand (see Figure 1) and the nonvariability of labor. Because Farm Bureau's unionized labor force is paid for time on the job, not time worked, and because the range of labor variability is small at each level of employment due to union policy, any continuous cost function must be regarded as an approximation of the exact cost-output relationships adopted for ease of manipulation.

> If stages and production lines are approximately defined to be independent except for the flow of materials between them, each may be thought of as having its own production function [10, p. 12].

> What is required is a stage by stage examination of alternative techniques and a selection of a set of techniques which minimize costs of producing any volume of marketing services, given the environment within which the firm must operate. Aggregation over stages then defines the optimum combination of factors [10, p. 14]. [see Figure 2].

In relation to this aggregation process it is important to point out something that French may have implied but did not overtly reveal. Total warehouse efficiency may not be optimized when the optimal functions from each stage are aggregated because a bottleneck may occur that would be more costly than combinations that include some nonoptimal technique-using stages. For example, the technique that optimizes input-output relationships in the unloading stage may cause inefficiencies when combined with the optimum stowing technique. This might occur if the first-stage flow was much faster than that in the second. Combining these stage flows could easily lead to product

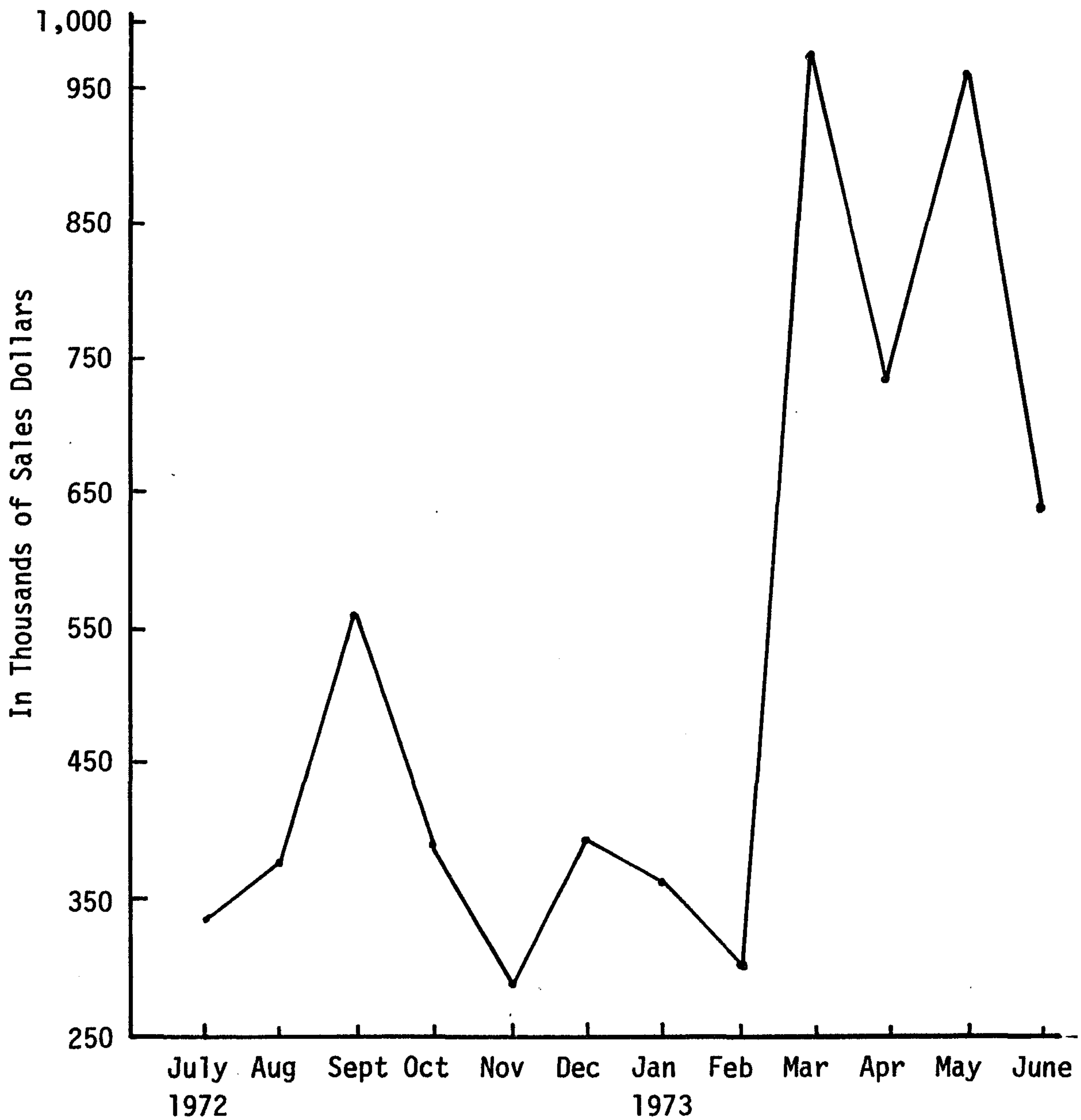

Figure 1. Total monthly sales through the Michigan Farm Bureau warehouses for fiscal year 1972-1973.

Source: Statement of operations and margins.

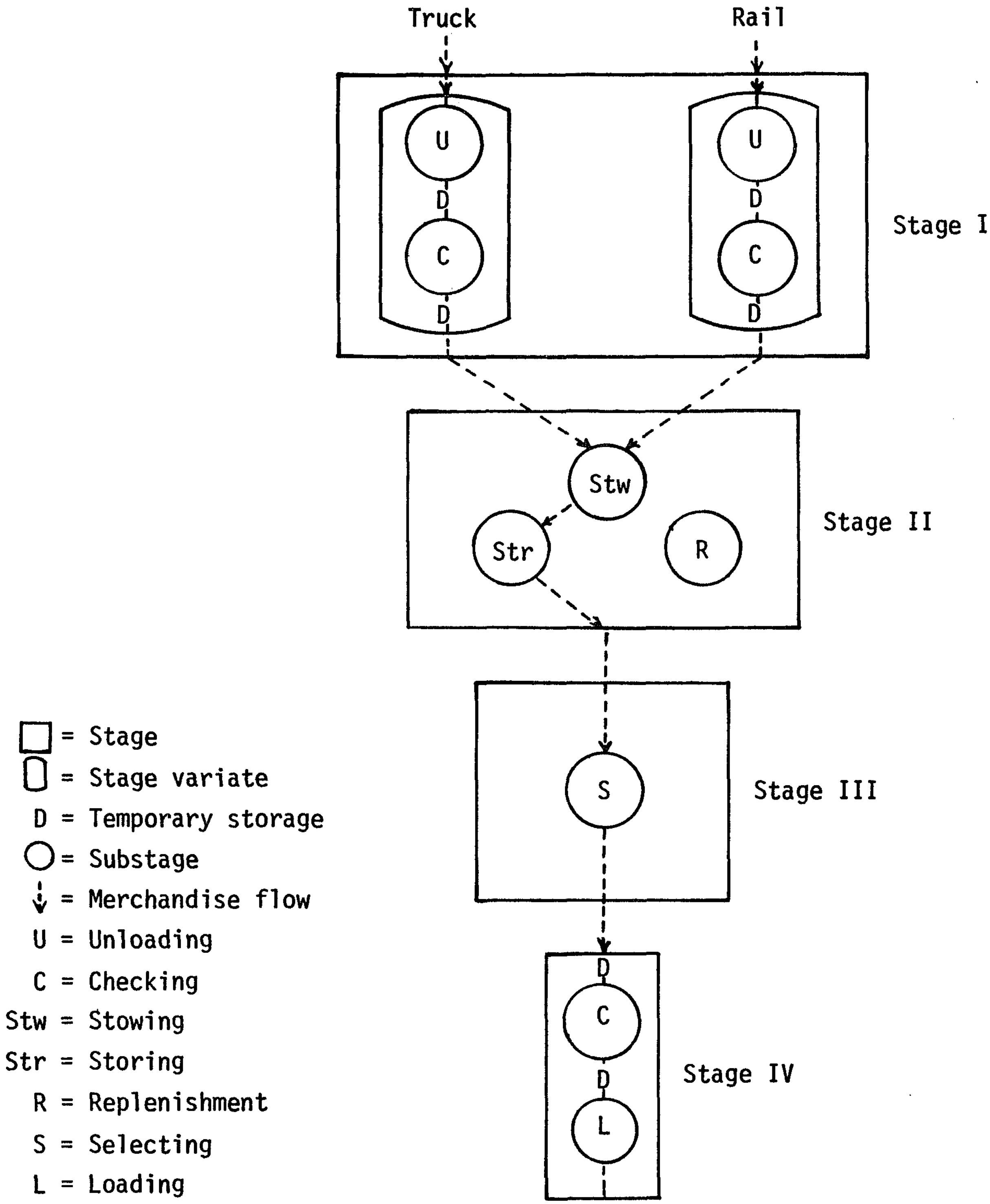

Figure 2. Warehousing stages.

stacking that would slow the stowing and possibly the unloading process. By remaining continually aware of possible nonlinearities, the stage-level production and cost functions can be of use given nonlinearities that are either measurable or obviously insignificant.

In the above example, a systems approach would help to alleviate such a problem by examining the trade-off between using the optimum stage technique at a slow rate or a slower unloading technique. This slower technique could be nonoptimizing for the stage alone but optimizing for the firm as a whole. The approach should also help to uncover other interdependencies. It may not, for example, be appropriate to treat the unloading and loading functions as separate entities. In reality, a loading technique may exist that would increase both loading and unloading productivities by leaving the men less fatigued after completing the loading process.

Length of Operation, Rate of Output, and Scheduling Variables

Firms change their rate of operation by increasing the operating speed of the existing technology or by adopting faster techniques. It is also possible, however, to work at a constant rate but for a longer period of time to achieve increased output. This length of operation variable, often not overtly discussed in neoclassical economic theory, is important in empirical work. Length of operation is of crucial importance in determining short-run cost functions and optimal plant size.

Analysis of the length of operation variable has not been ignored in economic literature. French, Sammet, and Bressler [11], point out that length of operation may have a linear cost function, while output rate is more conventionally curvilinear (see Figure 3). This implies that managers should adjust length of operations while holding rate at its cost minimizing level.

Nonlinearities in the cost functions with respect to length of operation might, but would not necessarily, occur because of fatigue or union restrictions on minimum pay or overtime. At Farm Bureau warehouses, lengthening operations may also introduce nonlinearities between the warehousing and the distribution or assembly functions. More tractors, trailers, and other distribution equipment may be required if, for example, the rate or length of operation in the distribution phase cannot be increased to handle increased warehouse output. A similar situation is also possible in assembling products into the warehouses. The entire system, including suppliers and dealers, might have to adjust to such a change but not be able to make that adjustment in the form of increasing their own length of operation.

A systems approach is important when looking at the interrelationships between stages of production. French refers to this need in terms of the interrelationships between time periods of production. He states that interrelationships in the state of the marketing system between periods may restrict output variation.

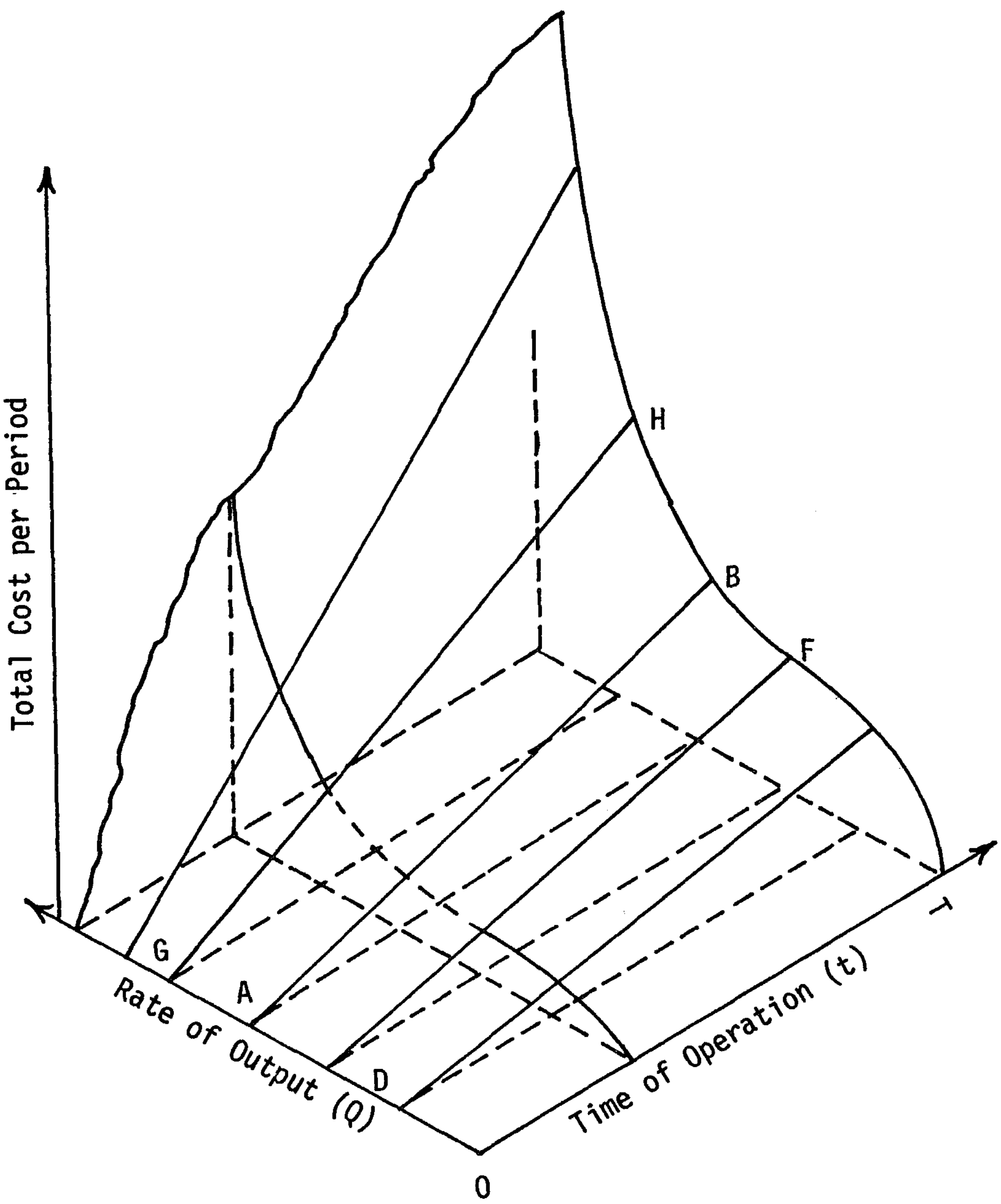

Figure 3. A cost surface for producing a single product by varying both rate and time of operation. Storage costs are assumed zero. [Source: 6, p. 560.]

"Thus, the optimalization process must be developed with respect to a sequence of decisions, rather than independently for each period" [10, pp. 23-24].

In theory, the various size plants on an envelope curve are assumed to operate at a uniform rate of output. With seasonal demand for services, however, the same quantity of services cannot be produced with each time period. With the constant length of run that is also normally assumed, theory often cannot explain such a problem. Firms, however, may be able to adjust their short-run length of operation in order to maintain a uniform output rate.

If a constant length shift is desired, a firm may decide not to change its length of operation. A constant rate of output can be maintained, however, because of the importance of timing or scheduling. Scheduling is a third variable beyond rate of output and length of operation. It has at its base an interrelationship between time periods that requires the related optimization process to be developed with respect to a sequence of decisions. The scheduling variable not only requires optimization over a set of fixed length time periods but also the optimization with respect to the length of each time period.

Warehouse workers during periods of high demand will work almost entirely at the basic functions of unloading, stowing, selecting, and loading products. In slack demand periods they will work on non-basic operations such as rearranging products and cleaning up spills. The length and timing of each task is varied, not the length of the total daily operation.

Again, it is possible to manage a constant output rate because of nontime specific or nonbasic tasks. Operations of this type, including overall management, some record keeping, cleaning, and maintenance, are those tasks not organized sequentially around materials flow. These tasks need not be completed at a specific point in time, instead, they need only be completed within some reasonable time span.

In essence, the scheduling variable changes the shape of the production function. To maximize over this variable is to search for the optimal combination of sequential and nonsequential tasks each day.

Assembly and Distribution Cost Functions

The discussion thus far has been in terms of theory and its empirical application to the problem as a whole. The emphasis will now shift to the transportation system. The overall transportation problem concerns distribution and assembly patterns, technologies, and plant location.

Assembly and distribution cost functions which address these issues have been analyzed using many operations research techniques. Among the several approaches found in the literature, linear programs and dynamic programs such as the transshipment model [2, 13] and Locksett method [23] abound. No one single approach, however, has been found to adequately handle the combination of complexities unique to this study. Problems of (1) tracking trucks so they will finish distributing near a backhaul point or warehouse, (2) irregular dealer demand, (3) sending partial loads, and (4) not being able to assume away fractional truck loads are some of the more troublesome to this research.

French perceives the general problem when he indicates that "because of still unresolved difficulties in handling the more complex routing problems, solutions in practice have typically been of a trial and error nature" [10, p. 37].

If he can make this statement in general without direct reference to the Farm Bureau complexities, one is inclined to believe that some optimizing simulator or Monte Carlo technique may be required in this research.

Basically, however, the transportation problem has been approached in two ways by researchers. Models solve this type of problem by either assuming continuity or discontinuity of space. In this case, a continuous space assumption would indicate that the volume demanded from Farm Bureau Warehousing Service is distributed evenly over Michigan [18, 1, 6, 26, 21]. On the other hand, if a discontinuous demand was assumed, the exact location of the volume demanded would become important [15, 17].

Continuous Analysis

As a representative of the group that takes the continuous approach, a selective review of J. P. Williamson, Jr., "The Equilibrium Size of Marketing Plants in a Spatial Market" should be instructive.

The intent of his paper is to show "how the equilibrium size of marketing plants located in a spatial market depends upon market density" [26, p. 953].[5]

Three assumptions that he makes are crucial for analyzing the usefulness of this approach in this study. First, it is assumed that uniform marketing exists in each producing area [26, p. 953]. To reinterpret this in distribution rather than assembly terms would be to say that uniform demand exists over each dealer area.[6] In the more general cases that these authors are dealing with, this assumption seems necessary and reasonable. To make this assumption in Farm Bureau's case would defeat the purpose of this transportation analysis because dealerships are not evenly distributed and demand by those dealers for warehouse service fluctuates widely.

Another assumption pointed out in a footnote [26, p. 954], is that a constant relationship exists between air distance and road mileage. Again, the relative unimportance of any error from this assumption in a general study becomes relatively more important in this more specific research.

Under these and other assumptions that Williamson makes, "and ignoring nonuniformity of terrain, assembly [distribution] costs will be minimized by assembling [distributing] any given quantity of commodity from [to] a circular supply [demand] area" [26, p. 964].

---

[5]The volume of business per unit of market area.

[6]French points out the appropriateness of this reversal when he speaks of "approaches used by . . . Williamson [26] [and others] . . . , will be in terms of assembly but can be reversed to apply to distribution activities as well" [10, p. 37].

A short review of two more continuous space applications should suffice to round out the description of the techniques used with respect to this approach. Boutwell and Simons [5], applied the following formula for calculating route miles (RM) once the aforementioned circle has been constructed.

$$RM = r + \frac{r}{\cos}\ \Theta + 2 \sum_{x=1}^{r} x \tan\Theta$$

where r = radius, R = the number of routes to be served, and Θ = the angle described by lines of length r dividing the circle into r equal segments.[7]

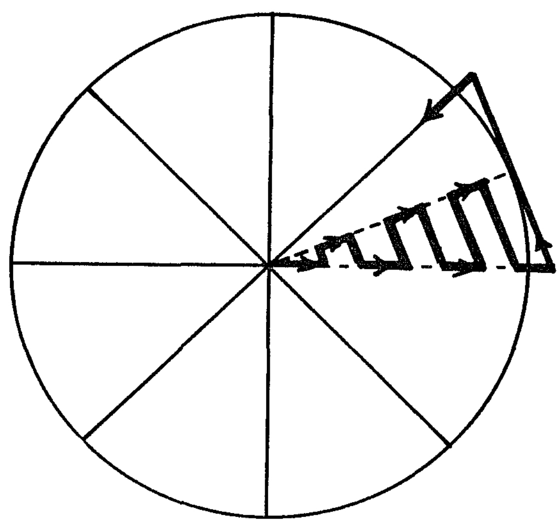

Figure 4. Assembly route organization and road travel.

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[7]Roads are assumed to follow paths similar to the arrowed line in Figure 4 [source: 7, p. 843]; and another point made by these authors relevant to the Farm Bureau research, but not necessarily relevant to this part of our discussion, is that marginal and average costs for route assembly may be constant over a considerable range of plant volume. "Route assembly can result in constant marginal and average assembly costs if addition of customers does not significantly

Henry and Burbee present "a synthetic analysis of space relationships designed to determine the net effects on assembly costs of change in (1) firm size, (2) supply density, and (3) transport distance" [14, p. 3]. They determine the size and number of crew-truck complements to achieve minimum labor inputs for each plant size from assembly matrices. They study location of broiler growing units, truck productivity in live bird transportation, labor productivity in loading live birds, and truck unloading time at the plant.

As in other continuous studies, they enclose their supply area with a circle. The area is enclosed to produce exactly the amount of poultry that will allow the centralized plant to run at capacity. They then assume that the poultry for each day's pick-up will be from one flock or gathered at an impound point from many flocks. This impound point is such that

> all the poultry in a given supply band is assumed to be located at impound points on a circle which is a certain distance inside the band. . . . Since the broilers are located evenly over the surface of the supply band, the problem is to locate a circle within the supply band which divides the area of the band (and the quantity of poultry) in half [14, p. 38].

Therefore, in a supply circle with a radius of 16.3 miles and impound point calculated to be on an inner circle with an 11.5 mile radius (see Figure 5), each day's route miles are calculated as being some function of the impound point radius.

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change the route structure and if a plant can avoid complete coverage of the area by selecting only those customers which can be added to the route conveniently" [5, p. 847].

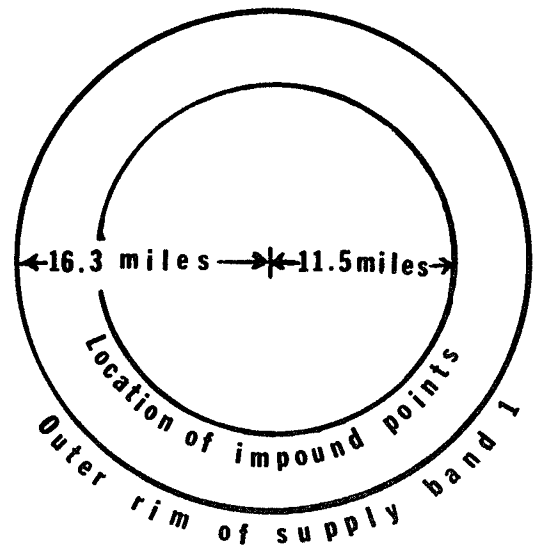

Figure 5. Location of impound points in supply band 1, 5,000 pounds per square mile per year density level. [Source: 14, p. 39.]

It should be noted that the problem of plant location is essentially assumed away in the continuous approach. Once the market circle is constructed, a one-plant firm or industry would find its optimal location at the center of that circle. The multiplant solution for optimal plant location becomes only slightly more difficult.

The continuous approach is not suited for this research because demand density is not uniform and demand areas are not regular and continuous in shape. The Farm Bureau has also limited the number of realistic choices of efficient locations and the warehouse cost functions may not be independent of these locations. These two missing ingredients are essential if the continuous approach is to be used [10, p. 88].

When taking all relevant assumptions and conditions into account, the adaptability of the continuous approach is doubtful. The following discussion and review of discontinuous studies adds reinforcement to the infeasibility of this approach for the proposed study.

Discontinuous Analysis

One of the early studies that fits this discontinuous classification was presented by Stollsteimer. Stollsteimer's model was developed to answer questions similar to those in this study. How many warehouses should there be? Where should they be located? How large should they be? Stollsteimer admits that his model does not simultaneously consider assembly, processing, and distribution costs. It will only handle processing and either distribution or assembly cost, not both when the two latter functions are distinct [24, p. 632].

The essence of Stollsteimer's model can be conceptualized graphically as in Figure 6.

He calculates minimum total processing (or plant) costs (TPC) and total transportation (assembly or distribution) costs (TTC) and sums of them. He presents two cases of economies of scale; one with plant costs independent of plant location, another where plant costs vary with location and two similar cases without economies of scale. Stollsteimer then goes on to report the effects of technical change and output expansion on the optimum number, size, and location of pear marketing facilities in a California pear producing region.

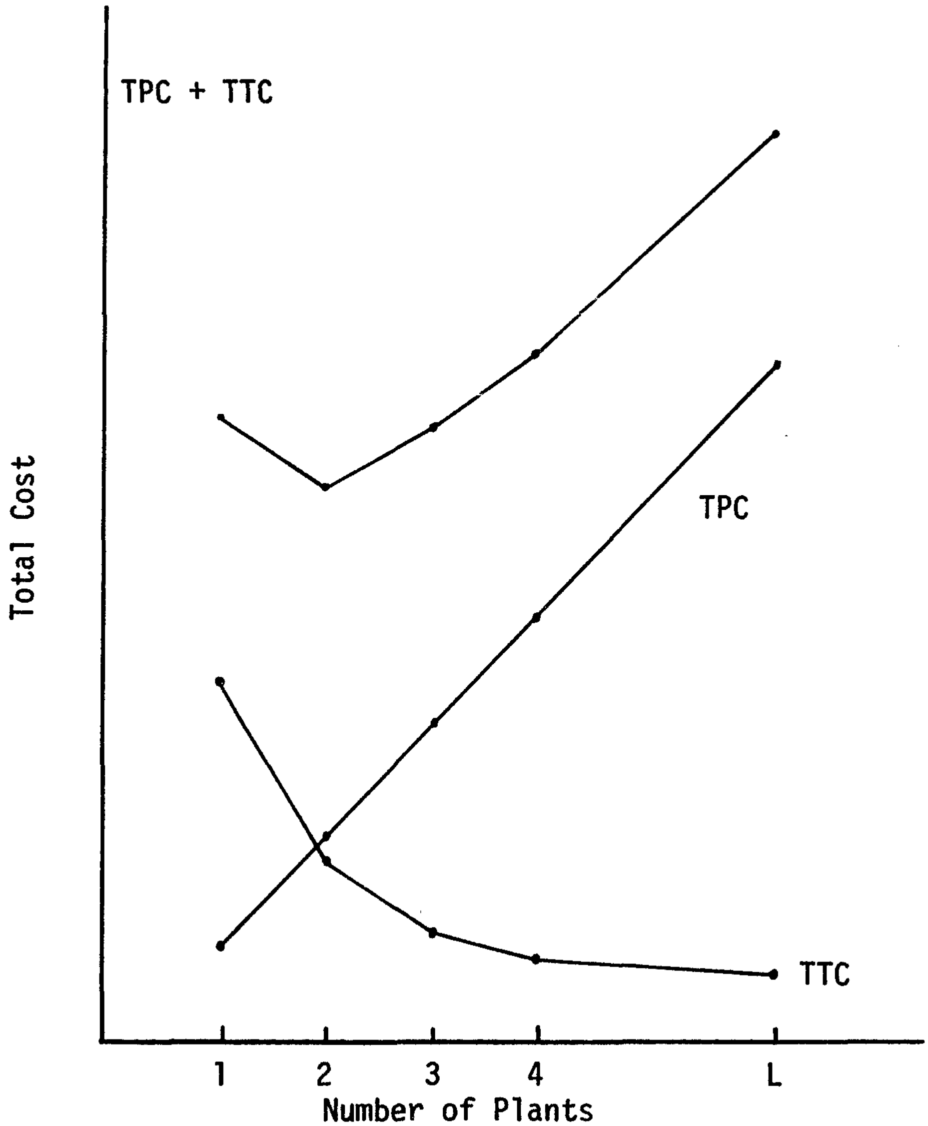

Figure 6. Stollsteimer's model.

The model has since been modified by Chern and Polopolus, Ladd and Halvorson, and Warrack and Fletcher among others. Chern and Polopolus [8] modified the model by substituting a discontinuous plant cost function for a continuous function, by drawing an explicit distinction between plant numbers and plant locations, by using their maximum plant size concept and by measuring excess plant capacity in optimal solutions. Indications were that these modifications show that the original model underestimated total plant cost. Warrack and Fletcher [25] introduced a way to solve large problems using the Stollsteimer model by incorporating a suboptimization technique. Ladd and Halvorson [16] present procedures for determining the sensitivity of a Stollsteimer model solution and the effects of continuous change in the parameters on the minimum cost solution.

Because Stollsteimer's model does not handle separate assembly and distribution cost functions, the transshipment model is used where the incorporation of both functions is important or necessary. As Logan and King first described it, the basic "transportation model is modified by specifying each production and consumption area as a possible shipment or transshipment point" [15, p. 97]. These authors were among the first to apply this transshipment approach to agriculture in their beef slaughter problem.

Because of important variables like backhauling and seasonality, a relatively simple transshipment linear program mushrooms into a bulky and cumbersome mixed integer one. Indeed, the branch and bound technique generally used in integer linear program algorithms are of such a nature that their cost becomes prohibitive as soon as they acquire any size.

The Locksett approach presented by Schruben and Clifton [23] is another discontinuous approach used to calculate assembly or distribution costs. It allows accounting for irregular demand as well as partial loads but as originally defined it does not force trucks to finish distributing near a backhaul point.

After assuming an initial solution of one round trip to each delivery point,

> the first step in the Locksett method is to compile a list of all possible pairs of points not involving the plant (or origin). . . . The second step is to compute the DSC (distance-saved coefficient) for each pair. . . . The third step is to consider joining the pair with the largest DSC on the same route. . . . The next step is to test the revised route for feasibility. The tentative pairing must meet four tests:
>
> a. Each stop must have at least one leg connected to the origin.
>
> b. Each stop must previously have been on a different route.
>
> c. A carrier of sufficient size must be available to carry the combined load.
>
> d. A carrier capable of traveling the required distance must be available [23, pp. 862-863].

Steps three and four are then repeated with the next largest DSC until all DSC pairings have been considered.

Of the discontinuous approaches reviewed only the Stollsteimer technique included the plant cost function overtly. This does not obviously preclude, however, the calculation of each cost function separately. Assembly, processing, and distribution cost functions could be calculated with the most appropriate methods available and, finally, aggregated in a manner almost exactly like the one used by Stollsteimer (see Figure 7). This would require existing nonlinearities to be obviously insignificant or quantifiable so that the final analysis could be adjusted to include them.

Although the discussion of the transportation cost functions is equally valid for assembly and distribution, the major concern in this study will be with the distribution side. More specifically, the concern is with simultaneous minimization of distribution and backhaul-assembly costs.

The justification for de-emphasizing the remaining assembly variables is found in the variables' classifications. Distribution variables are for the most part endogenous and controllable, whereas, once the warehouse location is established, assembly variables are almost exclusively exogenous and uncontrollable from Farm Bureau's point of view.

It should also be emphasized that assembly's classification as primary exogeneous and uncontrollable is not a detriment to the research but rather an advantage. Once warehouse demand is determined, assembly cost calculation becomes a straightforward task. Prices specific to location, product, volume, and timing can be extracted from manufacturers' freight rate schedules.

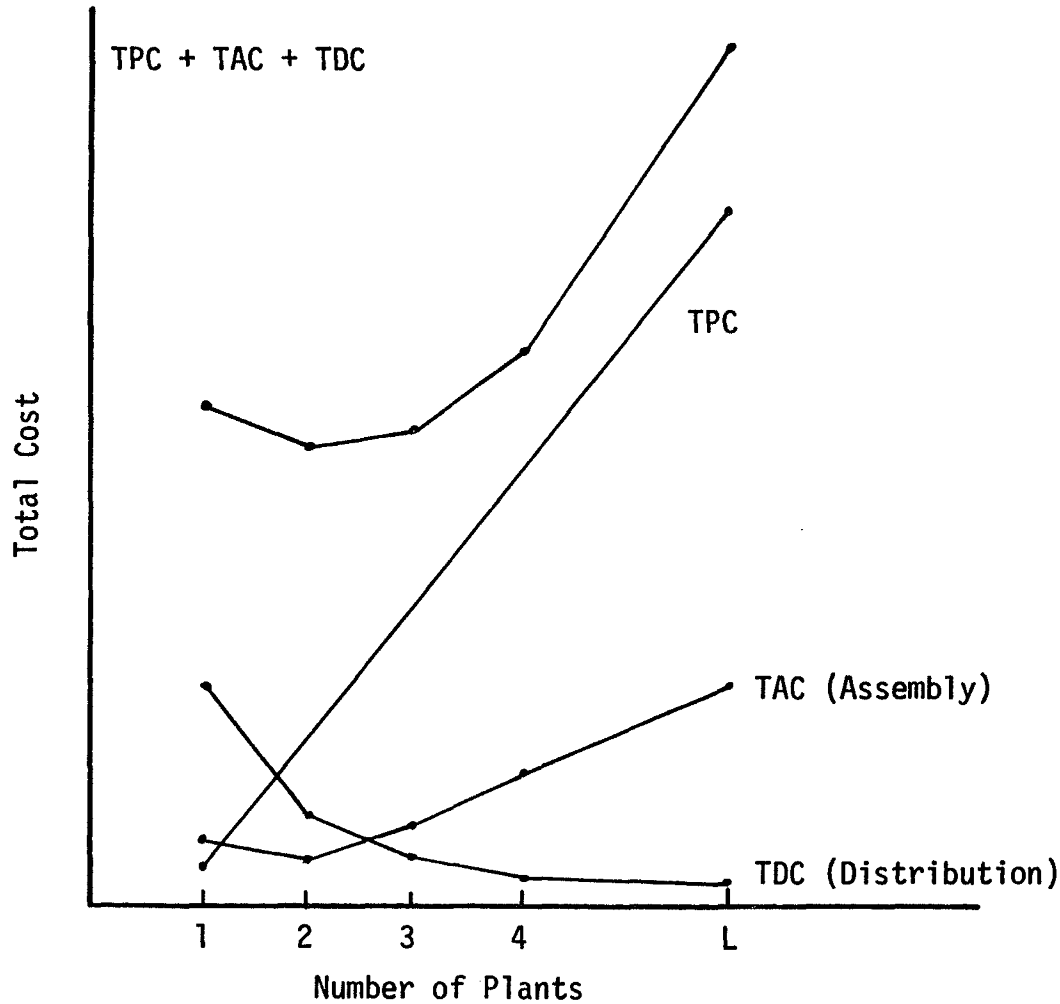

Figure 7. A conceptual Stollsteimer approach.

Estimation of Plant Cost Relationships

Approaches to estimating plant cost and efficiency relationships may be grouped into: (1) descriptive analysis of accounting data which mainly involves combining point estimates of average costs into various classes for comparative purposes, (2) statistical analysis of accounting data which attempts to estimate functional relationships by econometric methods, and (3) the economic engineering approach which synthesizes production and cost relationships from engineering data or other estimates of the components of the production function [10, p. 44].

Statistical analysis of accounting data will not be used because data are only available for the two existing warehouses. A sample of two is nowhere near the number required to do statistical estimation, especially when they are very similar in size and design. A sufficient sample would require data from numerous warehouses of various sizes.

Descriptive Analysis

Analyses of accounting data descriptively are popular for four reasons, yet, are limited in at least three ways in French's viewpoint [10, pp. 44-49]. Descriptive analyses are popular because they are: (1) relatively inexpensive, (2) easily understood by plant managers, (3) real costs not fabricated ones, and (4) inputs to more general studies once published.

This type of analysis is limited because differential accounting methods exist that may foil comparison or simply mislead a reviewer. Should this particular technique be used for the study, any data that has a potential for being misleading or misinterpreted could be reworked for the sake of clarity. In these cases, the analysis will go beyond mere description and become reinterpretation. Accountants, for example, can depreciate capital investments on an equal yearly basis or with a technique that depreciates away more of the equity in earlier years. In either case it is possible to have an item of equipment with significant market value being used in a firm long after it is officially listed at zero or salvage value on the books.

Descriptive analyses are also limited because they don't clearly identify individual factors that have influence upon the cost function. Other study techniques could, however, be used that would identify influential factors. The limitation does hold, however, for descriptive analyses alone.

Lastly, descriptions are limited because they are snapshots that give no parametric measures of functional relationships. Again, this is a limitation that would hold if the descriptive technique was to be used alone. The use of this procedure in conjunction with other less restrictive standard analytical techniques would allow insights into parametric, functional, and dynamic relationships that could not be discovered using the descriptive approach alone.

Economic Engineering

The economic engineering approach for use where accounting data are not available was originated in the early 1940's by R. G. Bressler, Jr. The original studies are listed and summarized in his book, City Milk Distribution [6].[8]

The nature of the approach is described by French [10, pp. 67-72], as consisting of four steps. The first step is systems description, where the various plant stages, their nature, and sequence of operation are determined through the use of process flow charts and job descriptions. Once this is accomplished, alternative production techniques are specified. In this particular study, the task would not likely be arduous because the range of possible technologies for this type of warehousing is limited. Farm Bureau managers are well versed in those warehousing techniques that can be operationalized with a good probability of success. Once reasonable, alternative technologies have been discovered, the third step is to estimate an overall production function by combining the stage production functions. Here, descriptive data of past performance are used as a base point for establishing labor performance standards where they are not available. The final stage is to synthesize the cost functions by applying factor prices.

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[8]Although there have been numerous economic engineering studies throughout the years, the classic study in the area was reported by French, Sammet, and Bressler [11]. The authors thoroughly described the procedure and theory behind using this approach and then applied it in their efficiency study on marketing. The economic engineering approach was used on a problem of local interest by Benjamin and Connor [3].

One of the main problems with the economic engineering approach is that it is relatively time-consuming, especially where new techniques are contemplated. Where expected procedures are similar to existing procedures, this approach should not be overly time-consuming because it would look at existing costs and how those costs might change in the new situation. Indeed, this procedure for existing technology is almost exactly like the descriptive analysis previously described with the expectation of a bit more data manipulation. Where new technologies are contemplated, however, the costliness in time is apparent. Here, operating costs must be estimated by looking at manufacturers' specifications or at the costs experienced by other companies that use similar techniques. In those instances where the researcher is forced to work exclusively with manufacturers' specifications, the task of estimating input-output relationships becomes especially difficult. The problem arises because of the joint objective of the manufacturer (i.e., that companies not only want to measure the efficiency of their machines but they also want to sell them). The practical conclusion then is that measurements are made under the most favorable environmental conditions. The researcher using this data is left with the knowledge that the data needs adjustment, but he does not have the magnitude (and possibly not the direction) of that change.

Other alleged problems with the economic engineering approach that are difficult to refute in a general manner are that it lacks findings of diseconomies "attributed to the use of constant input coefficients (especially for labor) and the inability to measure or account for coordination problems as plant scale increases" [10, p. 73]. Although these are hard to dispute in general in the specific Farm Bureau case, some doubt as to the extent of their validity may be cast. A main reason behind Farm Bureau's investigation of a one-warehouse system is their confident belief that coordination will be improved. Their concern is whether other costs will offset these expected co-ordination benefits. The other point, lack of definite pecuniary economies and diseconomies for inputs, can be more definitely refuted.

In a case where a research is dealing with one specific firm, input suppliers can be a source for the kind of price data needed. In the specific case of labor, estimates can be made by looking at the experience of other firms at each proposed location.

Studies that use the economic engineering or synthetic firm approach often do not declare that they are assuming perfect complementarity in their production functions. The assumption seems operative, however, from the manner in which they manipulate their data. They seem to implicitly assume that factors of production must be present in a certain given proportion in order to achieve given output level.

The decision as to whether or not the complementarity assumption is actually being made is mainly normative. Some economists, taking a pragmatic stand, may accept engineering data as approaching a local optimum output or a minimum cost point. To insist upon the global optimum or minimum in their eyes would be to push time and dollar budgets over the limit. In other words, engineering estimates give a place to start.

Many other economists would not be satisfied with local optima. They feel that research based on such unstudied information is misleading. The former starting point or pragmatic position could be used to explain the production functions that are used. The fact that it would be better to start by finding the high profit points on each production function is not questioned where budgets allow it.

Black [4] has pointed out that synthetic builders should be careful not to omit important aspects of cost. In the study of an individual firm the possibility of such an error should be limited. This is especially true for two reasons. First, the intricacies of a multifirm study are obviously eliminated. Second, a close working relationship with the firm in question would allow periodic reviews for accuracy. Such a firm could not afford to base an important investment decision on research results that do not include all aspects of cost.

Black also adds that "the estimates derived from synthesis are cut adrift from the standard measures of reliability" [4, p. 275]. This point should be kept in mind whenever the economic engineering approach is used, as should all of the limitations mentioned, and a continuous effort made to overcome them. In the case of validation, data should be checked against as many alternative sources of information as possible in order to gain confidence in the results.

Systems Simulation

The systems simulations design approach is similar to the economic engineering technique just discussed. It, too, can be used to model systems that are planned but not actually in existence. The simulation approach goes further than the normal economic engineering approach by exhibiting the dynamic characteristics of the system it is simulating. From another point of view, it is only a subpart of economic engineering in that it is but one method for acquiring the values and parameters needed for that approach.

According to Park and Manetsch [19, pp. 1-2], a system can be effectively simulated if it meets the following five criteria.

1. The aims or goals of the system are well enough defined so that they can be stated mathematically.
2. The major process involved can be mathematically modeled.
3. The decision-making process involved in planning and operating the system is centralized.
4. The planning horizon is long enough so that the planned process will have time to be implemented and operated.
5. The major processes have significant storage or memory effects and response delays so that they are dynamic.

This approach might be helpful in this research because of the prior discussion of time in the form of rate of output, length of operation, and scheduling. Additionally, the presence of ordering intervals, order lead times, and the need for parameter estimation dictate the need for a technique that will adequately take them into account.

The major disadvantages of the systems simulation approach is its costliness and complexity. These disadvantages follow from the fact that the basic algorithm must be built entirely by the researcher, requiring a familiarity with the system as great or greater than that required in economic engineering. This approach should, therefore, be avoided if a simpler technique could successfully meet the objectives set out for it.

CHAPTER III

VARIABLE TRANSPORTATION COSTS

Discussions with Farm Bureau Management have revealed their preference for descriptive analyses where accounting data are available. Where Farm Bureau data are not available (i.e., for costing out proposed investments), other techniques will be selected on the basis of their applicability. Justification for the approaches selected, beyond that previously discussed, will accompany the specific description of that technique.

The 1972-1973 fiscal year data were used in this and the warehouse cost portion of the research, as it was the latest available when the study was initiated. This fiscal year was selected as the base year for analysis and not updated because it had more characteristics representative of normal Farm Bureau operations than any of the more recent data that eventually became available. Since 1972-1973 and until recently, shortages in the economy have caused Farm Bureau Warehouse Management to follow procedures not previously necessary or expected, at least to such a high degree, in the future. Storage space, for example, became exceedingly more valuable because supplies, even at abnormally high prices, had to be purchased whenever they became available and stored until needed. For this reason all values presented in this dissertation are, unless otherwise stated, in

1972-1973 dollars. Instances when this procedure might cause biased results will be reviewed in the final chapter.

Variable transportation costs for the base year were calculated to include both the variable costs of assembling product into each of the two warehouses and of distributing supplies from the warehouses to all dealerships. The distinction between assembly and distribution costs must be made clear as some costs relating to assembling warehouse supplies are included as part of what will be called "distinction costs." Because of the advantage in using trucks that have delivered dealer supplies to haul merchandise back to the warehouse rather than make an empty return trip, a model of the related distribution cost system must, out of necessity, include some assembly costs. The 96 dealerships that place the highest demand on the warehouses along with the 11 most active backhaul points included in this portion of the study are listed in Appendix A and their distribution within Michigan's lower peninsula is displayed in Figure 8.

Variable Distribution Costs

Historical Description

A descriptive analysis of historical cost data are essential as a basis for comparison when analyzing alternatives for increasing the throughput of the Farm Bureau warehousing system. It will not only allow model verification through a comparison of the existing transportation cost structure and that arrived at in the computer model, but will also be the primary source of the variable cost figures and other parameters to be used in that model.

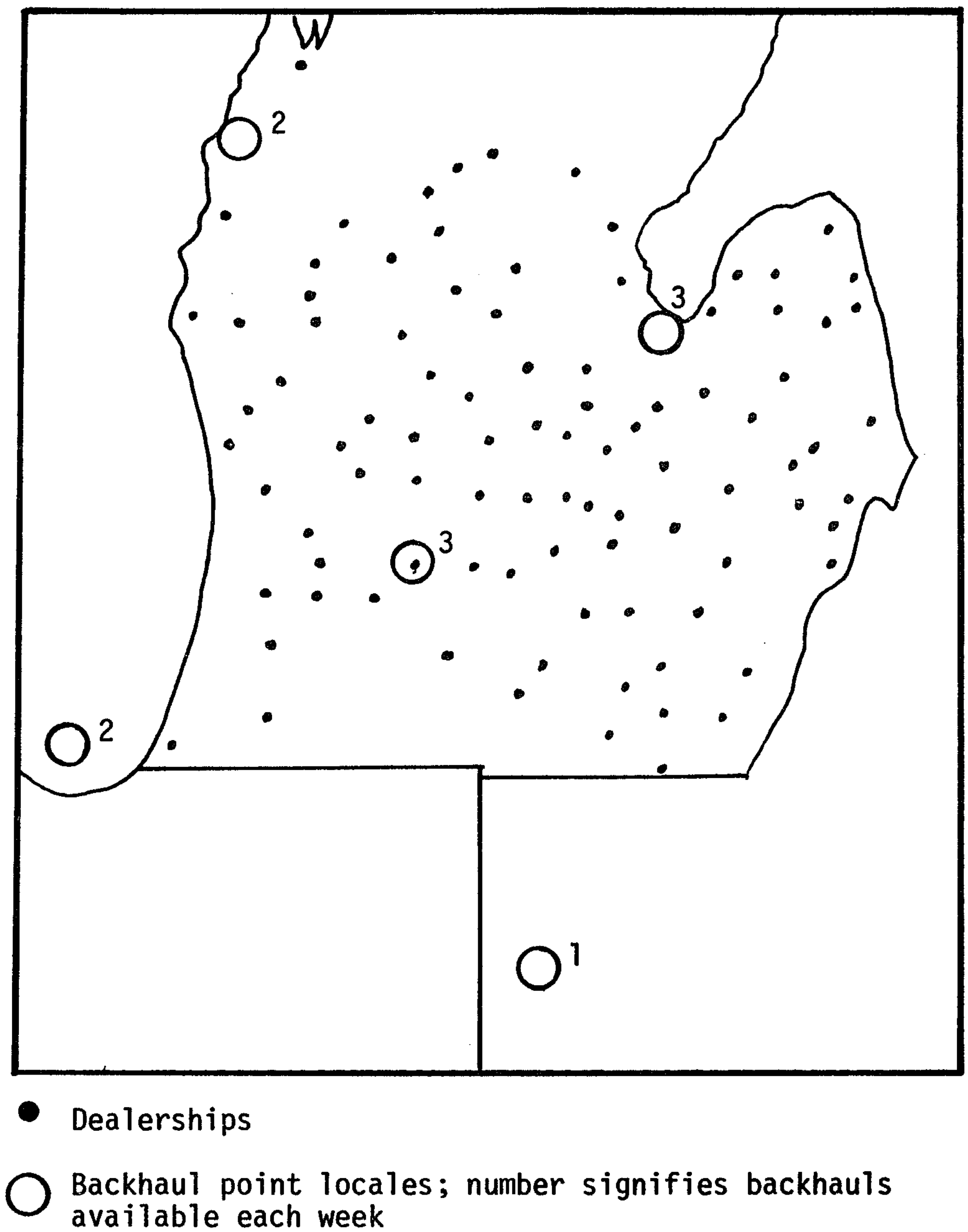

Figure 8. Michigan Farm Bureau dealerships and backhaul points.

Whenever a reference is made to variable costs, it immediately becomes necessary to explain the definition used to determine that classification. Because the distinction between fixed and variable costs depend on the length of time considered, the length of time that applies in this case must be examined. Here, the concern is with a short-run situation where only route configuration can be changed. All other variables, including plant location and technology configuration, are fixed.

The major variables that fluctuate directly with number of miles traveled include drivers' salaries, truck repairs, normal preventive maintenance, petroleum usage, tires and tubes. On the other hand, items like administrative salaries, licenses, and leasing expenditures (long-term leases with purchase options) are generally fixed within a limited range of the number of miles traveled.

Table 1 shows the fixed and variable costs taken from actual accounting data broken down as described above. With the total yearly variable costs at $156,150.00, the average weekly variable cost would be $1,253.25. With total truck miles for the year of 315,992, the variable cost per mile is approximately $0.50. Appendix B shows the existing routes with their associated demand, miles, and cost calculation.

By applying the $0.50 per mile of variable cost to the current fixed route structure, the resulting weekly variable cost is $1,606.00 for Jenison and $1,506.50 for Zilwaukee or a total weekly variable distribution cost of $3,112.50, $109.61 over the actual variable cost.

Table 1. Classification of Yearly Fixed and Variable Transportation Costs for the Michigan Farm Bureau

Expenses	1972-1973 Total Transportation Costs ($)	Average Costs (¢/mile)
FIXED COSTS:		
Payroll general	18,068	5.71
Payroll outside labor	1,143	0.36
FICA	4,145	1.31
MESC	1,743	0.55
Unemployment	230	0.07
Blue Cross	1,855	0.59
Group Insurance	879	0.28
Workmen's Comp.	2,086	0.66
Retirement & contrib.	4,349	1.38
Travel dept. head	734	0.23
Travel	1,811	0.58
Licenses	5,263	1.67
Office supplies	844	0.27
Plant supplies	1,331	0.42
Telephone & telegraph	4,042	1.28
Dues & subscriptions	486	0.15
Training	187	0.06
Outstate use tax	420	0.13
Insurance trucks	4,105	1.30
Truck lease	14,936	4.73
Tractor rental	4,736	1.50
Equipment rent	283	0.09
Depreciation trucks	10,649	3.37
Miscellaneous	914	0.29
Subtotal	85,239	26.98
VARIABLE COSTS		
Payroll trans.	76,447	24.19
Repairs & upkeep machinery	105	0.03
Repairs & upkeep trucks	34,662	10.97
Gas & oil	21,164	6.70
Tires & tubes	11,205	3.55
Truck expense	1,375	0.44
Road service	281	0.09
Normal maintenance	9,664	3.06
Trailer rental	1,247	0.39
Subtotal	156,150	49.42
TOTAL	241,389	

Source: "Statement of Operations and Margins, Transportation," June 31, 1973.

This derived cost is close to the actual weekly variable cost and leaves less than 4 percent error to be accounted for by deviations from the specified routes, errors in distances used, and other measurement errors.

The Model

The objective of this portion of the study was to build a model that would approximate the cost structure of the existing transportation system by constructing reasonably realistic routes. Once the model was verified in this manner, it was used to construct routes for proposed alternative one-warehouse systems. The total variable cost figures for each alternative were then on a common basis of comparison with the existing system.

Selecting a model that meets these objectives is not a simple task, especially because of the previously mentioned problems with irregular dealer demand, partial loads, and backhaul points. The Stollsteimer, simple transshipment, and mixed integer transshipment models must be dismissed from consideration because of oversimplifying assumptions or the high computational costs that result when they are adapted to include the above troublesome areas.

The Lockset model, however, was modified to force trucks to finish their deliveries near a backhaul point by simply adding a fifth restriction to the feasibility check. With this change it not only forced routes to properly include backhaul points but it also accounted for irregular dealer demands and partial loads. In addition to satisfying these requirements, it could be implemented without prohibitive computational time or cost.

The fifth restriction required that any backhaul point included in a route have at least one leg connected to the origin. The model was also altered to use dollar-saved coefficients so it not only reflects the fact that savings result by joining dealerships into routes but also that money is made (costs offset) by adding backhaul points to the routes.

The model divides dollar demands for each of the 16 product groups by conversion factors (see Appendix C) to arrive at cubic feet demands for each of the 16 categories by dealer. Summing the 16 product group demands give the weekly demand for each dealer in cubic feet (see Appendix D).

The individual products were divided into these 16 categories by grouping items of similar size to the extent possible. Once this was completed, conversion factors were calculated by selecting representative products from Farm Bureau's "Wholesale Location Inventory Status Report," February 11, 1974, for each product group according to three indicators of importance. A product was considered representative of a product group if it exhibited either high inventory value, large quantities on order, or frequent shipments in the prior 12 months. Conversion factors for each representative product were then calculated by dividing its size in cubic feet into the unit price. To arrive at the required group conversion factors each representative's conversion factor was weighted according to its importance within the group as indicated by dollar value. Demand in cubic feet could then be acquired from the division of each group's total dollar demand by its weighted conversion factors.

Initially, the model assumes one route for each dealer as in the unmodified model. With this as a starting point, dollar saved coefficients are calculated that indicate the number of dollars that could be saved by combining dealers to reduce the number of routes. Any dealer whose demand is greater than the maximum allowed on one trailer is listed as a round trip, one-dealer route. The residual demand is then recorded so that this dealer can later be included in a multiple-dealer route. Restrictions applied to the program keep the total cubic volume carried on one route under some maximum volume and, of course, force any backhaul component to come at the end of a route. Until a backhaul is included, the route is not directional. Once one is included, however, the route is obviously directional and must go in the direction that would put the backhaul last on the route.

This method does not guarantee the "one" minimum cost routing structure. It may, therefore, be possible to rearrange the ordering of the dealerships within a route to gain some saving. The model does, however, meet the objective of giving a common basis for comparison in evaluating alternatives.

Model Verification

In order to be valid it was necessary to construct the model so that it would approximate current average truck capacities as well as variable costs. This was important in order to have a model that reflects the current level of technology and management. Using the demand figures, calculated as previously explained, the current system showed Zilwaukee with average truck capacities of 47 percent and 48 percent and Jenison with 49 percent and 54 percent, respectively, for the first and second half years.[9] With these capacities as starting points, the model was adjusted until resulting average capacities and total variable distribution costs reflected, as closely as possible, those actually encountered in the warehousing operation.

The results of this comparison process are summarized in Table 2. Discrepancies between actual and modeled average capacities of up to 7 percent were experienced, although, the average model capacity for the system as a whole fell within 3.5 percent of the actual. The modeled average route capacities were obtained by establishing maximum capacities that would force acceptable average capacities. A 60 percent maximum for the Jenison model and one of 50 percent for the Zilwaukee model yielded the averages reported. In evaluating the one-warehouse alternative, a 54 percent maximum capacity was used. This figure represents an average of the Jenison and Zilwaukee maximum numbers weighted by the amount of demand experienced by the two.

Total weekly variable distribution costs, when modeled with the above maximum capacities, fell within 4 percent of the derived cost and were less than .01 percent over the actual accounting cost. This close fit allowed the acceptance of the modified model as a valid tool for evaluating the distribution costs for each of the seven proposed one-warehouse locations.

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[9]These averages were calculated on the current truck-trailer capacities of 2,400 cubic feet.

Table 2. Weekly Cost and Capacity Averages: A Comparison for Verification with 1972-73 Fiscal Year Data

	Average Truck Capacities		Route Costs		
	Actual (%)	Modeled (%)	Derived[a] ($)	Actual[a] ($)	Modeled ($)
First Half Year					
Jenison	49	49			1,628.50
Zilwaukee	47	42			1,378.50
Second Half Year					
Jenison	54	47			1,624.50
Zilwaukee	48	46			1,377.50
Yearly Averages					
Jenison	51.5	48	1,606.00		1,626.50
Zilwaukee	47.5	44	1,517.50		1,377.75
TOTAL	49.5	46	3,123.50	3,002.89	3,004.25

[a]The derived costs come from applying $0.50 per mile to the existing routes' miles, whereas the actual costs represent 1/52nd of the actual transportation costs reported for the year.

Results

Figure 9 illustrates a few of the route configurations that resulted from the modeling process for one of the single warehouse alternatives. In general, the model appears to be using a logical approach, although some of the connections selected may be improved upon slightly.

Table 3 lists the 1972-1973 cost results for the seven alternatives considered.[10] Examination of Table 3 reveals that only St. Johns, of the alternatives evaluated, had an absolute savings over the current system with respect to variable distribution costs in the first half year, while no one-warehouse alternative was less costly than the existing system in the second half year. An averaging of the two half years' weekly costs shows an absolute advantage for the current system, ranging from a $22.25 to a $256.75 savings depending on which one-warehouse alternative cost is used. Because of the possible errors which can be related to inaccuracies in mileages used, averaging errors, as well as other observation and measurement errors, this difference should not be classified as significant. In fact, such a small differential may have occurred as easily in the opposite direction. The conclusion, resulting from the figures, can only be interpreted as showing essentially no difference. This is made especially obvious because the highest cost alternative is only 8.54 percent above the weekly costs that occur in the existing system.

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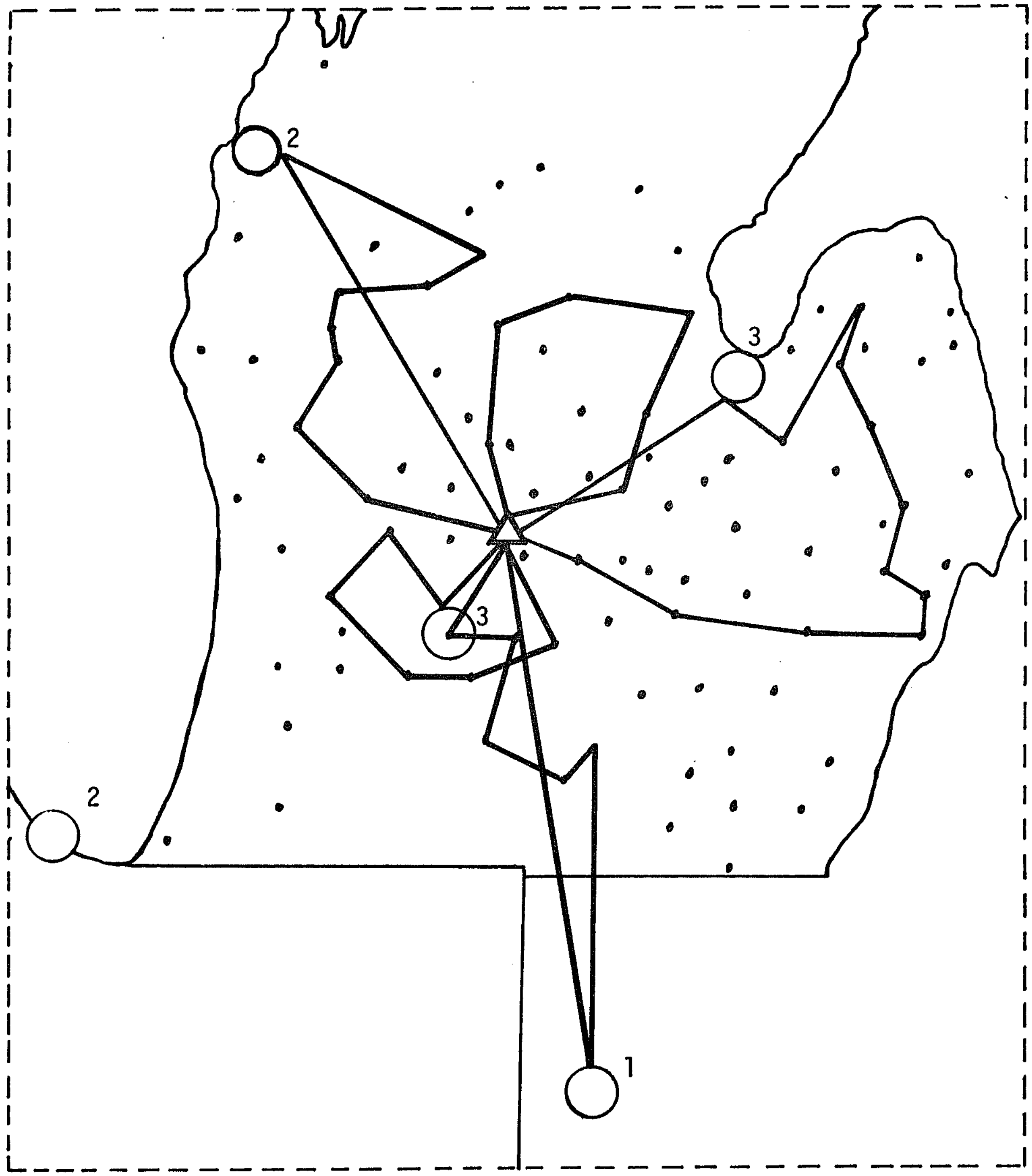
[10] For a complete listing of the route configurations from which the costs were calculated, see Appendix E.



△ = Proposed Lansing location.

• = Dealerships

◯ = Backhaul point locales; number signifies backhauls available each week.

Figure 9. Sample of lockset derived routes.

Table 3. Modeled Weekly Variable Distribution Costs for 1972-1973

	Current System	Seven Proposed Locations						
		St. Johns	Lansing	Ionia	Alma	Climax	Jenison	Zilwaukee
	$							
First Half Year								
Jenison	1,628.50							
Zilwaukee	1,378.50	2,983.00	3,101.50	3,099.00	3,127.00	3,273.00	3,250.50	3,258.50
TOTAL	3,077.00							
Second Half Year								
Jenison	1,624.50							
Zilwaukee	1,377.00							
TOTAL	3,001.50	3,062.00	3,072.50	3,147.50	3,079.50	3,225.00	3,254.50	3,263.50
Weekly Average								
Jenison	1,626.50							
Zilwaukee	1,377.75							
TOTAL	3,004.25	3,022.50	3,087.00	3,123.25	3,103.25	3,249.00	3,252.50	3,261.00

1979-1980 Analysis

Farm Bureau's problem stems from an expected need rather than a current felt need. It is, therefore, necessary to evaluate the alternative transportation systems with the changes that are projected. A major portion of this change is reflected by the projected demands presented in Table 4. They were put together out of the "Farm Supply Division Five-Year Projections: July 1, 1974-June 30, 1979" [20] and a meeting with Farm Bureau Management. The purpose of the meeting was to update the projections through June 30, 1980 and to determine the differential impact of the projections on the transportation systems, both actual and proposed.

Given this information, a two-step task remained before the desired projections were ready for use. First, the demand projections for 1979-1980 had to be updated to include petroleum products that were not previously included in the projections.

Rather than construct new product groups, petroleum products were included in previously defined groups displaying characteristics similar to the new petroleum products. The second part of the task was to deflate the projections which are stated in 1973-1974 dollars back to 1972-1973 dollars. For the price indexes used, see Table 4.

Conferences were held with Farm Bureau Management to determine what possible changes might occur as the result of moving to a one-warehouse system. The list of these changes along with some estimates of their impact follows.[11] The dollar value savings estimates

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[11] Impact estimates were provided by those people in the Farm Bureau system who were either most closely allied to the proposed change or who were most likely to have knowledge about it.

Table 4. Projected 1979-80 Warehouse Demands in Cost of Sales Dollars[a]

Product Group	1972-73 Demands	1979-80 Demands[b]	Percent Change	1973-74 Price Index[c]
1 Fertilizer	36,803.75	18,438.69	49.90	125.3
2 Seed	360,133.24	495,082.35	137.47	126.4
3 Feed	1,228,487.71	1,044,828.70	85.00	128.0
4 Medicinal supplies	529,039.91	979,887.71	185.22	115.2
5 Chemicals	1,138,015.06	4,791,849.80	421.07	112.6
6 Roofing	89,723.89	129,686.91	144.54	118.4
7 Panels and accessories	41,180.09	59,521.70	144.54	118.4
8 Building cosmetics and oil	69,163.51	100,970.08	145.99	118.4
9 Posts, poles and lumber	365,269.72	527,960.84	144.54	118.4
10 Fence	263,296.00	380,568.40	144.54	118.4
11 Electric fence	68,206.88	98,586.22	144.54	118.4
12 Bulkies	45,162.83	883,671.53	1,956.63	115.2
13 Flexibles	132,882.74	192,068.71	144.54	115.2
14 Tools	27,632.56	39,940.10	144.54	115.2
15 Semi-miscellaneous	119,982.19	131,380.49	109.50	115.2
16 Miscellaneous	1,005,234.14	1,501,135.30	149.33	115.2

[a]All numbers are in terms of 1972-73 dollars.

[b]In the projections the new petroleum items are added as tires and equipment in "bulkies," antifreeze in "chemicals," motor oil and grease in "building cosmetics and oil" and filters and miscellaneous petroleum in "miscellaneous."

[c]These indices are in 1972-73 dollars. They were calculated from the "Agricultural Prices" monthly. They were required to deflate 1979-80 demand projection made in 1973-74 dollars to 1972-73 dollars.

[d]The Farm Supply Division expects to sell more fertilizer in 1979-80 than in 1972-73, but much more of it will be shipped directly to the dealers, by-passing the warehouse.

presented in this section are totally the product of Farm Bureau calculations. The following two changes dealt directly with the transportation system.[12]

1. Reduce tractor-trailer ratio from two and one-half tractors per trailer to two. This would save $200.00 monthly in lease charges on three trailers or $7,200.00 per year. This is equal to $5,373.13 in 1972-1973 dollars.[13]

2. Eliminate interwarehouse transfers. Management estimates a $12,000.00 savings or $8,955.22 savings in 1972-1973 terms.

The total savings of $14,328.35 results totally from the elimination of costs that are unique to the two-warehouse system.

1979-1980 Results

Beyond these externally generated estimates, the projected analysis showed little significant change from the 1972-1973 relationships (see Table 5). Even the slight advantage held by the two-warehouse system is neutralized by the $14,328.35 of annual interwarehouse-transfer and trailer savings.

An important discovery was made, however. Without the transportation model, one might have anticipated an increase in transportation costs proportional to the increase in dollar demand. The model

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[12] Other projected changes will be more appropriately presented later.

[13] For these two deflation adjustments a deflation factor of 1.34 with 1972-73 equal to 100 was used. The value was calculated from price indices in "Economic Indicators," April 1975.

Table 5. Molded Weekly Variable Distribution Costs for 1979-1980

	Current System	Seven Proposed Locations						
		St. Johns	Lansing	Ionia	Alma	Climax	Jenison	Zilwaukee
	$							
First Half Year								
Jenison	1,756.50							
Zilwaukee	1,585.00	3,491.00	3,618.00	3,624.50	3,532.00	3,802.50	3,897.00	3,643.50
TOTAL	3,341.50							
Second Half Year								
Jenison	1,758.00							
Zilwaukee	1,575.50							
TOTAL	3,333.50	3,508.50	3,707.50	3,609.00	3,677.00	3,948.00	3,946.00	3,710.50
Weekly Average								
Jenison	1,757.25							
Zilwaukee	1,580.75							
TOTAL	3,338.00	3,499.75	3,662.75	3,616.75	3,604.50	3,975.25	3,921.50	3,677.00

demonstrated otherwise. It showed an increase in variable distribution costs of slightly over one-third. Investigation shows that this unexpected outcome results from the relationship between conversion factors and projected demand increases. This can be easily explained because products with high dollar values per cubic foot are expected to increase more than those with similarly measured high dollar values. This explanation that is so obvious expost was very unlikely to be discovered ex ante. Table 6 shows the comparison between volume and dollar demand increases from 1972-1973 to 1979-1980.

Variable Assembly Costs

Calculating the variable assembly costs for each alternative was a fairly straightforward process. The initial step was to extract the quantity values for those items with variable inbound freight rates (see Table 7) from the Farm Bureau accounting data computer tape. These quantities were then converted to their weight equivalents by determining the weight per unit for each product in a group. These raw conversion factors were then weighted by the percent of each product's value over the total group value to give a group conversion factor (see Table 7 for the specific numbers). The remaining calculation was simply a matter of multiplying weight equivalents times rate per hundred pounds to get the variable assembly costs (see Table 8).

Only the product groups listed in Table 7 were included because only they have inbound freight rates that vary with respect to location.

Table 6. Predicted Farm Bureau Product Demand Increases in Cubic Feet from 1972-73 to 1979-80

	Product Group	Demand in Cubic Feet 1972-1973	Demand in Cubic Feet 1979-1980
1	Fertilizer	20,446.5	10,243.7
2	Seed	54,565.6	75,012.5
3	Feed	767,804.8	653,017.9
4	Medicinal supplies	50,869.1	94,220.0
5	Chemicals	31,524.0	132,738.2
6	Roofing	4,398.2	6,357.2
7	Panels and accessories	1,855.0	2,681.2
8	Building cosmetics	7,057.5	10,303.1
9	Post poles and lumber	114,146.8	164,987.8
10	Fence	105,318.5	152,227.4
11	Electric fence	4,210.3	5,910.0
12	Bulkies	15,054.3	294,507.3
13	Flexibles	9,770.8	12,679.6
14	Tools	8,373.5	11,676.9
15	Semi-miscellaneous	29,264.0	32,044.1
16	Miscellaneous	108,089.7	161,410.3
	TOTAL	1,332,748.6	1,820,017.2

Dollar Demand Increase $\frac{\$11,393,292.10}{\$5,520,214.48} = 2.064$

Volume Demand Increase $\frac{1,820,017.2 \text{ ft}^3}{1,332,748.6 \text{ ft}^3} = 1.366$

Table 7. Products with Variable Inbound Freight Rates

Product	Quantity	Pounds/Unit
Steel posts	129,765 posts	9.50
Treated lumber	50,675 boards	53.86
Steel roofing	45,947 sheets	21.60
Fencing	20,615 rolls	181.20
Dog and cat	73,019 bags	37.00
Mineral	50,407 bags	50.00
Molasses	18,616 bags/barrels	50.00
Salt	150,342 bags	63.00

All other products carried in warehouse inventory have a flat rate for delivery into Michigan. The figures presented here will, therefore, not reflect total assembly costs but will reflect any advantage that one location might have over another in assembling products from manufacturers.

In order to calculate projected differential assembly costs, it was necessary to estimate increased requirements for those items featuring variable inbound freight rates. For this calculation it was assumed that the 1972-1973 to 1979-1980 increase would be proportional to the demand increase projected for the product groups that include those items. Once these values were available the assembly cost calculations were repeated for the 1979-1980 fiscal year.

Table 8. Variable Inbound Michigan Freight Rates

Product	B. Creek	Ionia	Jenison	Lansing	St. Johns	Zilwaukee	Alma
	¢/cwt.						
Steel posts	0.41	0.47	0.43	0.45	0.49	0.53	0.52
Fence	0.46	0.70	0.47	0.67	0.72	0.78	0.75
Steel roofing	0.41	0.47	0.43	0.45	0.49	0.53	0.52
Treated lumber[a]	1.00	1.07	1.04	1.04	1.05	1.09	1.09
	+0.66 excess	0.69 excess	0.67 excess	0.67 excess	0.68 excess	0.69 excess	0.69 excess
Dog food:							
Wells	0.65	0.66	0.66	0.67	0.67	0.67	0.67
Albers	0.88	0.90	0.92	0.94	0.94	0.94	0.94
Mineral	0.29	0.34	0.34	0.34	0.34	0.39	0.34
Molasses	0.27	0.29	0.32	0.27	0.32	0.38	0.27
Soy bean meal	0.40	0.43	0.42	0.44	0.445	0.60	0.46
Limestone	0.51	0.53	0.51	0.52	0.53	0.56	0.56
Salt:							
Marysville	0.39	0.37	0.42	0.32	0.32	0.28	0.37
Manistee	0.42	0.33	0.31	0.39	0.38	0.37	0.32

[a]The original 60,000 pounds costs $1.00 or more per pound but that over 60,000 pounds costs less than $0.70 per pound.

The variable cost calculation results are presented in Tables 9 and 10 along with the yearly distribution costs for each of the seven alternatives evaluated. Again, as in the distribution cost case, no particular location has an obvious major advantage. The 1972-1973 assembly costs show only a possible 6.4 percent savings or 3.8 percent added cost with respect to the current system, across the range of alternatives. The assembly calculations for the increases projected for 1979-1980 show essentially no relative difference from the 1972-1973 comparisons.

Total Variable Transportation Costs

In the final analysis the slight advantage held by the current system in assembling products turns into a small disadvantage when the one-warehouse transportation savings (including the variable interwarehouse transfer savings and the fixed cost savings from the reduced trailer requirement) are considered. Across the seven alternative warehouse locations the total variable transportation costs exhibit a range of from 3.9 percent savings to a 1.3 percent added cost when compared to the current system for 1972-1973 and 3.2 percent to 0.7 percent for the same range in 1979-1980 (see Tables 9 and 10). It seems likely that few modeling processes with this degree of intricacy could claim to be accurate enough to consider as significant a savings of less than 4 percent. Relationships of this small magnitude could as easily be reversed because of measurement error alone.

Table 9. Total Variable Transportation Cost Comparison, 1972-1973

Item	Two-Warehouse System		One-Warehouse System Proposed Locations						
	Actual	Modeled	St. Johns	Lansing	Ionia	Alma	Climax	Jenison	Zilwaukee
	$								
Total variable distribution	156,175.00	156,221.00	157,170.00	160,524.00	162,409.00	161,369.00	168,948.00	169,130.00	169,572.00
Distribution saving with one warehouse (-) = cost			-949.00	-4,303.00	-6,188.00	-5,188.00	-12,727.00	-13,429.00	-13,351.00
1972-73 total variable assembly		118,474.00	121,197.00	117,698.00	120,517.00	123,122.00	112,921.00	110,924.00	122,961.00
Assembly savings with one warehouse			-2,723.00	776.00	-2,043.00	-4,648.00	5,553.00	7,550.00	-4,487.00
TOTAL VARIABLE TRANSPORTATION COST		274,721.00	278,367.00	278,222.00	282,922.00	284,491.00	281,869.00	280,574.00	292,533.00
Savings or cost		---	-3,672.00	-3,527.00	-8,227.00	-9,796.00	-7,174.00	-5,879.00	-17,838.00
Less $14,328.35 trailer and transfer savings			10,656.35	10,801.35	6,101.35	4,532.35	7,154.35	8,449.35	-3,509.65

Table 10. Total Variable Transportation Cost Comparison, 1979-1980

Item	Two-Warehouse System	One-Warehouse System Proposed Locations						
	Modeled	St. Johns	Lansing	Ionia	Alma	Climax	Jenison	Zilwaukee
1979-1980 Costs	$							
Total variable distribution	173,550.00	181,987.00	190,463.00	188,071.00	187,434.00	201,513.00	203,918.00	190,684.00
Distribution cost with one warehouse		-8,437.00	-16,913.00	-14,521.00	-13,884.00	-27,963.00	-30,368.00	-17,134.00
1979-80 total variable assembly	143,303.81	138,996.49	134,216.54	137,932.22	142,056.29	124,625.31	123,745.50	142,719.61
Assembly savings with one warehouse		4,307.32	9,087.27	5,371.59	1,247.52	18,678.00	19,558.31	584.20
TOTAL VARIABLE TRANSPORTATION COST	316,853.81	320,983.49	324,679.54	326,003.22	329,420.29	326,138.81	327,663.50	333,403.61
Differential cost		-4,129.68	-7,825.73	-9,149.41	-12,636.48	-9,285.00	-10,809,69	-16,549.80
Less $14,328.35 trailer and transfer savings		10,198.67	6,502.62	5,178.94	1,691.87	5,043.35	3,518.66	-2,221.89

To this point, the lack of apparent advantage for any alternative only serves to emphasize the importance of three other activity sets.

First, the importance of factors such as average truck capacity, number of deliveries from manufacturers to warehouses, savings from quantity buying, supplier mix, and the portion of total supplies available from each supplier are stressed.

Second, the importance of the remaining warehouse engineering and cost estimation study is emphasized. It should play a significant role in estimating the impacts of two of these factors, namely, inbound supply runs and quantity buying.

Quantity buying is important because one of the items with a variable inbound freight rate could potentially experience a change in its average price per hundred pounds. Treated lumber has one rate for 60,000 pounds or less and a reduced rate for that amount over 60,000 pounds. In an 80,000 pound load, for example, the reduced rate applies only to 20,000 pounds. If the average load size changes with a one-warehouse system, the costs should be modified to correspond to that change. The warehouse cost study will give an indication of the likelihood for this kind of change in its comparison of the average monthly inventories carried in the one- versus two-warehouse system. A similar indication can also be obtained with respect to the number of inbound supply runs. These variables will not, of course, effect the relative attractiveness of any one proposed location but will have an impact on the desirability of the one-warehouse system.

The other three factors will not be quantified but should be evaluated subjectively if they deviate from what was assumed about them in this analysis.

Any substantial change in average truck capacities will likely affect the distribution cost in the opposite direction of that change. Should this average increase, more dealers could be included in one route. This would likely lead to a decrease in distribution costs. Farm Bureau does not expect this kind of change, however. It is their experience that the extra time and expense required to load the trucks more fully is not justified by the savings that result. The inbound freight rate for dog food is a function of its source. Currently, 90 percent of this product is supplied by a single supplier, and 10 percent by another supplier. Again, any change in this mix should be accounted for. Because two salt suppliers are now being used, it was assumed that each proposed location could acquire all the salt they would need from the closest supplier. Any deviation from this assumption should also be considered.

The last activity set is the group of factors not included up to this point in the study. Factors such as availability and cost of land, size of labor force, reaction of current employees, environmental considerations, and management's personal preferences become relatively more important.

CHAPTER IV

VARIABLE IN-WAREHOUSE COSTS

In analyzing variable warehouse operating costs it is necessary to evaluate the proposed one-warehouse alternative that does not have an established cost structure. For this reason some approach designed to predict nonestablished costs is required. Clearly, the economic engineering technique has the advantage in this area.

Chapter II laid out the advantages of using a systems approach for calculating parameters that display dynamic characteristics like those of the Farm Bureau warehousing system, when the extra time and cost can be justified.

The added benefits from the knowledge that would be gained about factors like rate of output, length of operation, scheduling, ordering lead times, ordering delays, and storage in the simulation process is thought to far outweigh the added costs. Even with simulation, an awareness must be maintained to avoid assuming independency where it does not exist.

The Nature of the Simulator

The simulator used in this research is macro-dynamic in nature. The dynamism follows from the importance of delays and interdependencies between time periods as was previously discussed. It is a macro-simulator despite the fact that it studies the individual firm, a micro-economic entity. The macro classification holds because the identity of individual units are lost in the process of aggregating over individuals and product lines. Although, theoretically, it is possible to model the system on a micro level the costs of engaging in such a tedious task far outweighs the benefits. This is especially true when the simpler macro approach is adequate.

Products were aggregated into product groups according to similarities in their three-dimensional measurements to facilitate space requirement calculations. Therefore, all related parameters are aggregated in the same manner out of necessity.

Worker productivities were aggregated in that the values used were those of the work group, not individual workers. This aggregation required special attention to work group structure. Should a two eight-hour shift system be implemented with specialization, for example, where the day shift unloads and stows and the night shift selects and loads, the average group productivities may increase, other things being equal.

In the simulation portion of this research two types of problems, design and identification, were faced. The design problem has, to some extent, already been discussed. A design problem is one that requires simulation of a system that does not exist. The system must be designed or built from scratch. The "Economic Engineering" section of Chapter II discussed the theory related to that technique as well as how it could be extended into a dynamic simulator.

The design problem was made easier by first solving an identification problem. An identification problem requires the use of the system's inputs and outputs, together with knowledge of the system itself to find equations that will simulate the system. By first identifying the existing two-warehouse system, economic engineering principles can then be applied to make incremental changes in the model of the existing system so that it would reflect the structure of the proposed one-warehouse system.

A theoretical foundation for constructing the identification model was obtained through a seven-step approach suggested by Park and Manetsch [19, pp. 18-12, 18-14].

The steps are presented in the form of seven questions as to the nature of the identification problem. Five of those questions and the answers that apply in the case of this research follow.

1. What are the variables and how are they modeled?

    a. Controllable input variables include order size, order frequency, number of laborers, delivery size, delivery frequency, inventory mix, and the number of dealers served, among others. The variables can be modeled in a very straightforward manner using dollar amounts, counts, and time intervals for example.

    b. Disturbance variables or noise is very low or nonexistent so that measured inputs and outputs will be very close to the actual ones.

    c. Inventory level, plant size, and plant costs are three major output variables for this portion of the model.

    d. Internal state variables include labor productivities, portion of variable as opposed to fixed labor, warehouse capacity, size and frequency of assembly carriers, farmer-consumer demand, and prices and wages.

2. What is known about the system structure?

   a. The system is dynamic because of the inherent importance of delays and storage to a warehousing system. Also, a mathematical integration technique will be necessary to determine stocks from flows. Such classifications must, in this case, come from prior knowledge of the system.

   b. The system is linear in this identification stage. In the design stage nonlinearities must be watched for because the stages are independent except for the flows between them. In the current system the flows are compatible, so a production function for the system can be obtained by aggregating the stage production functions. In the design stage, however, combining stage production functions may cause total costs to be greater than the sum of the stage costs in cases where bottlenecks occur between stages.

   c. The model has one main delay in the ordering process as well as lags that result when work loads get too large. The system's main inputs and outputs move in discrete bundles so that a model with discrete components is indicated.

   d. This model must reflect more than input/output behavior. The behavioral structure must be reflected for the later purpose of changing the structure to simulate the impact of expected technological and demand change.

3. Will the simulation be on-line, connected directly to the warehousing operations, constantly receiving data updates?

   This procedure will not use an on-line approach. Instead, an off-line approach will be used to condense the analysis of data representing a one-year history of warehousing operations into a few seconds of computer time.

4. What criteria for estimation are satisfactory?

   To validate this model the output need only be kept within an error bound around the actual data.

5. What are the properties of the stimator?

   The estimator should be corrected for any bias (i.e., it should be unbiased) although a biased estimator would be sufficient if a constant could be added to make it track

> actual outputs. Here, for example, the demand represented by the 96 sample dealers was obviously less than total demand of the entire dealer population. Knowledge of the total demand allowed the implementation of the correction procedure mentioned above; a constant was added to correct the demand input. The variance need only be acceptable, not best. Sufficiency is a property that will not be employed except to say that the estimator will have to provide a minimum of information. The minimum will be that amount of information deemed minimally necessary to make the desired comparison.

Further investigations of model parameters and assumptions can occur on two levels. First, there are those assumptions made when constructing the mathematical model before computerization. Second, at the next highest level of abstraction, more assumptions may be required as the model is computerized. Therefore, rather than discuss the assumptions in two places, they will all be analyzed within the computer model presentation.

The Modeling Procedure

Generally, the model as described in the block diagram of Figure 10 is designed to calculate variable operating costs and give approximations for labor requirements, inventory strategy, and warehouse size for a proposed one-warehouse system. Additionally, it serves to evaluate the inventory strategy presently being used.

With this brief, general purpose as a foundation, a more specific view of how the model works and how it fits into the research scheme will follow.

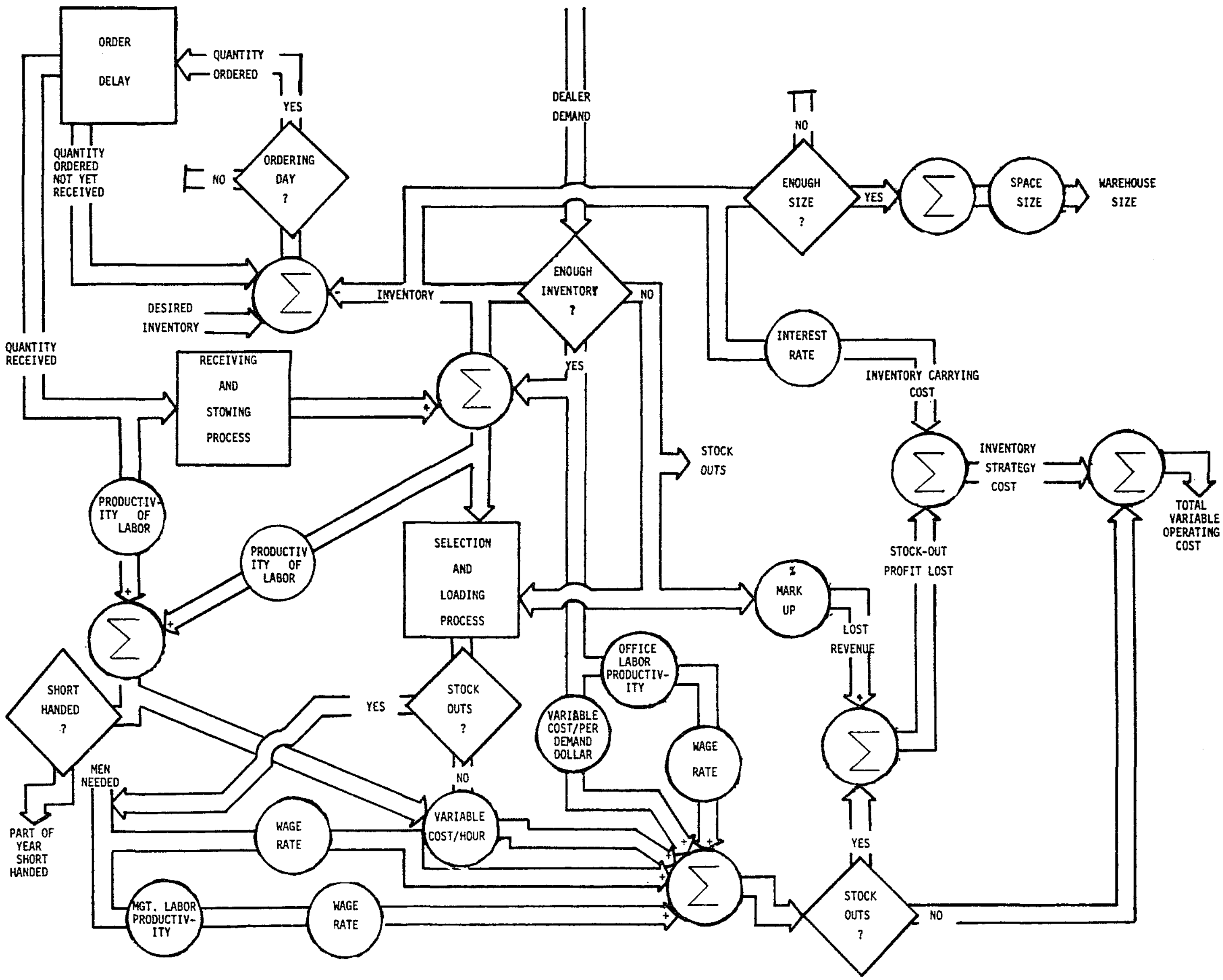

FIGURE 10. THE GENERAL WAREHOUSE MODEL

Fundamental Data

This section describes the data that was provided by Farm Bureau and used to build the warehouse models. The numbers in question (presented in Table 11) are called "Initial Parameters" because they are basic to the required calculations. Where specific warehouse levels do not appear, the numbers reported are used in all three models. Further comment on some of those values is necessary.

Time between orders.--The ordering-interval not only represents the time between orders, it also acts as a proxy for order size. In the course of a year the actual time between orders varies widely for each product. Some value, however, must be used to simulate the situation where orders for groups of similar products are accumulated and not made daily. In its basic role this variable shows that some products are ordered more frequently than others.

The variable also acts to approximate order size which is related but has unique qualities of its own that carry considerable weight. Order size could be incorporated directly if one absolute order size existed for each product group. As used here, the proxy variable is required because order size is a relative concept. A large order in a low-demand period might be considered small during periods of high demand. If ordering intervals were constant in actuality, relative order size could be approximated by artificially varying ordering-intervals within the simulator. Because the intervals are not constant, they were adjusted slightly and used for both ordering-interval and order-size. During high demand periods

Table 11. Initial Simulator Parameters for the 1972-1973, 1979-1980 Farm Bureau Systems' Models

Product Group	Lead Time in Days	Ordering Intervals in Days	Man Hours to Unload, Check, and Stow One Truck Load of Product	Mark Up as a Percent of Cost	Conversion Factors in Dollars per Cubic Foot
1 Fertilizer	2	5	1.40	0.28	1.8
2 Seed	3	20	7.27	0.12	6.6
3 Feed	10	8	7.27	0.19	1.6
4 Medicinal supplies	7	11	4.34	0.14	10.4
5 Chemicals	7	25	4.34	0.05	36.1
6 Roofing	22	17	0.67	0.30	20.4
7 Panels and accessories	55	10	16.0	0.30	22.2
8 Building cosmetics	10	9	8.0	0.30	19.8
9 Post poles & lumber	22	19	1.4	0.30	3.2
10 Fence	10	23	16.0	0.30	2.5
11 Electric fence	22	15	16.0	0.30	16.2
12 Bulkies	22	7	16.0	0.30	3.0
13 Flexibles	130	16	16.0	0.30	13.6
14 Tools	130	14	16.0	0.30	13.3
15 Semi-miscellaneous	22	13	16.0	0.30	4.1
16 Miscellaneous	22	12	16.0	0.30	9.3

	Zilwaukee	Jenison	End-End
Wage rates:			
Warehousemen	3.23	3.23	3.23
Office	2.80	2.80	2.80
Management	6.97	4.74	5.90
Expansion factor--sample to actual	1.154	1.337	1.23
Variable costs related to $ volume factor	0.0094	0.008	0.0087
Variable costs related to labor hours factor	0.335	0.28	0.31

Cost of carrying inventory--9.5%/year

Selecting and loading productivity--9.5 man hours/truck; new 4.55 man hours.

long order-intervals force large orders, but as lower demand is experienced order size becomes smaller. This reaction is due to more rapid depletion of inventories in high demand periods and an ordering formula that brings inventories to a desired level.

Labor productivities.--Productivities for warehousemen, including foremen (see Table 11), were acquired through interviews with the two warehouse managers. The initial productivities only account for the time required to complete each individual task. From this starting point an inefficiency factor of 22 percent was incorporated to account for hours that workers were setting up jobs, cleaning up after a job, moving between jobs, and taking breaks. Twenty-two percent was used to represent a reasonable average for Farm Bureau's estimates ranging from 20 percent to 25 percent.

Office worker productivity was calculated similarly. The important difference is that office worker productivity is set as a function of total daily dollar demand rather than the cubic demand of product groups.

In the case of office workers, it is important to recognize that the estimated productivity parameters reflect the actual efficiency of the workers. It does not show their productivity potential. Office workers, for example, were thought by management to have the potential to handle much more volume per man-hour than was measured in the model.

The model was also constructed with the capability to predict management labor requirements. At this point in the analysis, however, the decision was made to set management productivity so that one manager and one assistant would be assigned to each location despite the size of the labor force required. Farm Bureau management feels that the supervisory requirements for any warehouse within a reasonable demand range could be handled by one manager and his assitant. Management labor requirements are, therefore, not determined by the model. It does predict the number of clerks and warehousemen, however.

Other initial values.--Conversion factor calculation was necessary to convert demand expressed in dollars to demand expressed in cubic feet. They also made possible a calculation to approximate warehouse capacity requirements which will be explained later.

The initial product arrivals and beginning inventories needed prior to model generated arrivals were set at their actual values. The "actual" arrival values were calculated from Farm Bureau records using the formula:

$$QA = D - BI + EI$$

where:

QA = quantity that arrived,

D = demand,

BI = beginning inventory, and

EI = ending inventory.

All other initial values were used in the simulator directly from Farm Bureau records.

General Model Description

Once initialized the model proceeds in the following manner:

1. Actual demands by product group are read into the model from a specifically selected sample of 96 Farm Bureau dealers. These dealers account for 81.3 percent of the total warehouse cost-of-sales dollar demand. The monthly demands are then divided into daily demand groups according to the day they were to be served as determined by the transportation model (see Appendix B, "Jenison-Zilwaukee First and Second Half Year"). For example, monthly demands from dealers normally receiving supplies on one day of the week (i.e., Monday), are grouped and divided into fourths. This last division is necessary because the grouping actually represents a month of Mondays, and similarly for other days of the week. Daily demands of sample dealers are then adjusted to make the sample represent total dealer population (see Table 11 for these values).

2. Demands are then compared to inventory levels by product group. If there is enough inventory on hand, the total is loaded from inventory. If demand exceeds inventory for a particular product, all inventory is loaded, with the remainder coming out of any arrivals delivered that day. In instances where inventory plus new arrivals are not sufficient to fill demand, the shortage is recorded.

3. The space required for total inventory is calculated each day and the largest daily requirement reported. This number is an estimate of the actual space occupied by all the products. It does not take room for pallets, space between products, etc. into account.

A parameter is then established within the modeling process to convert space occupied into actual capacity requirements for the base year.

4. Orders are made according to:

$$QO(t) - DINV(t) + \sum_{n=1}^{t-1} [QO(n) - QA(n)]$$

where:

QO(t) = quantity ordered at time t,

DINV(t) = desired inventory at time t,

INV(t) = inventory at time t,

QO(n) = quantity ordered prior to time t, and

QA(n) = quantity delivered prior to time t.

5. Required man-hours of direct and office labor are then calculated at the daily level. For direct or warehouse labor the model calculates the minimum number of men required daily. This is accomplished by dividing the productivity for unloading, checking, and stowing a product into the amount received and the productivity for selecting and loading products into the amount sent out. Movement is converted from dollars to cubic measure and divided by the respective productivities expressed in man-hours required per cubic foot. The number of men actually used is compared to model-calculated estimates. The simulator actually calculates the number of days that the fixed labor force is inadequate. These simulator estimates when compared to actual values provide an indirect validation device for the labor productivities used. Correct productivity specifications should have

forced the number of short-handed days from the model to fall within the 8-25 range provided by management. Confidence in the simulator was reinforced when each of the base-year runs showed a short labor situation that fell within the range provided by Farm Bureau.

6. Net losses resulting from being out of stock for a demanded product is also calculated. The normal markups are reduced by expenses that would have been incurred had the product been on hand. The reductions come from the labor costs, hourly-related variable costs, and volume-related variable costs that would have been experienced.

7. Inventory carrying-costs are calculated by applying a daily finance charge to ending inventories and summing them over the year.

8. Arrivals, other than initial arrivals, are calculated by setting them at a point in time, t, equal to orders Lt days earlier, where Lt is the product specific lead time. Additionally, all orders are spread over three days, $t + Lt - 1$, $t + Lt$, and $t + Lt + 1$. This process was installed to substitute for management's ability to spread receipts of large orders over more than one day when a concentrated arrival might strain labor capacity. This allows the model to decrease labor requirements in the peak periods to more nearly represent reality. That it also has the tendency to underestimate labor requirements in other than peak periods is of little consequence because a fixed work force large enough to meet all but the very largest peak requirements will be more than sufficient to meet lower level requirements. Fixing the labor force at this level would seemingly cause idle time. It is

important to recognize, however, that all work required in the warehouse is not computed by the simulator. Work that is necessary but not sequential (not required at any one point in time but rather within some longer period of time) that can be done when unloading and loading is completed, such as cleaning spills and rearranging storage, acts to fill the time not accounted for in the model.

9. Finally, yearly totals including labor costs, work-related variable costs, and volume-related variable costs are calculated. Table 12 shows the items included in each of these categories. In addition to labor costs, the listed variable costs were classified according to whether they were thought to be a function of hours worked or business volume.

Analysis Process

Once the general model was formulated, data specific to each of the two existing warehouses was fed into it. The product-specific monthly-desired inventories were manipulated until model ending-inventories reflected actual inventories. In most cases the size of the monthly-desired inventories only estimates the inventory levels desired for the period in question. With longer lead times or delays between orders and arrivals, the variable must include expectation of future demand. If, for example, two products A and B, have six month lead times, are equal in the following four categories: (1) July inventories, (2) desired inventories for January, (3) expected deliveries between July and January, and (4) expected demand up

Table 12. Warehouse Operating Cost Classifications for Farm Bureau's 1972-1973 System

Operating Expenses	Zilwaukee Fixed	Zilwaukee Variable	Jenison Fixed	Jenison Variable	Total Fixed	Total Variable
	$					
Payroll General:						
Supervisory	1,751	--	1,522	--	3,273	--
Management & assistance	--	29,000	--	19,700	--	48,700
Office	--	11,648	--	11,648	--	23,296
Payroll Plant:						
Foreman & warehousemen	--	40,310	--	41,427	--	81,737
LABOR	1,751	80,958	1,522	72,775	3,273	153,733
Payroll outside labor	--	4,234	--	1,459	--	5,693
FICA	--	4,130	--	3,888	--	8,018
MESC	--	1,946	--	1,879	--	3,825
Federal unemployment	--	268	--	253	--	521
Blue Cross	--	2,112	--	2,178	--	4,290
Group insurance	--	798	--	692	--	1,490
Workmen's Compensation	--	4,075	--	3,094	--	7,169
Salary continuation	--	105	--	71	--	176
Retirement contribution	--	2,214	--	2,938	--	5,152
Training	--	--	--	202	--	202
Repairs/upkeep lift truck	--	3,821	--	2,139	--	5,960
Gas and oil	--	1,167	--	127	--	1,294
Tires and tubes	--	69	--	129	--	198
Lift truck expense	--	362	--	21	--	383
Normal maintenance	--	1,848	--	1,020	--	2,868
WORK RELATED	--	27,149	--	20,090	--	47,239
Travel	--	1,804	--	2,308	--	4,112
Demurrage	--	80	--	385	--	465
Rubbish disposal	--	--	--	15	--	15
Repairs/upkeep machinery equipment	--	1,820	--	28	--	1,848
Damaged merchandise	--	1,586	--	102	--	1,688
Office supplies	--	2,802	--	855	--	3,657
Mail and messenger service	--	--	--	9	--	9
Heat, light, and power	--	3,848	--	1,811	--	5,659
Plant and warehouse supplies	--	3,966	--	3,538	--	7,504
Telephone and telegraph	--	4,475	--	4,005	--	8,480
Postage	--	320	--	224	--	544
Insurance inventory	--	6,480	--	7,585	--	14,065
Equipment rent	--	--	--	179	--	179
VOLUME RELATED	--	27,181	--	21,044	--	48,225
Repairs/upkeep grounds	1,955	--	5,264	--	7,219	--
Advertising	35	--	--	--	35	--
Dues and subscriptions	--	--	120	--	120	--
Donations	125	--	--	--	125	--
Miscellaneous	113	--	1,832	--	1,945	--
Taxes--property	25,247	--	13,725	--	38,972	--
Insurance--building	1,799	--	1,223	--	3,022	--
Insurance--miscellaneous	54	--	104	--	158	--
Printing	82	--	--	--	82	--
Rent	--	--	120	--	120	--
Depreciation--building	5,912	--	4,987	--	10,899	--
Depreciation--machinery & equipment	1,253	--	342	--	1,595	--
Depreciation--lift trucks	4,881	--	886	--	5,767	--
Depreciation--office equipment	--	--	48	--	48	--
Car lease	1,626	--	--	--	1,626	--
Board expense	--	--	190	--	190	--
Remaining Fixed Costs	43,082	--	28,841	--	71,923	--
TOTAL	44,833	135,288	30,363	113,909	75,196	249,197
Plus Descriptive Account:						
Tractor & Truck rental	--	--	1,219	--	1,219	--
GRAND TOTAL	180,121		145,491		325,612	

Source: "Statement of Operations and Margins," June 30, 1973.

to January, but have different expected demands for January, the desired inventories used for ordering would have to include expected future demand.

		Product A ($)	Product B ($)
1.	July ending inventory	1,000	1,000
2.	July through December receipts	20,000	20,000
3.	July through December demands	-19,000	-19,000
4.	January beginning inventory	2,000	2,000
5.	January demand	-4,000	-1,500
6.	Net amount needed (-) or remaining (+)	-2,000	500
7.	Desired January ending inventory	1,500	1,500
8.	Necessary size of July order to arrive in January	3,500	1,000
9.	Necessary July desired inventory	4,500	2,000

With the situation described, product A requires that January receipts equal $3,500, therefore a July desired inventory of $4,500 would be required as the amount ordered is essentially desired inventory less inventory on hand, $4,500 - $1,000 = $3,500.

The two main purposes of the desired inventory estimations are (1) to force the model to track reality, and (2) to investigate other desired inventory levels in order to find where total inventory carrying cost and net profit lost from stock-outs were lowest.

Next, the two warehouse flows were combined in an End-to-End model and treated as if they were one, while all other parameters were left unchanged. By making only this one change it was possible to evaluate the solitary effect of inventory consolidation.

With this step accomplished the base period (1972-1973 fiscal year) analysis was complete. A model was available that could adequately track reality. The move to the projected impact analysis was then initiated by updating the End-to-End simulator so that it would represent a warehouse in the proposed one-warehouse system. It was updated by increasing labor productivities to reflect technological improvements. Office worker productivities were also changed in all three warehouse models. They were increased over the values measured in the base period to reflect the previously discussed higher potential productivities. Office productivities were increased again because of a finding from the transportation analysis with regard to projected demands. There it was found that although dollar demand more than doubled by 1980, demand in volume terms increased only a little over one-third. The reason for this apparent contradiction comes from larger projected increases for high dollar-to-volume items and smaller projections for low dollar-to-volume products (see Table 3 in Chapter III). The use of unchanged productivities would have overstated labor requirements. For this reason office productivities were changed so that they would be more closely related to transaction volume rather than dollar volume.

Once the indicated changes were made, demands were updated to reflect projected demand changes. It was then possible to calculate the costs that would occur in 1979-1980 with and without changing to a one-warehouse system.

The one-warehouse model provides cost comparisons as well as the factors from which the projected costs are calculated. It provides, for example, capacity and labor requirements for the one-warehouse system.

The analysis process used can now be summarized according to the four major steps required.

1. The model of the two existing warehouses will:

    a. demonstrate that the model can track reality within small error boundaries.

    b. give some feeling for the magnitude and sensitivity of design parameters like the factor used to change space occupied to space required.

    c. give inventory-strategy cost-functions with mathematically minimum cost-points.

    d. demonstrate how the current system would perform under expected future conditions.

2. The End-to-End Model will:

    a. give design parameters for the proposed one-warehouse system.

    b. calculate savings from flow consolidation.

3. The new one-warehouse model will:

    a. give an estimation of capacity requirements.

    b. give variable cost estimates.

    c. calculate an inventory strategy cost-function.

4. Together the models will:

    a. demonstrate how a one-warehouse system would have compared to the 1972-1973 warehouse system.

    b. demonstrate how the one-warehouse system would compare to the two-warehouse system in 1979-1980.

Model Verification

Table 13 shows the closeness of fit with respect to month-ending inventories between the modeled and actual data. These totals were not, however, used in the model's construction. Adjustments were made in the model to establish a close correspondence between actual and modeled month-ending inventories on a product basis. Once each product group adequately traced the actual situation the sixteen groups were totaled to arrive at the comparisons presented in Table 13.

Table 14 shows the representative desired inventory levels for the Jenison Warehouse that caused the model to approximate actual inventory levels. Desired inventory levels were also calculated for the Zilwaukee and End-to-End models but are not shown. The Jenison figures should be sufficient for an understanding of the process used.

The costs experienced by the Farm Bureau Warehousing System in 1972-1973 which were discussed earlier are presented in Table 12. With these values plus the initial parameters also presented earlier a comparison between actual and modeled costs was made (see Table 15). The comparison seemed to support the argument that the models constructed to trace reality in 1972-1973 could be justifiably used to evaluate performance in 1979-1980. A more elaborate scheme may have been necessary if the anticipated technological or policy changes under either alternative were more drastic.

Table 13. Monthly Inventory Levels, 1972-1973

Year and Month	Zilwaukee		Jenison		End-to-End	
	Actual	Modeled	Actual	Modeled	Actual	Modeled
	----------	----------	---------- $	----------	----------	----------
1972:						
June	917,050	908,234	778,935	776,003	1,695,985	1,686,023
July	893,834	875,234	734,964	707,413	1,628,798	1,588,175
August	902,329	879,045	742,320	727,144	1,644,649	1,620,965
September	862,554	818,711	747,905	719,702	1,610,459	1,568,331
October	872,447	851,270	710,917	691,103	1,583,364	1,535,280
November	850,854	850,816	705,824	717,271	1,556,678	1,587,415
December	858,501	856,610	731,233	740,467	1,589,734	1,586,302
1973:						
January	1,015,018	888,646	852,043	763,213	1,867,061	1,763,233
February	1,231,688	1,213,504	1,019,370	1,051,645	2,251,058	2,273,234
March	1,013,852	1,033,256	968,555	968,550	1,976,402	2,028,664
April	947,574	962,215	922,516	932,003	1,870,090	1,870,032
May	745,526	813,414	831,540	796,126	1,577,066	1,507,773
June	603,724	622,498	660,322	652,622	1,264,046	1,271,274

Source: Gross margin worksheets and model.

Table 14. Desired Inventory Levels for the Jenison Warehouse, 1972-1973

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Month	Fertilizer	Seed	Feed	Medicinal Supplies	Chemicals	Roofing	Panels and Accessories	Building Cosmetics	Posts, Poles, and Lumber	Fence	Electric Fence	Bulkies	Flexibles	Tools	Semi-Miscellaneous	Miscellaneous
July	954	35,620	85,287	61,882	203,031	nc[a]	nc	11,419	nc	41,862	nc	nc	nc	nc	nc	nc
August	954	53,430	85,287	61,882	203.031	21,439	nc	11,419	82,813	41,862	12,251	9,709	nc	nc	27,432	348,805
September	954	53,430	102,344	61,882	203,031	21,439	14,088	11,419	82,813	41,862	12,251	9,709	nc	nc	27,432	300,892
October	954	53,430	102,344	61,882	203,031	21,439	14,088	11,419	82,813	41,862	12,251	9,709	nc	nc	27,432	216,566
November	954	53,430	85,287	61,882	203,031	21,439	14,088	11,419	82,813	41,862	12,251	9,709	nc	nc	27,432	191,651
December	954	53,430	85,287	100,868	203,031	21,439	14,088	11,419	82,813	41,862	12,251	9,709	nc	nc	27,432	191,651
January	954	53,430	85,287	100,868	446,668	21,439	14,088	11,419	99,376	41,862	12,251	9,709	39,378	9,626	27,432	191,651
February	954	81,926	68,230	100,868	578,638	21,439	14,088	11,419	99,376	41,862	12,251	9,709	39,378	9,626	27,432	214,649
March	5,726	81,926	102,344	100,868	594,881	16,079	8,453	11,419	99,376	41,862	12,251	6,650	39,378	9,626	27,432	191,651
April	954	81,926	85,287	100,868	446,668	16,079	8,453	11,419	69,066	41,862	15,926	6,650	39,378	15,113	27,432	172,486
May	954	53,074	110,873	100,868	402,001	16,079	11,270	11,419	69,066	41,862	12,251	6,650	39,378	15,113	19,202	222,315
June	954	53,074	106,609	0	203,031	16,079	11,270	11,419	69,066	41,862	12,251	6,650	39,378	15,113	19,202	176,319

[a]Where no values appear, desired inventories were not required because model generated arrivals were not calculated. The arrivals for those months were set at their actual values.

Table 15. Annual Variable Cost Comparison, 1972-1973 Data

Variable Costs	Jenison		Zilwaukee		End-to-End	
	Actual	Modeled	Actual	Modeled	Actual	Modeled
	$					
Labor	72,775.00	71,676.80	80.958.00	80,953.60	153,733.00	153,004.08
Hour related	20,090.00	20,069.50	27,149.00	26,567.61	47,239.00	47,431.49
Volume related	21,044.00	21,806.08	27,181.00	27,119.45	48,225.00	48,025.87
TOTAL	113,909.00	113,522.38	135,288.00	134,640.66	249,197.00	248,461.45

Results

Inventory Strategy Costs

The first set of outputs from the simulation process allows analysis of current inventory strategies. Table 16 and Figures 11 through 13 show the results of the analysis. The actual cost incurred is estimated by the model at 100 percent of the desired inventory required to make the model track reality. By reducing the desired inventory levels and, therefore, the inventory carried, inventory carrying costs are decreased.

The model indicates that the Zilwaukee location could cut its inventory level to 80 percent before incurring even the slightest level of stock-outs. Similarly, Jenison could reduce its inventory by 10 percent. If it were possible to consolidate inventories to one location, inventories could then be decreased to 73 percent before like levels of stock-outs would occur. The likely reason for this lower inventory requirement is that the high fluctuations in demand from two locations cancel out when inventories are consolidated.[14]

---

[14] Here it is essential to clarify the variable used to represent demand and the zero stock-out level that results from its use. The zero level of stock-outs reported from the simulator has a small error associated with it. Indeed, stock-outs did occur in 1972-1973, but those were considered by Farm Bureau to be of little significance. One could not expect stock-outs to result when cost of sales figures are used as a proxy for demand. This is apparent because cost of sales figures represent sales made and not unfilled requests. A small adjustment of less than .01 percent of sales was introduced through the adjustment factors but no inventory outs were predicted by the simulator.

Table 16. Inventory Strategy Cost Comparison, 1972-1973

Item	Zilwaukee	Jenison		End-to-End
	---------- $ ----------			
100%[a]				
Stock-outs	0	0		0
Inventory carrying cost	84,828.88 +	75,111.84	= 160,002.09	161,109.98
TOTAL	84,828.88	75,111.84		161,109.98
90%				
Stock-outs		836.03		
Inventory carrying cost	NA	65,465.16		NA
TOTAL		66,301.19		
80%				
Stock-outs	95.94	2,496.93		0
Inventory carrying cost	67,076.26	56,000.00		119,760.76
TOTAL	67,172.20	58,496.93		119,760.76
73%				
Stock-outs				1,486.23
Inventory carrying cost	NA	NA		105,293.76
TOTAL				106,779.99
70%				
Stockouts	563.45	4,298.71		2,462.75
Inventory carrying cost	55,620.56	46,083.19		101,000.00
TOTAL	56,184.01	50,381.90		103,462.75
60%				
Stock-outs	2,035.05	7,444.12		7,358.40
Inventory carrying cost	46,000.00	36,000.00		82,000.00
TOTAL	48,035.05	43,444.12		89,358.00
50%				
Stock-outs	17,830.14	27,468.81		19,727.32
Inventory carrying cost	37,000.00	25,000.00		61,845.71
TOTAL	54,830.14	52,468.81		81,573.03
40%				
Stock-outs				83,922.37
Inventory carrying cost	NA	NA		42,000.00
TOTAL				125,922.37

[a]Reflects percent of desired inventory level that was required to make the simulator track reality.

[b]NA = No analysis was run because other results would provide little if any additional information.

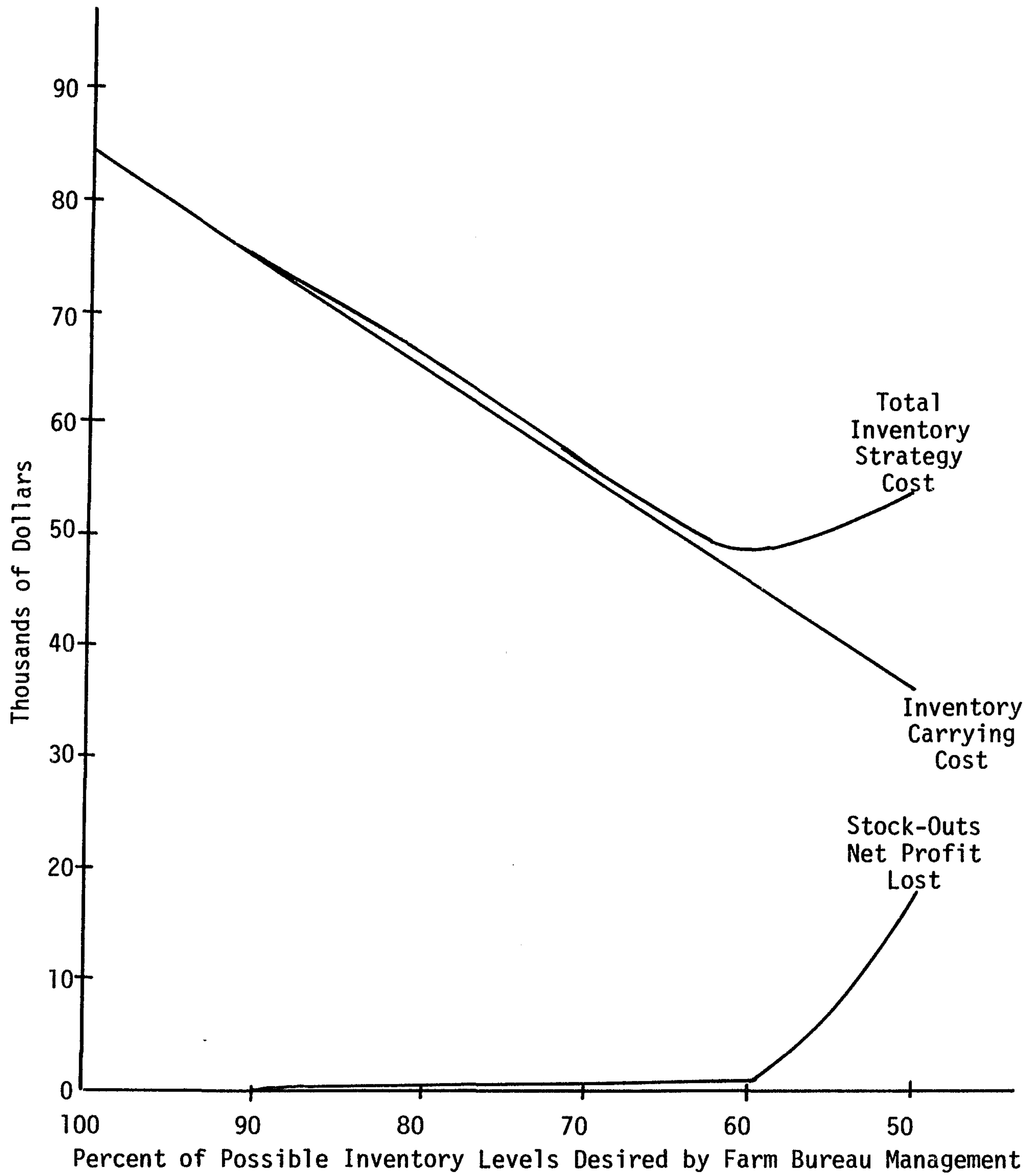

Figure 11. Zilwaukee strategy costs for 1972-1973.

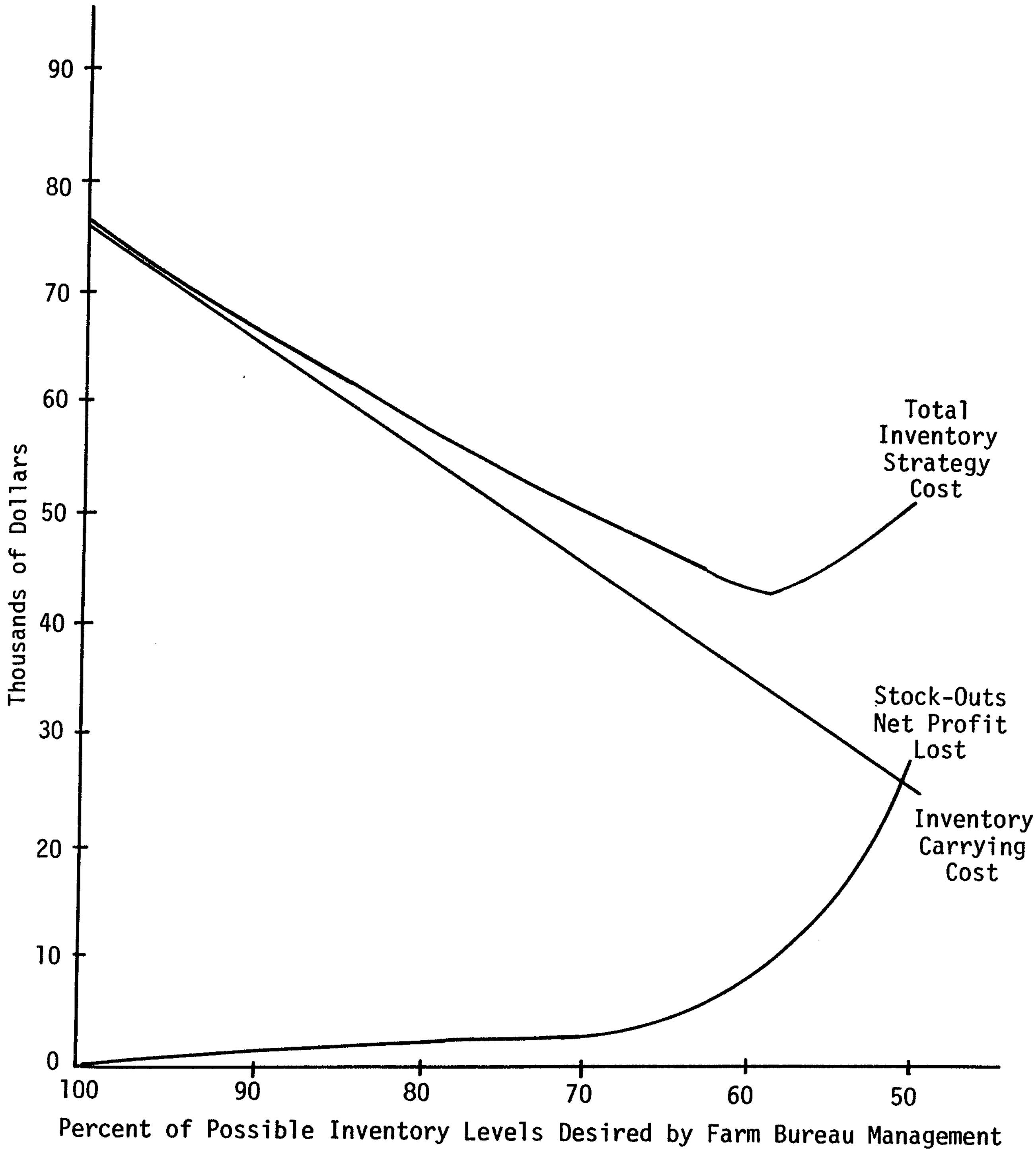

Figure 12. Jenison strategy costs for 1972-1973.

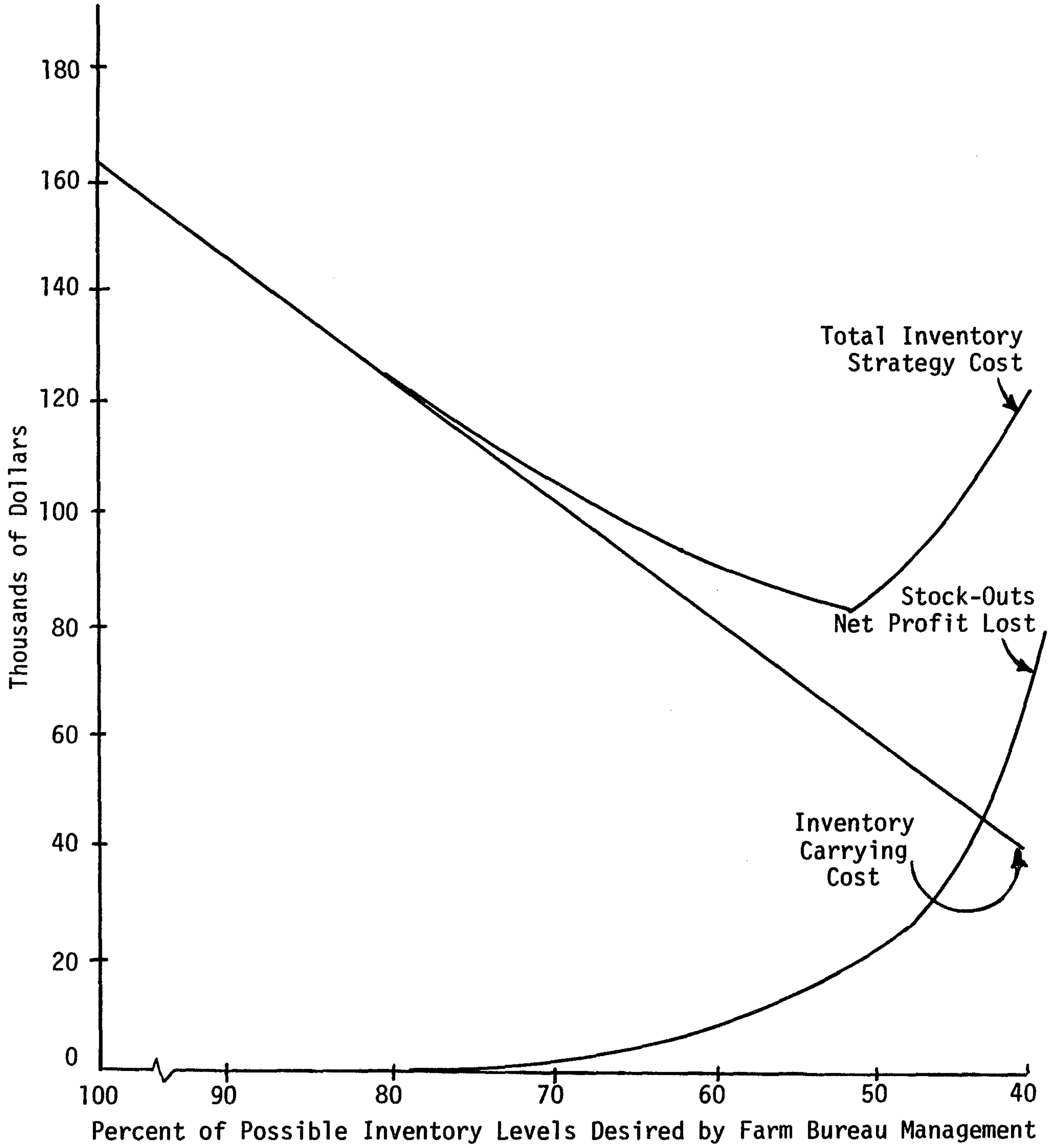

Figure 13. End-to-end strategy costs for 1972-1973.

By reducing inventory levels, to a point where trace stock-out levels are experienced, some savings result. By going to a centralized inventory, savings would be $26,693.40 in 1972-1973 (see Table 16 for Zilwaukee at 80 percent, Jenison at 90 percent, and End-to-End at 73 percent of desired inventory level). By moving to the minimum inventory strategy-cost levels (60 percent for both Zilwaukee and Jenison) a saving of around $9,906.14 results. It seems safe to conclude that a savings of 6 to 16 percent over current inventory carrying costs is meaningful, despite the possibility of some modest error within the model.

Estimated Parameters

By modeling the two-warehouse system as if the inventories are consolidated at one location it is possible to estimate two parameters necessary for the construction of the new one-warehouse simulator. These parameters are the desired inventory levels and the capacity requirement parameters.

The One-Warehouse System

Previously it has been reported that conferences with Farm Bureau management resulted in predictions of transportation savings should a one-warehouse system be implemented. These same conferences were the source of additional predictions for one-warehouse related savings over the two-warehouse system. The savings estimates described below are totally Farm Bureau calculations. The savings calculated by the simulator are not presented here, they will follow in a later section.

1. Include one manager, one assistant manager, and two foremen. This was included in the simulator and will be reported later.
2. Decrease the number of yard trucks from five to two. This will lengthen the useful life of the five tractors on hand. The data for these trucks are presented below.

Yard Trucks Owned:	Purchase Date		Description	Book Value
Zilwaukee	1967		Allis Chalmers	$ 1,636
Zilwaukee	1971		John Deere	7,486
Jenison	1973		IT80	13,335
Yard Trucks Leased:				
Zilwaukee	1974	50 months	Baker	$336.70/month
	(The lease charge declines with the book value--book value ranges from $10,853 to $200 over 50 months.)			
Jenison	1974	50 months	Clark	$307.08/month
	(The lease charge declines with the book value--book value ranges from $10,978 to $224 over 50 months.)			

The values for the leased trucks average $325.00 per month, ranging from $350.00 for the first month to $300.00 for the 50th month. Cutting to two tractors with one warehouse would save $11,700.00 annually or $325.00 per truck per month. In 1972-1973 dollars, this would represent a $8,730.34 savings.[15]

[15] For the remaining deflation adjustments a deflation factor of 1.34 with 1972-1973 equal to 100 was used. The value was calculated from price indices in "Economic Indicators," April 1975.

3. Packing dealer orders in shrink packs should:
    a. Reduce damage to merchandise. Farm Bureau's estimate of savings from the damage reduction is $2,000 annually.
    b. Decrease pallet requirements. Farm Bureau Management estimates a $700 per year savings here.

       This $2,700.00 in 1975 dollars from 3a and 3b represents a $2,014.93 savings in 1972-1973 dollars.
    c. Save four man-hours in the loading of each truck for peddle runs. The dollar savings is estimated for this portion of the change by the simulator. The results will be reported later.
4. Use a slot system for storage. In this system each product has a specific designated storage location. Farm Bureau estimates that loading time would be decreased by 10 percent (9.5 hours times 0.1 equals 0.95 hours) due to ease in finding the products to be loaded. Again, this estimate is included as one of the updated parameters in the new warehouse simulator.
5. Cut to one switching tractor from two. The Zilwaukee tractor was purchased in March of 1973 for $7,352.90 and is depreciated at the rate of $306.40 per year. There is no book value recorded for the Jenison switching tractor. These machines were once road tractors converted for use in switching railroad cars. Given the 1973 purchase date, the savings in 1972-1973 dollars is the actual amount depreciated or $306.40.

Two other savings were considered but dismissed. The first had to do with lift trucks. Management feels that five forklifts could do the work required in a one-warehouse facility. As six forklifts are now assigned to the two warehouses, an apparent savings was forecast. This is not an actual savings, however, as Farm Bureau Management later decided that five tractors would also be adequate in the current system because of the idle time now being recorded by the six forklifts.

Farm Bureau Management also expected savings from quantity discounts in the purchase of chemicals and medicinal supplies. Table 17, however, shows that the average chemical order size would not increase substantially in a one-warehouse system. In fact, less than 600 additional cubic feet of carrier space per load is indicated. This seems to indicate that no significant savings would result from quantity discounts.

The savings from a one-warehouse system predicted by Farm Bureau Management are summarized below:

Annual One-Warehouse Savings Predicted by Farm Bureau Management in 1972-1973 Dollars:

Three less yard trucks	$ 8,730.34
Shrink pack pallet and damage reduction	2,014.93
One less switching tractor	306.40
	$11,051.67

Table 17. Chemical Order Size Comparison Between a One- and Two-Warehouse System Using 1972-1973 Data

Day Ordered	Order Size in Cost of Sales Dollars		
	Jenison	Zilwaukee	End-to-End
1	1,775.19	1,328.89	3,104.08
25	2,928.24	3,061.62	0
50	3,876.96	4,382.04	4,065.99
75	4,308.89	2,106.93	7,129.71
100	4,527.42	240.03	4,409.85
125	1,360.41	17,382.69	268,790.16
150	245,490.63	327,938.58	357,646.38
175	160,711.92	64,422.60	205,895.34
200	58,599.54	67,546.23	136,413.45
225	51,760.95	37,469.97	85,754.19
250	0	18,503.79	0
	536,340.15	544,383.37	1,073,209.15
Average order size	53,634.00	49,489.40	119,245.45

If one load is divided between two warehouses:

average order size = 98,247.59

$$\$199,245.45 - \$98,247.59 = \frac{\$20,997.86}{CF=\$36.1} = 581.7 \text{ more cu. ft.}$$

Changes such as removing the ordering functions from the warehouses or eliminating at-warehouse dealer pickups were not included in this analysis as they are expected to occur regardless of which warehouse alternative is selected. The purpose of this action was to emphasize the impacts from differences between the two alternatives; it is assumed that similar changes would have similar effects.

The 1979-1980 Simulator

To review, two changes were found to be necessary in all models to prepare them for the projected analysis. First, managers' productivities were changed to reflect Farm Bureau's opinion that only two managers are needed per warehouse. Second, office productivity was increased to show a higher potential than the model measured and again to reflect the smaller increase in transactions as opposed to dollar demand. The one-warehouse model also was changed to reflect the new slot system and shrink pack technologies by reducing loading time from 9.5 to 4.55 man-hours per truck. Although this man-hour savings seemed large, Farm Bureau management stood solidly behind their estimate.

It should be mentioned that most of the labor requirement stems from the unloading function where product flows fluctuate widely and not from the loading function where it is regular from day to day. Therefore, the loading productivity can have sizable errors and not greatly affect the final labor requirements.

In this portion of the study it was also necessary to update the numbers used for the past year's demand. When desired inventory is a function of demand one year earlier, it becomes necessary to update the previous year's demand for each new year evaluated. Similarly, the values for beginning inventories and initial arrivals required updating. All alterations were achieved by applying to the values in question the percentage changes used for projecting demands (see Table 4 in Chapter III).

With these changes included in the model, the next step was to compare performances between the two alternatives at the 1979-1980 demand levels.

Simulator Results With Projected Demands

The results from the simulator with respect to projected demands and improved technology are summarized in Table 18 and Figures 14 through 16. If the same relative levels of desired inventories are used that resulted in minor levels of stock-outs with 1972-1973 data, both components of the two-warehouse system would be over their capacity by 1980.

At the same safety stock level used in 1972-1973 Jenison would require 173,648 cubic feet more space than is available and Zilwaukee 85,153 cubic feet more. With the current storage capacity, Zilwaukee's net loss from stock-outs would be $1,379.45 with an inventory carrying cost of $117,496.92. The similar amounts for Jenison would be $10,432.95 and $97,149.19 (see Table 19).

Table 18. Inventory Strategy Costs by Capacity and Percent of Desired Inventory Level Projected 1979-1980

Item	Zilwaukee		Jenison		New	
	cubic feet	dollars	cubic feet	dollars	cubic feet	dollars
100%[a]						
Size	NA[b]		NA		903,533	
Stock-outs						0
Inventory carrying cost						398,136.76
TOTAL						398,136.76
90%						
Size	NA		433,648		NA	
Stock-outs				1,212.11		
Inventory carrying cost				167,763.61		
TOTAL				168,975.72		
80%						
Size	345,153		374,194		686,498	
Stock-outs		118,36		3,592.99		0
Inventory carrying cost		156,104.19		144,070.00		299,961.44
TOTAL		156,222.55		147,662.99		299,961.44
73%						
Size	NA		NA		610,535	
Stock-outs						2,154.76
Inventory carrying cost						265,600.82
TOTAL						267,755.58
70%						
Size	292,469		NA		NA	
Stock-outs		775.12				
Inventory carrying cost		130,346.49				
TOTAL		131,121.61				
65%						
Size	266,127		NA		523,721	
Stock-outs		1,379.45				6,523.15
Inventory carrying cost		117,496.92				226,493.96
TOTAL		118,876.37				233,017.11
60%						
Size	239,785		257,586		478,225	
Stock-outs		2,593.01		10,432.95		10,538.88
Inventory carrying cost		104,678.65		97,149.19		202,132.69
TOTAL		107,271.66		107,582.14		212,671.57
53%						
Size	NA		NA		422,432	
Stock-outs						18,187.74
Inventory carrying cost						168,430.67
TOTAL						186,618.41
50%						
Size	188,351		213,231		398.521	
Stock-outs		24,417.72		38,623.77		26,446.70
Inventory carrying cost		79,663.91		75,018.36		154,172.14
TOTAL		104,081.63		113,642.13		180,618.84
40%						
Size	NA		NA		317,436	
Stock-outs						111,737.68
Inventory carrying cost						108,901.97
TOTAL						220,639.66

[a]Reflects percent of desired inventory level that was required to make the simulator track reality.

[b]NA = No analysis was run because other results would provide little if any additional information.

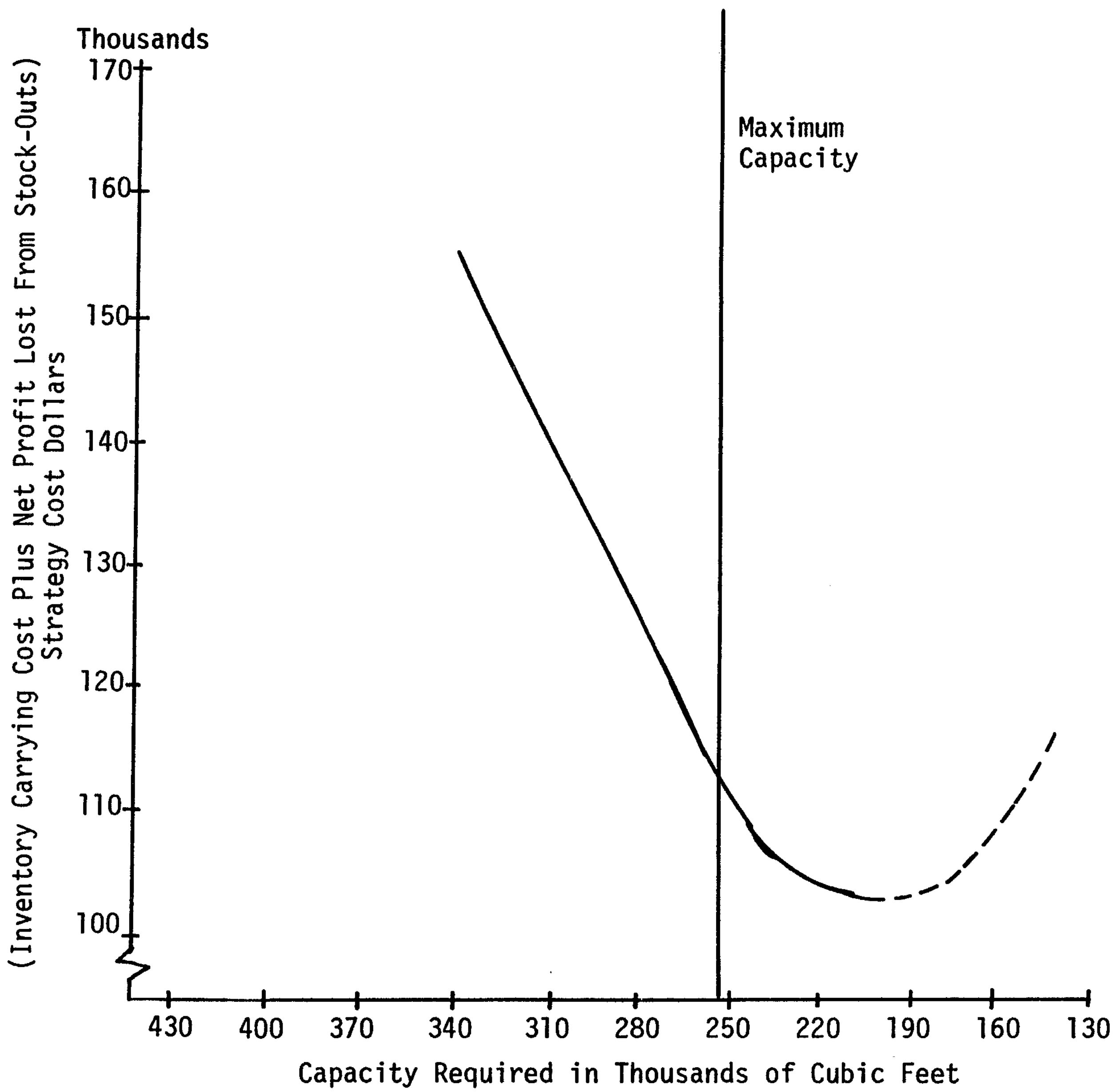

Figure 14. Zilwaukee strategy costs and capacity requirements for 1980.

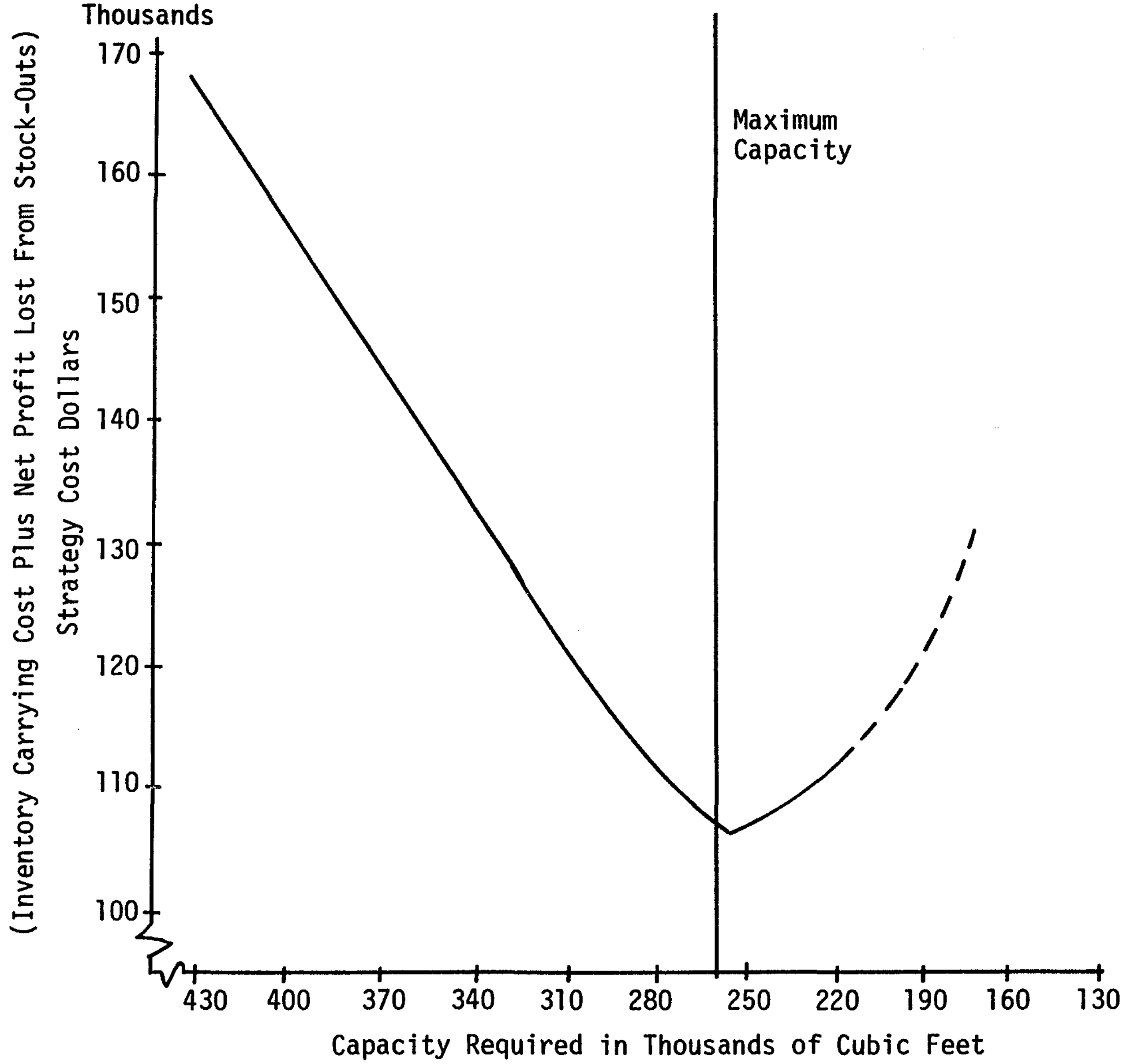

Figure 15. Jenison strategy costs and capacity requirements for 1980.

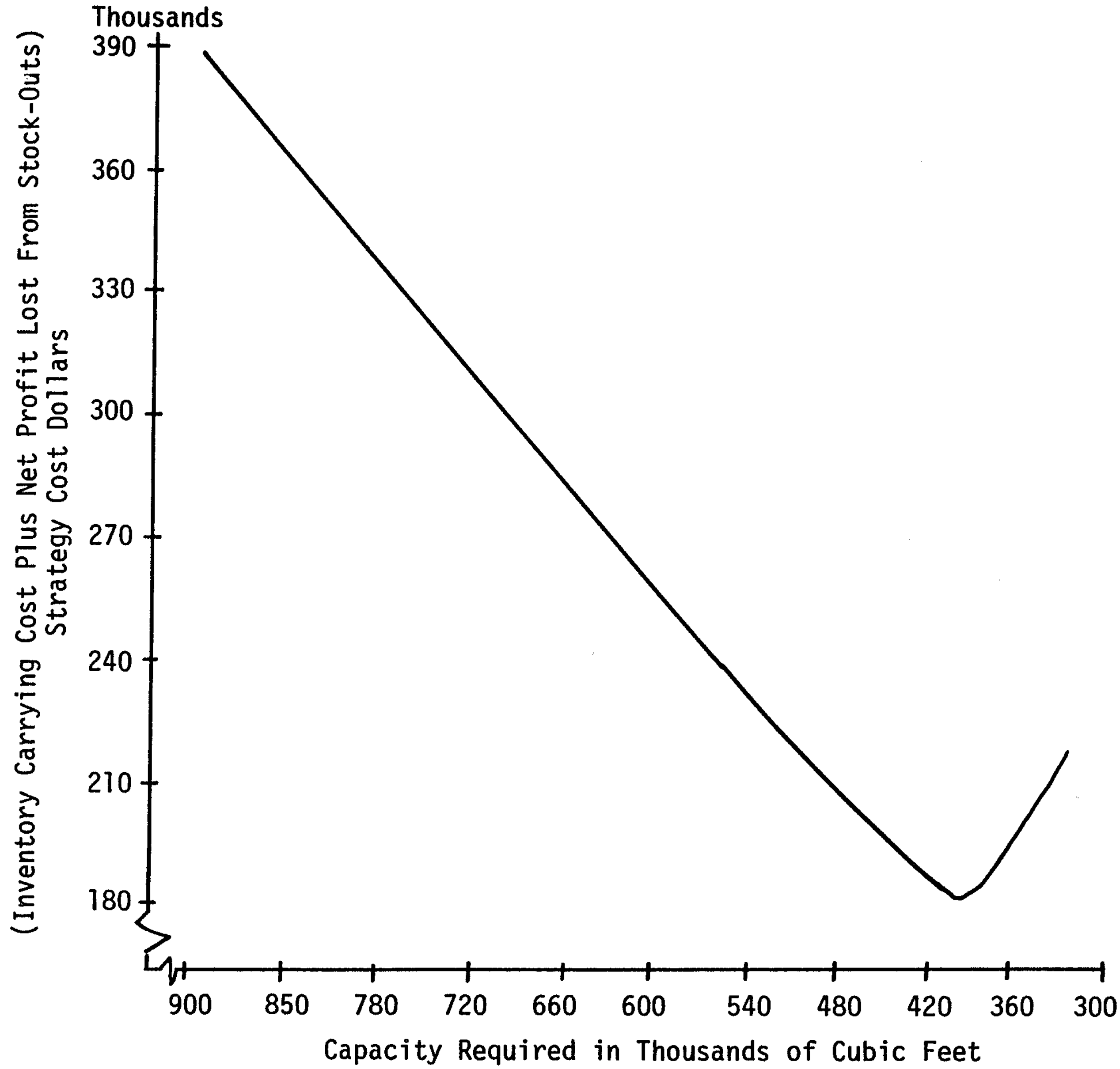

Figure 16. The one-warehouse system's strategy costs and capacity requirements for 1980.

Table 19. Annual Warehouse Cost Comparisons Between a One- and Two-Warehouse System at Approximately Equivalent Performance Levels or Stock-Out Rates

Item	Number of Warehouses in the System				
	Two			One	
	Zilwaukee	Jenison	Total	Cost	Differential
	$				
Net profit loss	1,379.45	10,432.95	11,812.40	10,538.88	1,273.52
Inventory carrying cost	117,496.92	97,149.19	214,646.11	202,132.69	12,513.42
Labor cost	107,827.20	85,113.60	192,940.80	148,616.00	44,324.80
Variable Costs Related to:					
Labor	36,122.11	23,831.81	59,953.92	46,070.96	13,882.96
Dollar volume	55,608.47	43,806.80	99,415.27	98,927.54	487.73
TOTAL	318,434.15	260,334.35	578,768.50	506,286.07	72,482.43
Other savings related to one-warehouse					11,051.67
GRAND TOTAL					83,534.10

The new one-warehouse system would give approximately the same performance while using 45,488 less cubic feet of storage space or a saving of $12,513.42 in inventory carrying costs. Shrink pack and slot system productivity improvements provide further savings in labor and labor-related variable costs. At this performance level, the two-warehouse system would require 18 warehousemen (two foremen, and 16 workers), four clerks, two assistant managers, and two managers.

The new one-warehouse system would need three less warehousemen (two foremen and 13 workers), four clerks, one manager, and one assistant manager. The difference here is $44,324.80 more savings for the new warehouse in 1979-1980. There are also other variable cost savings related to labor costs and business volume that amount to $13,883.96 and $487.73, respectively. These model estimates plus the $11,051.67 of plant cost savings previously estimated by Farm Bureau gives the one-warehouse system an advantage of $83,534.10 in 1980.

The most apparent implication of the result is, however, that the current system could not, without major policy and technological changes, continue much, if any, beyond the projected demand level for the 1979-1980 fiscal year.

The simulator has shown that by 1980 the Zilwaukee warehouse would lose $1,379.45 worth of profits, $4,733.73 cost of sales dollars, and be near the mathematically minimum inventory-strategy cost point (see Figure 14). A review of that figure does not, in itself, substantiate the position that the current system could not continue beyond 1980. There are, however, two related considerations that emphasize the reality of that position.

The first of these considerations has to do with the shape of the inventory-strategy cost curve. The inventory-strategy cost function (net profit lost plus inventory carrying cost) decreases gradually to a minimum and then increases sharply. Because the model cannot be 100 percent accurate, it is important to know the repercussions of making various errors. For example, the cost of adopting a 50 percent strategy when the 60 percent level is the actual minimum is much higher than when a 50 percent strategy is implemented and the 40 percent level is the true minimum (see Figure 17).

The second consideration is consumer ill-will. Because ill-will wasn't quantified, the probability of underestimating net losses increases at the lower desired inventory levels. This is true because the tendency to change suppliers would seemingly increase with the increase in out-of-stock replies to dealer requests.

It is, therefore, not only quite probable that it is more costly to be on the lower side of the "true" minimum cost point, but it is also likely that this costliness is underestimated in this analysis. With the above data in mind, it would be very difficult to recommend staying with the unmodified Zilwaukee warehouse much beyond 1980.

The importance of 1980 and possibly pre-1980 as the deadline for change is reemphasized upon analyzing the other half of the current system. The results show that the Jenison warehouse will have already been forced to its mathematically minimum inventory-strategy cost by 1980. The kind of safety margin enjoyed by the 1980 Zilwaukee warehouse will not be available to the Jenison location. As a result, policy and technological changes by 1980 seem inevitable for the current system.

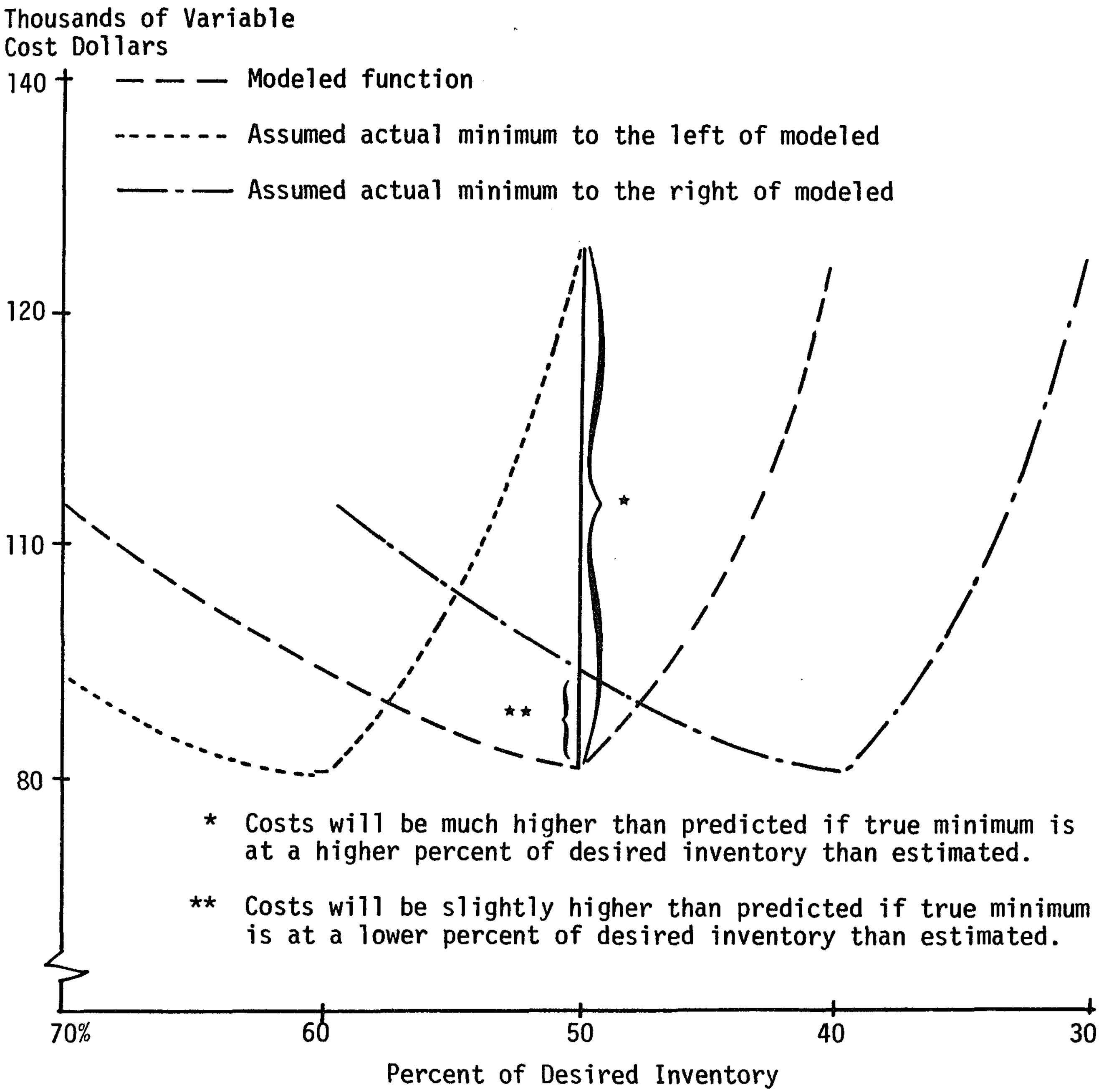

Figure 17. New warehouse inventory strategy costs: predicted costs versus true values.

Warehouse Size Alternatives

It has been shown that the current system may not be able to handle all that is required of it by 1980. Further evaluation of the one-warehouse system's ability to meet those requirements would, therefore, seem desirable.

All capacities greater than 478,000 cubic feet, where the one-warehouse system duplicates the current system's low 1980 performance levels, and those capacities less than 900,000 cubic feet, where the high 1972-1973 performance is duplicated will be considered. The $83,500 savings at the smallest of these capacities has already been reported.

This savings should, however, be weighed against stock-outs and potentials for expansion. First, it should be decided whether $10,538.88 of net profit lost (approximately $36,000 cost of sales dollars) is an acceptable level of performance. Second, without room for expansion an expectation of higher future demands will force even higher levels of stock-outs. If higher demand is expected, would Farm Bureau be willing to cut the safety margin for error and poor customer relations even finer (see Figure 16)?

Clearly, there are reasons for examining larger capacities. Moving from the 478,000 cubic feet size toward the 900,000 cubic feet of capacity (see Figure 18), the new system's $83,534.10 is being eroded away by ever-increasing inventory carrying costs. This erosion continues until, at the 900,000 cubic foot level, the annual variable cost

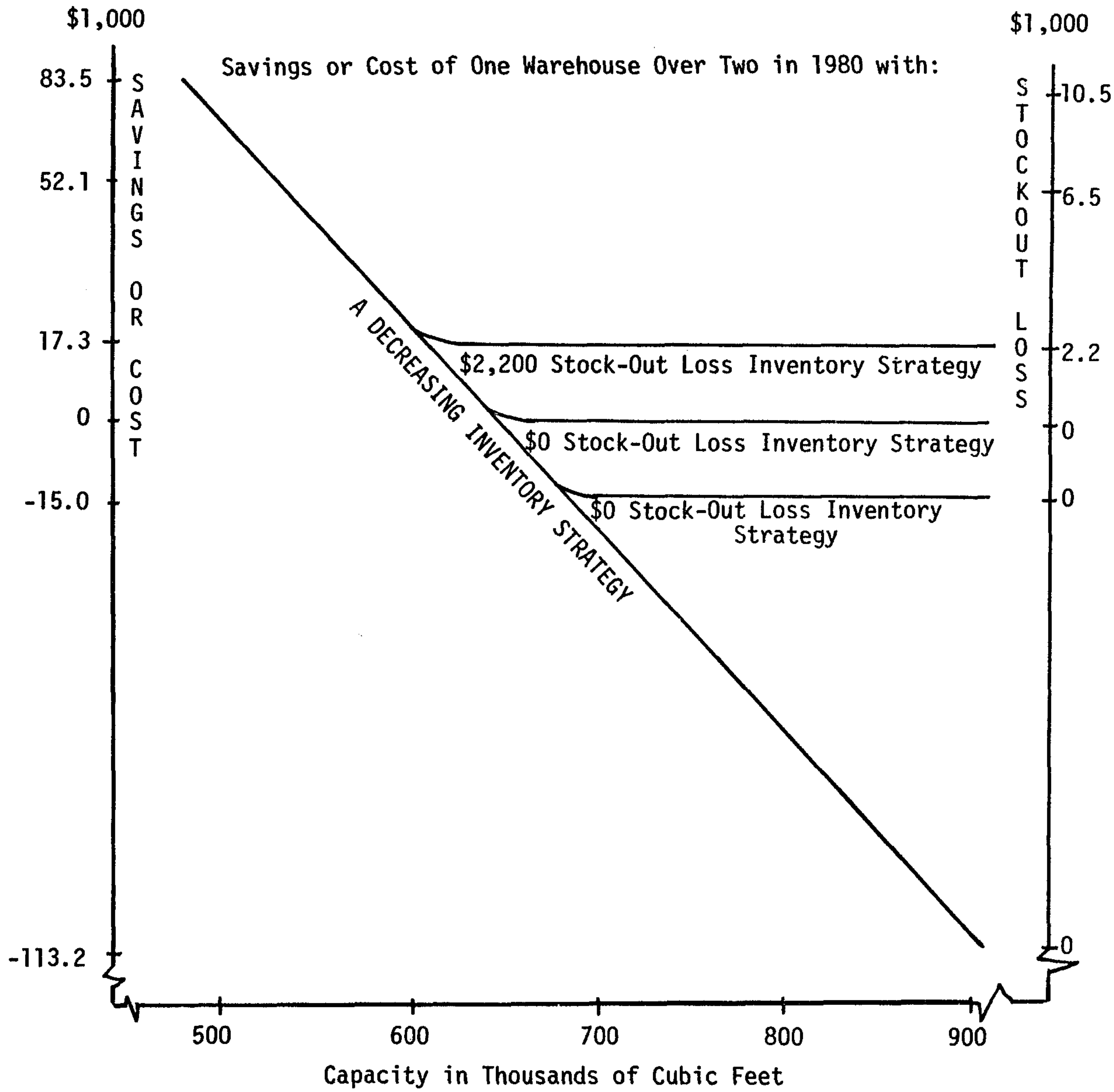

Figure 18. New warehouse capacity selection.

is $113.2 thousand more for the one-warehouse system than the current system. This is very deceptive, however, because the two alternatives are no longer comparable.

The $113,200 would be paying for a zero level of stock-outs, safety stocks equivalent to the 1972-1973 situation, plus room for expansion. This amount would move Farm Bureau to the situation described from the one with $83,534.10 of savings but also with $11,800 of net profit lost, no safety stocks, and no room for expansion.

The change from $83.5 thousand of savings to $113.2 thousand of cost over the range of capacities considered arise from the simplistic assumption that for each size considered, the relevant inventory-strategy would be one that utilizes the warehouse's full capacity. The "variable strategy" line in Figure 18 shows this naive assumption. The other three lines in Figure 18 attempt to circumvent this problem by showing the 1980 savings following from three different fixed inventory strategies. Once fixed, the strategy is changed only when forced to do so by capacity restrictions. This highlights the benefit of building a larger warehouse; that is, the ability to handle expanded demand without being forced into an undesired inventory strategy.

Strategies other than the three presented in Figure 18 can be evaluated by selecting an acceptable stock-out level and constructing a line at that point parallel to the horizontal axis.

At this point in the analysis, the size selection for the one-warehouse system revolves around expected demand increases and desired warehouse life. A fourteen year life and two extreme demand increase expectations will be used for illustrative purposes only. Here a fourteen year life is measured from the base period, which implies a search for the warehouse capacity that would allow the desired inventory strategy to continue through 1987.

By 1980, expectations are that capacity requirements will have increased by 402,802 cubic feet from 500,731 cubic feet (from the 1972-1973 End-to-End Model at 100 percent of desired inventory) to 903,533 cubic feet (from the 1979-1980 New Model at 100 percent of desired inventory). If the same increase occurs in the following seven years, required capacity would be 1,306,335 cubic feet, if zero stock-outs and the same level of safety stocks that were available in 1972-1973 is desired. This is a very optimistic expectation, but it was used to establish the upper end of the range of desired capacities. If, however, demand stays at the 1980 level, a 903,533 cubic feet capacity will be adequate.

Given an inventory strategy that accepts $2,154.76 of losses from stock-outs, a warehouse of 1,013,337 cubic feet would be adequate. On the other hand, if demand is expected to plateau after 1980, it could be accommodated by a warehouse of 610,535 cubic feet (see Table 20).

Table 20. One-Warehouse Capacity Requirements for Performance To Be Acceptable Until 1987 for Two Performance Levels and Two Demand Projections

	Capacity Requirement	
	Inventory Strategy	
Expected 1980-1987 demand increase	Same as that used in 1972-1973	An acceptable net profit loss of less than $2,000.00
Same as that experienced from 1973-1980	1,306,335 cubic feet	1,013,337 cubic feet
No increase after 1980	903,533 cubic feet	610,535 cubic feet

Construction Timing

Another decision that would arise should a one-warehouse system be selected has to do with selecting the correct time to build. The answer is not obvious because data are only available for two time intervals, 1972-1973 and 1979-1980.

Again, as in the capacity decision, the desired inventory strategy is central to the issue. Table 21 shows calculations that should aid in this decision. The inventory strategy of accepting trace levels of net profits lost is one that might be preferred by Farm Bureau. For any other performance level, calculations similar to those that follow can be made.

With this inventory strategy, the Jenison location would effectively use 182,913 cubic feet in 1972-1973 and expect an increase in space required of approximately 36,000 cubic feet per year. At this rate, Jenison's capacity would be reached in the latter part of 1975.

Zilwaukee, however, could continue until mid-1975 before reaching capacity with the 20,000 cubic feet per year increase.

The inventory strategies required to allow the current system to run until mid-1980 without modification has already been presented. It was shown that Jenison and Zilwaukee would reach capacity by the end of the 1979-1980 fiscal year if stock-out levels of $10,432.45 net profits lost were accepted, respectively.

A word of caution is essential at this point. The vital assumption in this analysis is that the 1980 projections were treated as if they would be achieved in equal yearly increments. Should more of the increase occur in the earlier years, capacities would be reached earlier, and conversely.

Table 21. Construction Timing for the Proposed One-Warehouse System

Location	Capacity Required: Zilwaukee	Capacity Required: Jenison
Inventory Strategy	80% of Dinv[a]	90% of Dinv
	----------- cubic feet -----------	
Fiscal Year:		
1972-1973	207,230	182,913
1979-1980	345,153	433,648
Increase	137,923	250,735
Yearly increase	19,703	35,819
Capacity required by end of:		
1973-1974	226,933	218,732
1974-1975	246,636	254,551
1975-1976	266,339	290,270
Over warehouse capacity by:	mid 1976	mid 1975

[a]Dinv is the desired inventory level used in the warehousing system in 1972-1973.

CHAPTER V

INVESTMENT ANALYSIS

In the evaluation of the one-warehouse system, the discussion has been in terms of absolute dollar savings for the 1979-1980 fiscal year. In order to evaluate the attractiveness of this proposal it is necessary to analyze the nature of the cash flows in the years before and after 1980, including investment requirements and residual values not yet considered.

The warehouse savings presented previously were generated from a comparison of the current system and a one-warehouse structure that would exhibit equivalent performance. Chapter IV indicated that a larger building would be required to improve upon that 1980 performance. It is, therefore, important to know what size building Farm Bureau would select if they decide to proceed with construction of a one-warehouse system. With this knowledge the magnitude of the required investment can be determined.

Farm Bureau management currently feels that a 610,535 cubic feet capacity would be sufficient. They have also determined that the new system could be in operation by the end of the 1975-1976 fiscal year.

It was suggested in the previous chapter that the current system could not continue beyond 1976 at acceptable levels of performance.

Here, however, the comparison will be made as if the choice is between investing in the new one-warehouse system and continuing with the unmodified existing facilities. The warehousing system would, of course, experience ever decreasing levels of performance if the latter alternative were selected. Ill-will was not included in the net profit lost calculations. As the current system's stock-outs increase, the importance of ill-will will be magnified and the accuracy of the function that excluded it decreased. A second method for continuing the current system would be to carry only high priority inventories while dropping others to take advantage of limited facility capacity. This change, a policy change, would likely generate another kind of ill-will. Ill-will would result because dealers would be forced to choose from a smaller variety and might have to acquire supplies directly from manufacturers.

Cash Flows

A comparison of the variable costs for a 610,535 cubic feet warehouse (see Table 22) and those for the existing system indicates that only net profits lost and inventory carrying costs differ from those of the smaller warehouse previously examined (see Table 19, Chapter IV). As expected, the larger warehouse has greater inventory carrying costs but lower net profits lost because it is capable of carrying larger inventories. Even though the inventory cost is higher in this warehouse than those in the current system, the other savings allow it to show a net savings for 1979-1980.

Table 22. Warehouse Cost Comparisons Between the Current and Proposed Warehouse Systems as Predicted for 1979-1980

	Two-Warehouse System			One-Warehouse System		
					Differential Savings or Cost (-)	
	Zilwaukee	Jenison	Total Variable Cost	Total Variable Cost	In 1972-73 Dollars	In 1975 Dollars
	$					
Net profit lost	1,379.45	10,432.95	11,812.40	2,154.76	9,657.64	13,192.34
Inventory carrying cost	117,496.92	97,149.19	214,646.11	265,600.82	-50,954.71	-69,604.13
Labor cost	107,827.20	85,113.60	192,940.86	148,616.00	44,324.80	51,416.77
Variable costs related to:						
Labor	36,122.11	23,831.81	59,953.92	46,070.96	13,882.96	18,964.12
Dollar volume	55,608.47	43,806.80	99,415.27	98,927.54	487.73	666.24
Subtotal	318,434.15	260,334.35	578,768.50	561,370.08	17,398.42	14,635.34
Other one-warehouse savings[a]	NA[b]	NA	NA	NA	11,051.67	14,809.24
Total	318,434.15	260,334.35	578,768.50	561,370.08	28,450.09	28,292.28

[a]Yard truck, switching engine, damage, pallet, and slot system savings.

[b]Not applicable.

All annual net savings are expected to be at the values given for 1979-1980 from the time the warehouse begins operation except for net profit lost and inventory carrying cost. The labor savings and other advantages (in yard truck, switching engines, damage, pallet, and slot system savings) related to a one-warehouse operation will not change. Inventory carrying cost and net profit lost values will change, however, because the demand volume is not as high in the earlier years. The differentials for these values will increase over the years until they reach those listed for 1979-1980.

Chapter IV disclosed a linear relationship between the amount of inventory carried and the cost of carrying inventory. If the one-warehouse structure had been in operation in 1972-1973, the amount of inventory carried in the two systems would have been equivalent. In subsequent years the two-warehouse system would be forced to stay at the 1975-1976 inventory level, despite increased demand, while the proposed warehouse could increase its inventory level after 1975-1976. As a result the expectation is that the differential in inventory carrying costs would expand in a linear manner from zero in 1972-1973 through the $50,954.51 of added costs predicted for 1979-1980. With this basic assumption, the additional inventory costs expected for the one-warehouse system in other years were calculated; see Figure 19 and Table 23.

Savings from decreased net profit losses were calculated in a similar manner; see Figure 20 and Table 24. The linearity condition that exists with respect to inventory carrying costs does not, however,

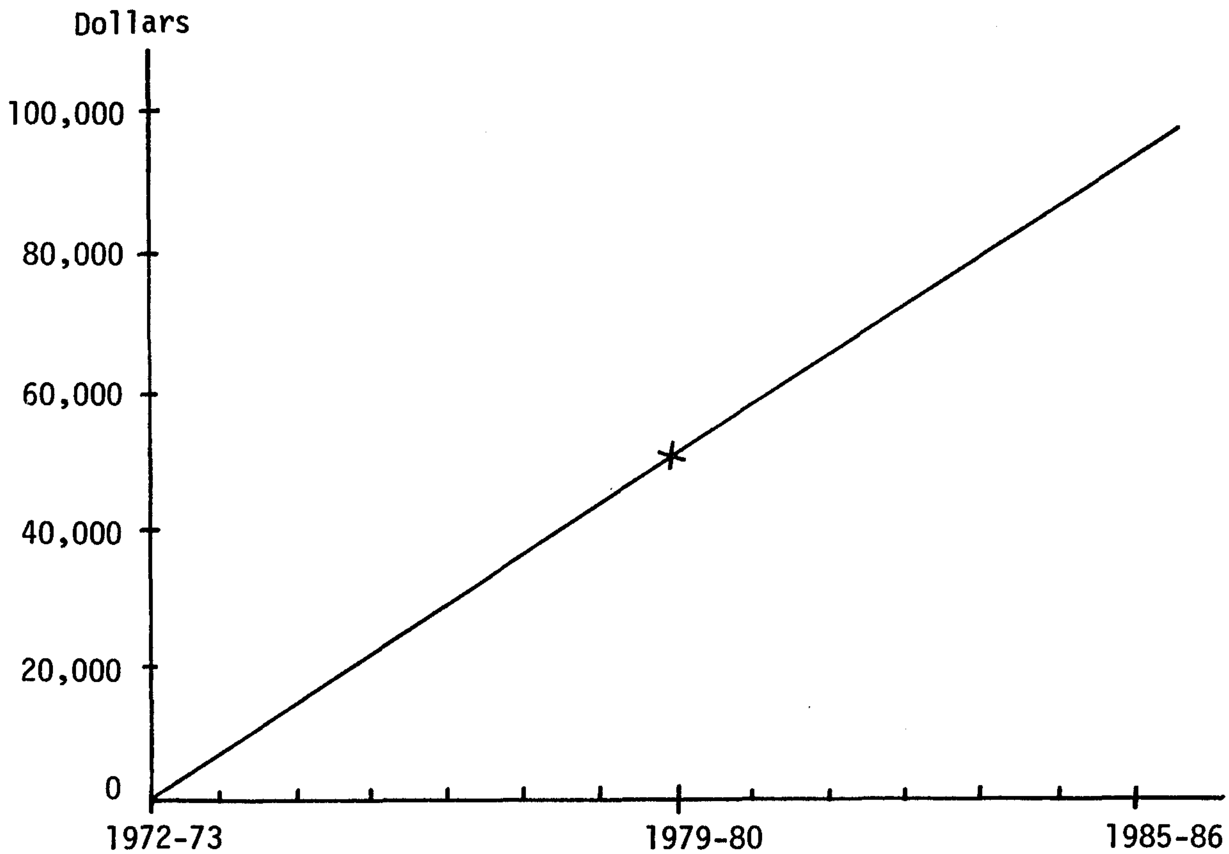

Figure 19. Estimated additions to cost from higher inventory carrying costs in a one-warehouse system.

Table 23. Estimated Additions to Cost from Higher Inventory Carrying Costs in a One-Warehouse System

Year	In 1972-73 Dollars	In 1975 Dollars
1976-1977	29,116.98	39,773.79
1977-1978	36,196.94	49,445.02
1978-1979	43,675.47	59,660.69
1979-1980	50,954.71	69,604.13
1980-1981	58,233.95	79,547.58
1981-1982	65,513.19	89,410.02
1982-1983	72,972.44	99,680.35
1983-1984	80,071.68	109,377.91
1984-1985	87,350.93	119,321.37
1985-1986	94,630.17	129,264.81

Table 24. Estimated Savings from Lower Net Profits Lost in a One-Warehouse System

Year	In 1972-73 Dollars	In 1975 Dollars
1976-1977	5,518.65	7,538.48
1977-1978	6,898.31	9,423.09
1978-1979	8,277.98	11,307.72
1979-1980	9,657.64	13,657.64
1980-1981	11,037.30	15,076.95
1981-1982	12,416.96	16,961.57
1982-1983	13,796.57	18,846.11
1983-1984	15,176.29	20,176.29
1984-1985	16,555.95	22,615.43
1985-1986	17,935.62	24.500.06

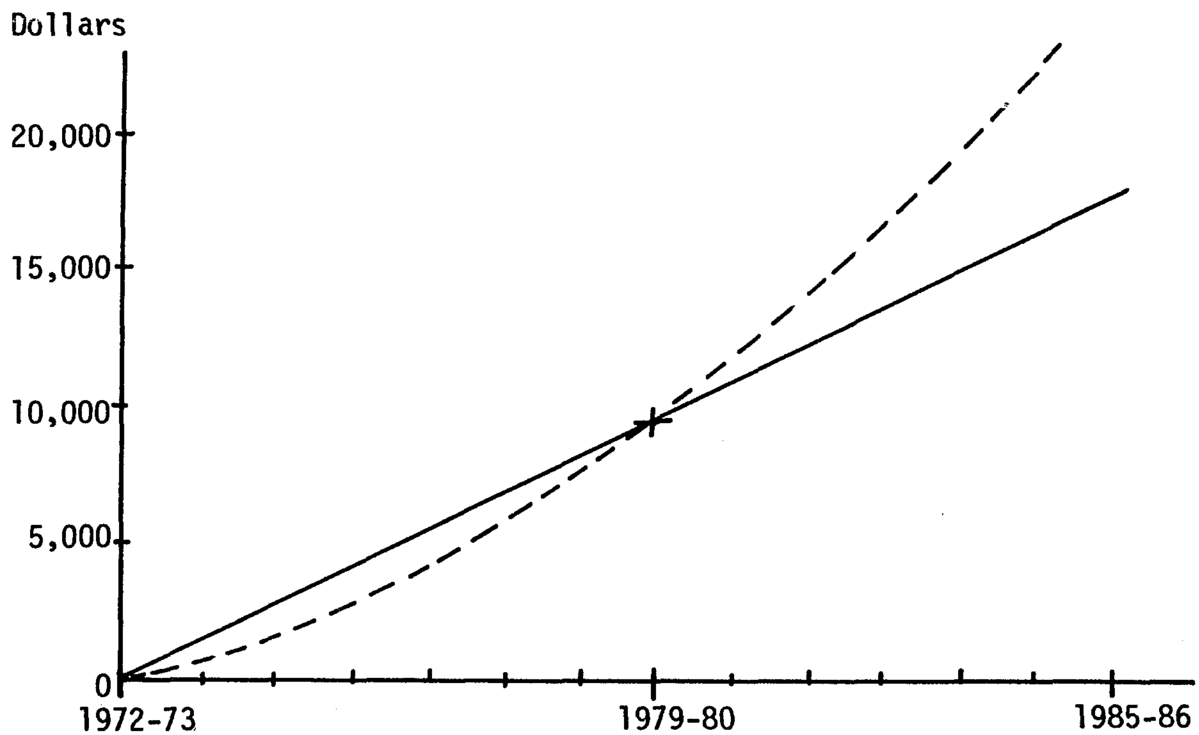

Figure 20. Estimated savings from lower net profits lost in a one-warehouse system.

strictly hold for stock-out losses. Figures 14 through 16 in Chapter IV show that as the inventory-to-demand ratio decreases (demand is held constant while inventory is reduced), the net profits lost from stock-outs increase slowly up to a point but then increase sharply. By 1979-1980 the current system is expected to be beyond that point. The proposed system will be experiencing some stock-out losses but only at low levels. In fact, considerable demand increases could occur before stock-out losses increase faster than the carrying cost savings, unlike the current system (see Figure 21).

The possible shape of the true function derived from expected differentials like those in Figure 21 is presented in Figure 20 with the contrasting linear approximation. That figure demonstrates that the linear approximation overestimates savings in the early years and underestimates them after 1979-1980.

The cash flow estimates to this point in the evaluation have been expressed in 1972-1973 dollars. Because the cost estimates that will follow are in 1975 terms, it is necessary to adjust all cash flows to one common basis or year. Analyses using 1972-1973 dollars have been appropriate because the concern was with absolute performance comparisons in a year representing normal Farm Bureau operations. Investment-cash flow analyses should, however, include relative changes in savings and costs resulting from differential inflation rates. The impact on cash flows from these differential inflation rates will be evaluated both objectively and subjectively. The objective evaluation will be accomplished by expressing the savings and costs previously

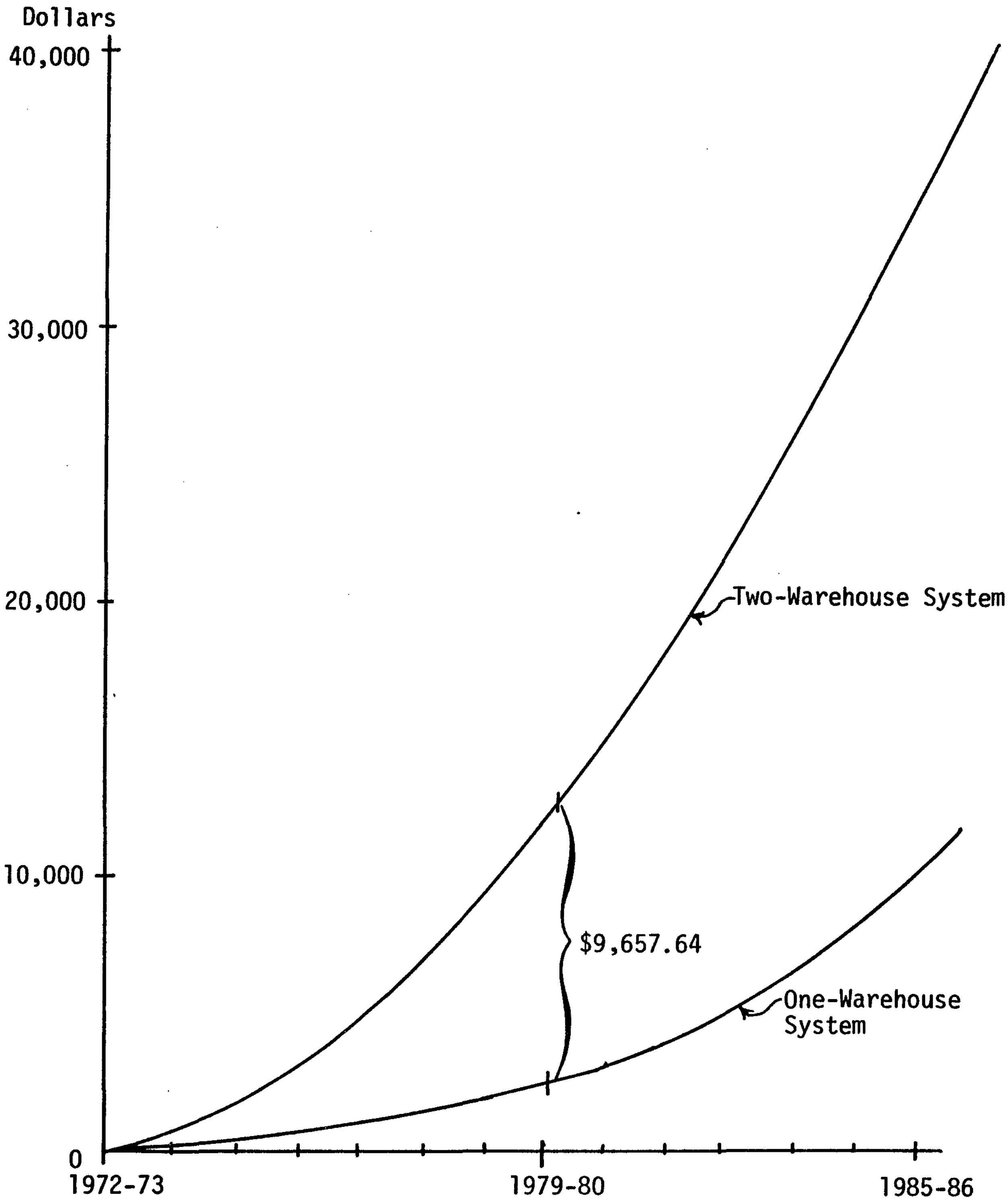

Figure 21. Net profits lost.

calculated for 1972-1973 in 1975 dollars. Once rates of return are calculated from values expressed in 1975 terms the possible effects of subsequent inflation can be investigated subjectively.

Tables 22, 23, and 24 include the 1975 values for the 1972-1973 estimates. These estimates were inflated using an index of 136.6 for agricultural inputs from the "Agricultural Prices" monthly and 116.0 for labor from the "Michigan State Economic Record." The index used for site-related savings not already in 1975 terms is 134, originally used to convert them from 1975 to 1973 dollars (see page 97 of Chapter IV).

In addition to warehouse cost savings, some possible transportation savings associated with one warehouse were indicated in Chapter III. Calculations there revealed a differential of between $10,198.67 savings and $2,221.89 added cost depending on which one of the seven proposed location costs are used. Because a location has not been selected, the Climax transportation savings of $5,043.35 will be used. The Climax number is used because it is the median point for the seven values calculated and is, therefore, with the information available to this point, the most representative. In 1975 dollars the $5,043.35 becomes $6,152.88. An index of 122 for transportation equipment from the "Wholesale Prices and Price Index" was used as a proxy index for transportation services.

If the one-warehouse system is implemented, required investments would include costs for the building itself, shrink pack equipment, other new equipment,[16] transportation and installation of transferred equipment, and construction of a railroad siding. Because a site has not been selected, a fairly exact estimate of these last three costs is not available. The investment estimate will, however, be increased and a range of values used that will likely contain any reasonable value that might result for these site-related costs.

According to Farm Bureau management and contractor estimates a suitable building will cost $259,400.00. The shrink pack technology will be $15,000.00 while the twenty acres of land desired is expected to cost $5,000 per acre or $100,000.00. The total investment without costs for equipment transfer, new equipment, and railroad siding is $374,400.00

Farm Bureau expects the railroad siding to cost $20 per foot. With this price an additional investment of between $13,200.00 and $26,400.00 will be used for a range of between one-eighth and one-fourth of a mile of railroad siding. It is also expected that costs for the remaining transfer and equipment variables will fall within a range of $10,000.00 to $20,000.00. In total, the new warehouse system is expected to cost between $397,600.00 and $420,800.00.

Two other cash flows are important in addition to those already discussed. If the new system is implemented, Farm Bureau Services expects to sell one of their warehouses for $100,000.00 and transfer

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[16] The plan would be to transfer all required equipment from the two-warehouse system; however, some small investment may be necessary if existing equipment is not compatible with the new building.

the other within Farm Bureau to another division at its book value--$189,147.42. These transactions would add to cash inflows once the new warehouse is operating. The $100,000.00 building has a zero book value and has been owned by Farm Bureau for enough years to classify its sale as a capital gain. This classification exempts $25,000.00 of the sales price so the after tax return from the two warehouses will be $270,397.42 with their 25 percent effective tax rate.

The remaining cash flow of importance is the residual value of the new building at the end of the evaluation time period. Farm Bureau uses straight line depreciation so the residual will be x/30 of the initial value where x equals the years of life remaining in the warehouse.

Evaluation Interval

Selecting the number of years over which to evaluate the proposed investment, 30 - x, is an important yet fairly arbitrary decision. Because Farm Bureau depreciates their warehouses over a thirty-year expected life, a thirty-year period might be considered.

There is, however, a problem with this long interval stemming from the assumption that Farm Bureau will either construct the new warehouse or continue with the current system unchanged. Over such a long period it seems likely that alternative warehouse system investments could not be avoided. Because estimates for alternative investments have not been included in this research, the value of this longer evaluation period is questionable.

On the other hand, a very short analysis time, say to 1980, could also be misleading because the residual value of the new warehouse in 1980 would dominate the analysis (only four years, 4/30 of the warehouse life would be depreciated away).[17] It is necessary, therefore, to select a length of time that will make the residual value less important without conflicting with the investment-no investment assumption. By evaluating the cash flows for one-third of the new warehouse's expected useful life, through 1985-1986, the distortion from both shortcomings should be minimal.[18] It also seems more likely that Farm Bureau could, with difficulty, continue the current system without major investments over an eleven-year interval.

With this eleven-year interval (ten years of warehouse life used) the residual value for the new warehouse will range from $181,733.33 to $190,533.33 for initial investments of $397,600.00 and $420,800.00, respectively. These residuals are expected for the building and the railroad siding. The equipment investment of $10,000.00 to $20,000.00 will be totally depreciated over the ten years of this evaluation.

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[17] For those familiar with discounting procedure, the present value of one dollar expected at the end of five years is $0.49718, nearly half of its current value when discounted at a rate of 15 percent.

[18] With discounting procedures the present value for one dollar at the end of eleven years is only $0.21494 at 15 percent and still under one-half $0.47509 at the low discount rate of 7 percent.

Return on Investment

A single rate of return will not sufficiently evaluate the proposed one-warehouse alternative. A proper analysis should survey a range that includes the most likely cash flows. A range for the initial investment has previously been discussed with respect to the site-related variables: new equipment, equipment transfers, and rail siding. Other similar realistic possibilities should also be evaluated. Unfavorable results from any one contingency might disqualify or devalue an otherwise profitable investment.

One contingency has to do with the expectation for demand beyond 1980. Farm Bureau's selection of the 610,535 cubic foot warehouse suggests, according to the capacity recommendation in Chapter IV, that they expect demand to plateau at the 1980 level. The after tax cash flows in Table 25 must therefore be adjusted to account for this possibility. The adjustment requires that the savings from 1980-1981 through 1985-1986 be the same as the value for 1980-1981. The savings were, however, calculated to decrease for that period because of the higher inventory carrying costs required to meet demands increasing at a rate equivalent to that prior to 1980-1981. The flows in Table 25 were calculated with an initial investment of $397,600.00: $259,400.00 for the building, $13,200.00 the low end of the expected range of costs for the railroad siding, $15,000.00 for shrink pack equipment, $10,000.00 for the lower expected costs of transferring old and buying new equipment, and $100,000.00 for land.

Table 25. Annual Cash Flows After Taxes for a $397,600.00 Initial Investment Through 1985-1986

Year	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
	Before Income Tax Cash Flows for a One-Warehouse System at Year End[a]	Taxable Cash Flows (1 - Additional Depreciation of $5,234.67 per Year)[b]	Income Tax (3 x 0.25)[c]	After Tax Cash Flows (1 - 4)	After Tax Warehouse Residual Value	Total After Tax Cash Flows (4 + 5)[d]
	$					
1975-1976	0	0	0	0	270,396.42	270,396.42
1976-1966	53,621.06	48,386.39	12,096.60	41,524.46	0	41,524.46
1977-1978	45,834.44	40,599.77	10,149.94	35.684.50	0	35.684.50
1978-1979	37,503.40	32,268.73	8,067.18	29,436.22	0	35.684.50
1979-1980	29,909.88	24,675.21	6,168.80	23,741.08	0	23,741.08
1980-1981	21,385.74	16,151.07	4,037.77	17,347.97	0	17,347.97
1981-1982	13,407.92	8,173.25	2,043.31	11,364.61	0	11,364.61
1982-1983	5,022.13	-212.54	-53.14	5,075.27	0	5,025.27
1983-1984	-3,345.25	-8,579.92	-2,144.98	-1.200.27	0	-1,200.27
1984-1985	-10,849.57	-16,084.24	-4,021.06	-6.828.51	0	-6,828.51
1985-1986	-18,908.38	-24,143.05	-6,035.76	-12,872.62	281,733.00	268,860.71

[a]Includes $85,856.37 of constant yearly flows from labor, labor and volume related variable costs, damage, pallet, yard truck, switching engine and slot system savings plus the inventory carrying cost and slot system flows of Tables 23 and 24.

[b]Includes $9,080.67 per year of added depreciation for the building and its rail siding plus $1,000 for equipment less $4,154.00 of old depreciation. Negative values represent losses to reduce taxable income.

[c]Negative values represent tax credits, a source of cash.

[d]The $397,600.00 investment would also be an outflow in the beginning of the 1975-1976 fiscal year.

These flows when adjusted for demand leveling-off at the 1980 level resulted in a 16.23 percent rate of return after taxes. This and the remaining returns were calculated according to the formula:

$$\sum_{t=0}^{n} \left[\frac{A_t}{(1+r)^t} \right] = 0$$

where:

A_t = cash flow for period t,

n = the last (eleventh) period, and

r = the internal rate of return.

This return includes three yearly net profit lost savings values that were slightly overestimated as previously explained. Because of the relatively low magnitude of those savings the internal rate of return should not be grossly overstated.

The evaluation of the remaining contingencies will include estimates of residual value sensitivity, a point of earlier concern. In the situation described above the warehouse residual value could decrease 63.3 percent before the return would drop below 14 percent (see Table 26).

Table 26. Internal Rate of Return and Sensitivity Calculations Through 1985-1986 for a One-Warehouse System

	Demand Expectations from 1979-80 Through 1985-86				Residual Value Sensitivity		
Depreciable Investment[a]	Continue to Increase at the 1972-73 to 1979-80 Rate	Plateau at the 1979-80 Level	Internal Rate of Return on Investment (IRR)	Residual Value of the New Warehouse by the End of 1985-86	Dollar Amount that Residual Could Decrease Without Greatly Changing IRR	Percent Decrease in Residual	Resultant IRR
($)			(%)	($)	($)	(%)	(%)
297,600.00	No	Yes	16.23	181,733.33	115,071.88	63.3	14
320,800.00	No	Yes	14.63	190,533.33	32,769.80	17.2	14
297,600.00	Yes	No	14.12	181,733.33	4,987.15	2.7	14
320,800.00	Yes	No	12.63	190,533.33	100,506.89	52.8	10
450,500.00	No	Yes	8.98	277,000.00	55,061.02	19.9	8
450,500.00	Yes	No	7.19	277,000.00	55,936.92	20.2	6

[a]The depreciable investment includes the warehouse and siding value depreciated over thirty years and equipment over ten, but does not include the $100,000.00 for land.

Sensitivity Analysis

Table 26 shows five additional contingency rate of return calculations. The second row of that table indicates that a 14.63 percent return would result if the previous analysis was only modified to include the higher costs for site-related variables.

The third row of the same table reports a 14.12 percent return should demand not plateau at the 1979-1980 level. The 2 percent decrease resulted solely from including the flow estimates from Table 25 for 1980-1981 through 1985-1986 rather than holding them at the 1980-1981 levels as in the initial calculation. This return, however, is not overestimated as was suggested in the first case. Here the three overestimated values for 1976-1977 through 1978-1979 should be more than offset by the six underestimated values for 1980-1981 through 1985-1986, depending on the magnitude of the offsetting errors.

The final three internal rate of return calculations represent differing mixes of initial investments and one or the other of the two previous demand expectations. The $450,500.00 initial outflow is made up of a building cost 50 percent higher than the one previously used as well as the higher site-related estimates. This calculation also gives an indication of returns that would be expected from a building with 50 percent more floor space at the lower price level initially used.

There is at least one other area of concern that is difficult to quantify that can be adequately handled subjectively. By stating the 1972-1973 savings calculations in 1975 dollars, differential inflation rates for labor, transportation, and agricultural inputs have been accounted for through 1975. The returns as presented, however, have included zero inflation for the post 1975 estimates.

In the most general sense, inflation would cause the cash flows for 1976-1977 through 1985-1986 reported in Table 25 to increase, resulting in higher rates of return for each of the contingencies previously evaluated. Inflation could also, with limited subjective interpretation, demonstrate the opposite effect.

In Table 22 the 1979-1980 savings were lower when expressed in 1972-1973 terms. In that analysis additional inventory carrying costs for the proposed warehouse were offset by savings from numerous other sources, including a relatively large savings from labor. The inflation index for labor showed a 16 percent increase for those years while all other values, inventory carrying costs among them, increased at a faster rate. In 1975 terms, therefore, there was relatively less labor savings to help offset inventory carrying costs than in 1972-1973. Should the same relative rates of inflation continue through 1985-1986, the flows reported in Table 25 would have to be decreased and the internal rates of return, as presently calculated, would be overestimated.

It is important to note, however, that this alleged over-estimation is a strict conceptual extrapolation of the mathematical estimates used in these calculations. What the mathematics cannot reflect is the fact that the warehousing alternatives under evaluation are not operating at equivalent performance levels. If the current system were to continue by deleting product lines of lesser importance, the resulting loss in revenue from those products would add greatly to the savings as currently expressed for the one-warehouse system.

The previous analysis has evaluated Farm Bureau's likely short-run strategy for continuing their current system: accepting higher stock-outs as demand increases. In the longer run, critical inventory shortages may force Farm Bureau into another strategy for maintaining their unmodified current facilities. Should they decide to delete entire product lines, the internal rates of return from the comparison with the larger one-warehouse system will increase substantially. An internal rate of return of over 70 percent ensues from the following assumptions:

1. Once the current system reaches capacity at some desired performance level, product lines will be deleted to maintain that performance level.
2. Continued products will exhibit average dollar-to-volume ratios like those in the current system.

Given the above assumptions, stock-out profit lost values that were previously used are replaced by the much larger differentials from sales plateauing at the 1975-1976 level for the existing system but continuing to grow with demand for the one-warehouse system.

This last analysis provides objective input as a basis for subjective analysis of the product-deletion approach. To claim more for the objective analysis might be misleading because of the narrowness of assumption number two. It seems equally as likely that continued product lines could exhibit dollar-to-volume ratios unlike those of the current system. Higher ratios, for example, would lead to higher sales and higher inventory carrying costs than those used in the objective analysis.

If, on the other hand, the current system continued with all product lines, accepting higher and higher losses from being out of stock, it is likely that both warehouses would be past the critical point on their net profit loss functions. This situation would create savings for the one-warehouse system that would tend to offset the increased inventory carrying costs.

In essence, this last argument stems from knowledge of the costs that exist when the one and two-warehouse alternatives are compared at equivalent performance levels (see Table 19, Chapter IV). When the two alternatives are performing equivalently the one-warehouse system demonstrates an advantage in each cost area. With this in mind, the only possible effect of inflation, whether or not they are differential rates, would be to increase the yearly savings flows and the related internal rates of return.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Increasing demand for agricultural products has forced an ever decreasing farm population to provide more output from fewer acres. Farmers in Michigan are no exception. They too are attempting to remain competitive in all agricultural enterprises by increasing their productivity.

The Michigan Farm Bureau, in its role as input supplier, plays a vital part in this attempt to increase productivity. To remain competitive, Farm Bureau must also continually strive to keep its costs low. They are concerned, however, that their warehousing facilities are not adequate to meet the expected increase in demand for agricultural inputs.

The purpose of this research was to determine whether the existing warehouse system is sufficient to fulfill expected needs. In addition, Farm Bureau requires that the current system's capabilities be weighed against those of a centrally located one-warehouse system. The objective was to compare projected future assembly, distribution, and warehouse cost structures for the current facilities to those for each of seven proposed one-warehouse locations.

A modified lockset model was selected for use in analyzing distribution costs. The method can account for irregular dealer demands, partial load delivery requirements, and backhaul supply points without excessive computational costs, where other methods cannot. The many and varied product lines carried in the Farm Bureau warehousing system were aggregated into sixteen representative product groups. This aggregation process facilitated the calculation of dollar to cubic feet conversion factors necessary to the modeled reconstruction of historic capacity and cost experiences. The distribution portion of the transportation analysis proceeded by constructing modeled routes that exhibited average capacities and variable costs similar to those experienced in actual practice. Once the lockset model adequately duplicated existing behavioral structures, its validity was established for calculating the proposed one-warehouse location's distribution costs.

Assembly costs for suppliers not included as backhaul elements in the distribution study were analyzed descriptively. Variable inbound freight rates were applied to the quantity of products received or expected at the two-warehouse system and at each of the seven proposed one-warehouse locations. The majority of the products assembled into Farm Bureau warehouses have standard costs for delivery anwhere in Michigan. The assembly cost calculations, therefore, included only those few product lines with freight rates that vary with distance and therefore location.

The findings from the transportation analysis exhibited no substantial advantage for any of the seven one-warehouse locations proposed. Similarly, no advantage was found for a one-warehouse system over the current two facilities with respect to transportation costs. This lack of advantage holds even though Farm Bureau predicted a $14,328.35 savings beyond that calculated in the model for eliminating interwarehouse transfers and reducing trailer requirements.

Without the lockset model an increase in transportation costs proportional to projected increases in dollar demand might have been expected. The model, instead, calculated cost increases only one-third the size of the projected dollar demand increase. What is obvious with lockset is that the demand increases in cubic measure are not as great as that indicated by the dollar amount. Further investigation into the cause of this result showed that predictions for demand increases for high dollar-to-volume products were larger than those with low dollar-to-volume ratios.

With the transportation study completed, only the study of in-warehouse operations remained. Warehouse operating costs were analyzed using a combined economic-engineering systems-simulation approach. An economic engineering technique was required in order to determine cost structures for a system not yet in existence, the proposed one-warehouse system. Knowledge with respect to important dynamic factors such as rate of output, length of operation, scheduling, ordering lead times, ordering delays, and storage was extended beyond what could be gained from a basic economic engineering study by using a systems simulator.

The operations simulator for the two existing warehouses demonstrated that it could track reality within small error bounds. It also performed three other functions in addition to model verification. First, it provided indicators of magnitude and sensitivity for design parameters necessary in constructing the one-warehouse model. Second, the current systems model generated inventory strategy cost functions showing the trade-off between costs of inventories carried and profits lost for being out of items requested. Third, the simulator's most important function was to demonstrate how the current system would perform under expected future demand conditions.

The End-to-End Model built to react as if the current system could have consolidated inventories, gave design parameters for the proposed one-warehouse system in addition to calculating savings that would be made possible through inventory consolidation. It was the End-to-End Model that was modified according to Farm Bureau and manufacturer specification in developing a model for the proposed one-warehouse system.

The capabilities of the new-warehouse simulator allowed it to generate capacity requirements and inventory strategy cost functions to compare with those calculated for the current system. It was also the source of variable cost estimates required in comparing the two systems' performances for the 1979-1980 fiscal year.

The essence of the findings from this portion of the research can be expressed in terms of inventory strategy costs, capacity restrictions, and variable cost comparisons. A strict mathematical interpretation of the quantified variables would indicate that the current system could minimize inventory-related costs by reducing stock levels 40 percent if one ignores ill-will created by higher stock-out rates. On the other hand, the results imply that the existing system could not continue until 1980 with current performance levels because of capacity restrictions. Lastly, the two-warehouse system would cost Farm Bureau a total of $83,534.10 more in 1979-1980 at the forced lower performance level than would a one-warehouse system providing a similar service.

Warehousing and transportation enterprises have been analyzed separately. An investment analysis was performed to tie the two together and to include cost estimates and cash flows not previously evaluated. The cash flow estimates for 1985-1986 were made possible through linear approximations and extrapolations for inventory carrying cost and net profit lost differentials. In addition, internal rate of return calculations were made for several different investment contingencies to better account for costs that could not be predicted with sufficient accuracy.

The after tax rates of return ranged from 7.19 percent to 16.23 percent over the entire set of contingencies evaluated. The two lowest returns were calculated for a warehouse costing 50 percent more than the estimates made by Farm Bureau and their building contractor. The remaining rates that start at 12.63 percent and increase up to the 16.23 percent figure include Farm Bureau cost estimates for building, land, and shrink-pack machinery plus differing combinations of possible costs for the railroad siding, new equipment, and equipment transfer. The contingencies also include two extreme demand predictions and sensitivity analyses that measure the importance of warehouse residual values.

Conclusions

1. The 1972-1973 and 1979-1980 distribution costs for each proposed one-warehouse location would not be substantially higher than those in the current two-warehouse system. It therefore follows that little substantial difference exists between the one-warehouse alternatives.

2. The one-warehouse locations would have slightly lower assembly costs than those exhibited by the present system.

3. For all intensive purposes the assembly savings from the one-warehouse locations cancel the existing system's distribution savings. Therefore, all alternatives are essentially equivalent with respect to transportation costs.

4. Should Farm Bureau decide to select a site for a one-warehouse system, the importance of variables other than those overtly included in the analysis is emphasized. Factors such as availability and cost of land, size of local labor force, and management's personal preferences become relatively more important than they would have been if any one location had exhibited superior cost savings.

5. Quantity discounts will not be a source of savings for the one-warehouse system. The warehouse simulator indicated no substantial difference in the size of supply receipts between the two systems.

6. Other things equal, lower inventory levels will gain more savings from inventory carrying costs than losses from stock-outs in either system.

7. The 1979-1980 variable costs for the unmodified two-warehouse system would be substantially higher than those for a one-warehouse system that provides equivalent service.

8. Equivalent service could be provided with less capacity requirement in the one-warehouse facility.

9. Major modifications will be required in the current warehousing system by 1979-1980 unless management accepts substantially higher stock-outs than they have in the past, or unless they modify their service policy by deleting product lines of lesser importance.

10. Internal rate of return estimates were made conservative by basing them upon an assumption that the existing facilities could continue, without modification, through the 1985-1986 fiscal year. Expenditures for improving that system would increase the calculated return values to some degree depending upon the magnitude of the investments that would be required.

Recommendations

Most of the recommendations to be drawn from this research come directly from the conclusions made in the previous section. A review of that section will likely suggest some appropriate actions so those recommendations will not be listed in this section. Recommendations that do not follow directly from the conclusions are presented below.

1. If a decision is made to invest in the one-warehouse system and no other modifications are made in the current system, the new warehouse should be operating by mid-1976. This assumes a maximum acceptable net profit lost in the $1,300.00 neighborhood. Higher minimum acceptable levels would, of course, extend this deadline.

2. With the same maximum stock-out level ($1,300.00), the new building should have between 610,535 cubic feet and 1,013,337 cubic feet of capacity in order to be adequate until 1987. The smaller value would be adequate if demand levels off at the 1979-1980 level. The larger value assumes an increase in demand between 1980 and 1987 equal to the 1973 to 1980 increase. Lower acceptable stock-out levels or longer desired warehouse life times would increase these requirements.

3. Scheduling has been mentioned as a method for keeping the total rate of output constant in the face of highly seasonal or fluctuating demand. Because management was assumed constant in this study, the scheduling function should be investigated as a potential source of improved output. A less immediately important nonsequential task may be rescheduled, for example, to keep it from hindering those that are sequential.

4. Demand predictions may not include proportional increases in dollar and volume terms, therefore future planning should include estimates for both values.

5. Reductions in inventories to take advantage of the potential savings demonstrated in this study should not be taken to the minimum points calculated. This is true because consumer ill-will was not included in the inventory strategy cost functions and because it is more costly to be below the true minimum cost inventory level than it is to be above it.

6. The internal rate of returns for the one-warehouse investment should be weighed against Farm Bureau's cost of capital and evaluated in context of the conditions within which the calculations were made. If any of the returns are outside Farm Bureau's range of acceptability, the decision to accept or reject the investment should include probability estimates for those contingencies that caused the unfavorable values.

7. The decision to accept or reject the one-warehouse system should also include subjective impact estimates for important non-quantifiable factors such as reactions of the current employees, their union, and the local community.

8. Farm Bureau might also want to re-evaluate other alternatives to their current system that were previously thought less desirable than the one-warehouse option. In light of this research they may, but would not necessarily, decide to investigate some of these options more thoroughly.

9. Farm Bureau might also capture a greater return from their investment in this research if they could integrate these analyses

techniques into their decision processes. The modified lockset model, for example, could be easily adapted to aid in the route structuring process. The warehouse simulators might be used for either of the two alternative warehousing systems to assist in ordering and inventory strategy, as well as labor force planning. It, however, would be more difficult to incorporate into Farm Bureau's computer system.

10. Finally, Farm Bureau Services and other agribusiness firms should continue to take advantage of studies that use university resources. Increased university-industry intimacy should provide advantages to both participants by improving theory's applicability while seeking sound solutions to actual agribusiness problems.

Taken as a whole, the research demonstrates some relative economic advantages for a one-warehouse system but no real preference for any one of the seven proposed locations. If the new warehouse is not operationalized, some other alternative will be needed to keep service from deteriorating with the unmodified two-warehouse system. In all, the study confirms the Michigan Farm Bureau's suspicion that their warehousing system may not be adequate to sufficiently accommodate expected future demand increases.

APPENDIX A

DEALERSHIPS AND BACKHAUL POINTS

APPENDIX A

DEALERSHIPS AND BACKHAUL POINTS

Reference Code	Dealer Name	Reference Code	Dealer Name
1	Cadillac	31	Hart
2	Evart	32	Scottville
3	Reed City	33	Chicago, Joliet, Calumet*
4	Traverse City	34	
5	Battle Creek, Climax	35	Battle Creek, Hillsdale
6	Coldwater, Union City	36	and surrounding area*
7	Hillsdale	37	Manistee
8	Allegan	38	Lima, Kenton*
9	Buchanan	39	
10	Eau Claire	40	Saginaw, Midland, Bay City*
11	Holland	41	Bay City*
12	Three Oaks	42	Brooklyn
13	Watervliet	43	Chelsea
14	Kalamazoo	44	Dexter
15	Marcellus	45	South Lyon
16	Mendon	46	Ypsilanti
17	Schoolcraft	47	Caro
18	Albion	48	Crosswell
19	Charlotte	49	Marlette
20	Hastings	50	Mt. Clemens
21	Lake Odessa	51	New Haven
22	Leslie	52	Richmond
23	Marshall	53	Snover
24	Nashville	54	Yale
25	Portland	55	Elkton
26	Big Rapids	56	Harbor Beach
27	Fremont	57	Kinde
28	Kent City	58	Minden City
29	Stanwood	59	Pigeon
30	Coopersville	60	Ruth

Reference Code	Dealer Name	Reference Code	Dealer Name
61	Sebewaing	91	Owosso
62	Ubly	92	St. Johns
63	Adrian	93	Almont
64	Blissfield	94	Armada
65	Deerfield	95	Capac
66	Highland	96	Lapeer
67	Ida	97	Oxford
68	Maybee	98	Washington
69	Tecumseh	99	Fowlerville
70	Willis	100	Holt
71	Gladwin	101	Howell
72	Pinconning	102	Lansing
73	Sterling	103	Mason
74	West Branch	104	Webberville
75	Claire	105	Williamston
76	Falmouth	106	Battle Creek, Hillsdale, Blissfield*
77	Marion	107	Midland, Bay City, St. Johns*
78	McBain		
79	Merritt		
80	Breckenridge		
81	Hemlock		
82	Mt. Pleasant		
83	Remus		
84	Vestaburg		
85	Chesaning		
86	Durand		
87	Lennon		
88	Middleton		
89	Mt. Morris		
90	Ovid		

*Backhaul supply points.

APPENDIX B

EXISTING ROUTE STRUCTURES

APPENDIX B

EXISTING ROUTE STRUCTURES

Jenison

Total Variable Distribution Cost $1,600.00

Reference Number	Route Component	Miles	Weekly Demand in Cubic Feet per Half Year: First Half Year	Weekly Demand in Cubic Feet per Half Year: Second Half Year
	Jenison to:			
3	Reed City	76	3	1
2	Evart	19	212	253
1	Cadillac	42	18	7
4	Traverse City	52	777	964
	Manistee	65	1,010	1,225
	Return	128		
		382		
	Jenison to:			
7	Hillsdale	121	162	171
6	Coldwater-Union City	24	499	574
5	Climax	39	416	392
35	Battle Creek	0	1,077	1,137
	Return	261		
	Jension to:			
11	Holland	26	118	209
8	Allegan	27	296	345
13	Watervliet	36	54	56
10	Eau Claire	18	23	22
9	Buchanan	19	170	181
12	Three Oaks	22	65	20
34	Chicago	80	726	833
	Return	414		

Reference Number	Route Component	Miles	Weekly Demand in Cubic Feet per Half Year: First Half Year	Weekly Demand in Cubic Feet per Half Year: Second Half Year
	Jenison to:			
15	Marcellus	74	246	320
16	Mendon	33	380	376
17	Schoolcraft	29	44	66
14	Kalamazoo	15	605	928
41	Bay City	143	1,275	1,690
	Return	121		
		415		
	Jenison to:			
25	Portland	41	7	34
21	Lake Odessa	17	32	39
20	Hastings	22	632	563
24	Nashville	39	11	19
19	Charlotte	24	249	299
22	Leslie	24	292	284
18	Albion	34	102	88
23	Marshall	12	4	5
36	Battle Creek	14	1,329	1,331
	Return	77		
		304		
	Jenison to:			
28	Kent City	32	533	521
27	Freemont	42	467	359
29	Stanwood	34	385	374
26	Big Rapids	17	52	76
40	Bay City	98	1,437	1,330
	Return	121		
		344		
	Jenison to:			
30	Coopersville	29	643	394
31	Hart	66	341	584
32	Scottsville	28	366	468
38	Manistee	27	1,350	1,446
	Return	128		
		278		
33	Chicago round trip backhaul			
39	Lima-Kenton round trip backhaul			

Zilwaukee

Total Variable Distribution Cost $1,506.50

Reference Number	Route Component	Miles	Weekly Demand in Cubic Feet per Half Year: First Half Year	Second Half Year
	Zilwaukee to:			
45	South Lyon	82	15	21
46	Ypsilanti	32	171	174
44	Dexter	18	44	94
43	Chelsea	14	133	179
42	Brooklyn	34	126	34
	Return	121	474	502
		301		
	Zilwaukee to:			
47	Caro	30	259	468
49	Marlette	35	17	31
53	Snover	25	235	165
54	Yale	39	391	410
48	Croswell	28	24	26
52	Richmond	17	2	12
51	New Haven	69	8	69
50	Mt. Clemens	8	3	4
	Return	93	939	1,185
		344		
	Zilwaukee to:			
61	Sebewaing	50	72	104
59	Pigeon	16	294	221
55	Elkton	0	230	216
57	Kinde	35	39	63
56	Harbor Beach	35	91	77
60	Ruth	56	586	433
58	Minden City	28	15	13
62	Ubly	28	38	39
	Return	91	1,365	1,166
		339		

Reference Number	Route Component	Miles	Weekly Demand in Cubic Feet per Half Year: First Half Year	Second Half Year
	Zilwaukee to:			
68	Maybee	120	64	73
70	Willis	0	12	16
65	Deerfield	26	17	18
67	Ida	26	173	133
64	Blissfield	26	41	114
63	Adrian	14	82	136
66	Highland	59	388	307
69	Tecumseh	48	163	100
	Return	120	940	897
		439		
	Zilwaukee to:			
72	Pinconning	34	478	505
73	Sterling	17	361	366
74	West Branch	36	808	527
71	Gladwin	34	265	195
	Return	14	1,912	1.593
		191		
	Zilwaukee to:			
75	Clare	61	42	12
77	Marion	34	64	181
78	McBain	19	263	261
76	Falmouth	23	218	261
79	Merritt	0	96	162
	Return	102	683	877
		239		
	Zilwaukee to:			
81	Hemlock	18	271	231
80	Breckenridge	30	4	56
82	Mt. Pleasant	22	505	272
83	Remus	21	266	224
84	Vestaburg	80	91	95
	Return	146	1,137	878
		317		

Reference Number	Route Component	Miles	Weekly Demand in Cubic Feet per Half Year: First Half Year	Second Half Year
	Zilwaukee to:			
97	Oxford	76	66	59
93	Almont	27	56	91
96	Lapeer	21	551	396
98	Washington	40	122	83
95	Capac	41	--	33
94	Armada	27	--	28
	Return	100	795	690
		332		
	Zilwaukee to:			
85	Chesaning	30	318	523
88	Middleton	29	10	17
92	St. Johns	18	275	338
90	Ovid	9	24	24
91	Owosso	13	91	70
86	Durand	17	198	269
87	Lennon	23	25	29
89	Mt. Morris	27	132	167
	Return	32	1,073	1,437
		198		
	Zilwaukee to:			
101	Howell	72	205	336
99	Fowlerville	12	519	238
104	Webberville	0	2	8
105	Williamston	15	86	152
106	Battle Creek	130	812	734
	Return	106		
		335		

APPENDIX C

PRODUCTS BY PRODUCT GROUP

APPENDIX C

PRODUCTS BY PRODUCT GROUP

		Conversion Factors
01 FERTILIZER:		1.8
470000-479999[a]		
02 SEED:		6.6
440000 THROUGH 446999		
03 FEED:		1.6
450000 THROUGH 453213		
453215 THROUGH 453236		
453247 THROUGH 453253		
435255 THROUGH 456999		
04 MEDICINAL SUPPLIES:		10.4
45321400-45321499	HORSE CARE	
458000-458999 } 459000-459999	ANIMAL HEALTH	
482200 THROUGH 48299999	ORTHO	
483000 THROUGH 48349999	MISC. CHEM.	
05 CHEMICALS:		36.1
480000 THROUGH 48119999	HERB., INSECT., FUNG.	
447000 THROUGH 44709999	SEED TREATMENT & INOCULANTS	
06 ROOFING:		20.4
460000-460499	STEEL ROOFING	
460500-460599	ALUMINUM ROOFING	

[a]Farm Bureau product line identification code.

		Conversion Factors
07 PANELS AND ACCESSORIES:		22.2
461000-661299	FIBERGLASS PANELS	
461300-4613599	POLE BARN NAILS	
461600-461699	NAILS & STAPLES	
08 BUILDING COSMETICS:		9.8
462000-462199	ASPHALT ROOFING	
462200-462599	PAINT	
462600-462699	TURPENTINE	
462700-462799	PAINT BRUSHES & ROLLERS	
462800-462899	BROOMS & BRUSHES	
462900-462999	POLYETHYLENE	
09 POST, POLES, AND LUMBER:		3.2
463000-463199	ROUND POSTS	
463200-463399	ROUND POLES	
463400-463499	SQUARE POLES	
463500-463599	PRESSURE TREATED LUMBER	
463600-463699	TREATED LUMBER & GLUE	
463700-463799	DIMENSIONAL LUMBER	
463800-463899	STEEL POSTS	
463900-463999	GATES	
10 FENCE:		2.5
464000-464099	DOMESTIC FARM FENCE	
464100-464299	IMPORTED FARM FENCE	
464300-464399	WIRE	
464400-464599	WELDED WIRE FABRIC	
464600-464999	MISCELLANEOUS FENCE	
11 ELECTRIC FENCE:		16.2
465000-465099	ELECTRIC FENCE ACCESSORIES	
465100-465199	ELECTRIC FENCE	
12 BULKY CONTAINERS:		3.0
465200-465299	TANKS	
465300-465499	FOUNTAIN, TROUGHS & HEATERS	
465500-465899	FEEDERS	
465900-465999	TRASH BURNERS & LAUNDRY TUBS	

		Conversion Factors
13 FLEXIBLES:		13.6
466000-466199	TWINE	
466200-466299	CHAIN	
466300-466399	ROPE	
466400-466499	PLASTIC PIPE	
466500-466599	WORTHINGTON PRODUCTS	
466600-466799	LADDERS	
466800-466899	TARPS	
14 TOOLS:		3.3
467000-467299	LAWN MOWERS & ACCESSORIES	
467300-467599	POWER TOOLS	
467600-467799	HAND TOOLS	
15 SEMI-MISCELLANEOUS:		4.1
468000-468099	BARN DOORS & ACCESSORIES	
468100-468299	BARN EQUIPMENT	
468300-468399	FEED BINS, AUGERS & CRIBS	
468400-468499	GALVANIZED WARES	
468500-468599	SPRAYERS, DUSTERS & FOGGERS	
468600-468699	SEEDERS, WHEEL BARROWS, & CEMENT MIXERS	
468700-468899	CALF, POULTRY EQUIPMENT, & ELECTRIC SUPPLIES	
16 MISCELLANEOUS:		9.3
469000-469999		

APPENDIX D

WEEKLY AVERAGE SEMIANNUAL DEALER DEMAND IN CUBIC FEET

APPENDIX D

WEEKLY AVERAGE SEMIANNUAL DEALER DEMAND IN CUBIC FEET

Dealer[a] Code	0	1	2	3	4	5	6	7	8	9
First half year:										
0		18	212	3	777	416	499	162	296	170
1	23	118	65	54	605	246	380	44	102	249
2	632	32	292	4	11	7	52	467	533	385
3	643	341	366	0	0	0	0	0	0	0
4	0	0	126	133	44	15	171	259	24	17
5	3	8	2	235	391	230	91	39	15	294
6	1,786	72	38	82	41	17	388	173	64	163
7	12	265	478	361	808	42	218	64	263	96
8	4	271	505	266	91	318	198	25	10	132
9	24	91	275	46	0	0	551	66	122	519
10	0	205	0	0	2	86	0			
Second half year:										
0		7	253	1	964	392	574	171	345	181
1	22	209	20	56	928	320	376	66	88	299
2	563	39	284	5	19	34	76	359	521	374
3	394	584	468	0	0	0	0	0	0	0
4	0	0	34	179	94	21	174	468	26	31
5	4	69	12	165	410	216	77	63	13	221
6	1,633	104	39	136	114	18	307	133	73	100
7	16	195	505	366	527	12	261	181	261	162
8	56	231	272	224	95	523	269	29	17	167
9	24	70	338	91	28	33	396	59	83	238
10	0	336	0	0	8	152	0	0		

[a]Dealer codes along the vertical portion of the table represent the first sub-part of the entire dealer code while the horizontal portion represents the second half. In the first half-year dealer 67, for example, had demand for products requiring 173 cubic feet of truck space.

APPENDIX E

GENERATED ROUTE CONFIGURATIONS FOR SEVEN PROPOSED ONE-WAREHOUSE LOCATIONS

APPENDIX E

GENERATED ROUTE CONFIGURATIONS FOR SEVEN

PROPOSED ONE-WAREHOUSE LOCATIONS

Jenison-Zilwaukee First Half Year

Jenison--Variable Distribution Cost $1,628.50

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 20, 25, 19, 5, 24, 40, W	1,347
2--W, 22, 23, 18, 7, 6, 16, 36, W	1,439
3--W, 26, 3, 2, 4, 1, 37, W	1,062
4--W, 27, 32, 31, 38, W	1,174
5--W, 30, 8, 34, W	939
6--W, 11, 13, 10, 9, 12, 15, 17, 14, 35, W	1,325
7--W, 28, 29, 41, W	918
8--W, 33, W } Round Trip Backhauls	
9--W, 39, W } Round Trip Backhauls	

Zilwaukee--Variable Distribution Cost $1,378.50

ROUTE NUMBER AND COMPONENTS	
1--W, 43, 42, 68, 69, 65, 63, 64, 70, 66, 67, 106, W	1,199
2--W, 55, 53, 47, W	724
3--W, 59, 61, 56, 58, 62, 57, 60, 52, 48, 49, W	1,178
4--W, 74, 71, W	1,073
5--W, 75, 77, 79, 78, 76, 84, 83, W	1,040
6--W, 82, 80, 88, 92, 90, 91, 86, W	1,107
7--W, 85, 81, W	589
8--W, 93, 95, 54, 94, 51, 50, 98, 97, 96, W	1,197
9--W, 99, 105, 104, 101, 45, 46, 44, 87, 89, W	1,199
10--W, 72, 73, 107, W	839
11--W, 60, W	1,200

Total Variable Distribution Cost $3,007.00

Total Miles: 6,014

Jenison-Zilwaukee Second Half Year

Jenison--Variable Distribution Cost $1,625.00

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 21, 22, 19, 5, 24, 36, W	1,033
2--W, 26, 3, 2, 4, 1, 37, W	1,301
3--W, 27, 32, 31, 38, W	1,411
4--W, 14, 34, W	928
5--W, 11, 8, 13, 10, 9, 12, 15, 35, W	1,153
6--W, 20, 39, W	563
7--W, 17, 16, 6, 7, 18, 23, 25, 40, W	1,314
8--W, 30, 28, 29, 41, W	1,289
9--W, 33, W Round Trip Backhaul	

Zilwaukee--Variable Distribution Cost $1,377.00

ROUTE NUMBER AND COMPONENTS	
1--W, 59, 61, 56, 58, 62, 57, 60, 52, 48, 49, 53, W	1,184
2--W, 72, 55, 47, W	1,189
3--W, 75, 77, 79, 78, 76, 84, 83, W	1,196
4--W, 82, 80, 88, 92, 90, 91, 86, W	1,046
5--W, 85, 81, W	754
6--W, 93, 95, 54, 94, 51, 50, 98, 97, 96, W	1,173
7--W, 104, 43, 42, 68, 69, 65, 63, 64, 70, 66, 67, 45, 87, W	1,168
8--W, 89, 44, 46, 101, 99, 105, 106, W	1,161
9--W, 71, 74, 73, 107, W	1,088
10--W, 60, W	1,200

Total Variable Distribution Cost $3,001.50

Total Miles: 6,003

St. Johns First Half Year

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 18, 16, 14, 36, W	1,083
2--W, 22, 19, 25, 20, 21, 33, W	1,212
3--W, 26, 3, 32, 31, 27, 38, W	1,229
4--W, 28, 30, 11, 34, W	1,294
5--W, 80, 73, 9, 12, 10, 13, 15, 17, 8, 24, 35, W	1,274
6--W, 5, 23, 6, 7, 42, 39, W	1,207
7--W, 87, 89, 49, 48, 52, 60, 57, 62, 58, 56, 61, 59, 40, W	1,239
8--W, 43, 44, 46, 67, 65, 70, 66, 68, 64, 69, 63, 106, W	1,288
9--W, 72, 55, 53, 47, 41, W	1,202
10--W, 75, 79, 4, 1, 78, 77, 37, W	1,260
11--W, 76, 74, 71, 107, W	1,291
12--W, 83, 2, 29, 84, 88, 92, W	1,239
13--W, 85, 81, 82, W	1,094
14--W, 90, 96, 93, 95, 54, 50, 94, 51, 98, 97, 45, W	1,236
15--W, 105, 104, 101, 99, 86, 91, W	1,101
16--W, 60, W	1,296

Total Variable Distribution Cost $2,983.00

Total Miles: 5,966

St. Johns Second Half Year

1--W, 4, 1, 78, 107, W	1,232
2--W, 19, 24, 14, 21, W	1,285
3--W, 22, 5, 39, W	676
4--W, 26, 3, 32, 31, 38, W	1,129
5--W, 25, 20, 8, 11, 34, W	1,151
6--W, 71, 73, 9, 12, 10, 13, 15, 17, 23, 35, W	1,231
7--W, 18, 7, 6, 16, 36, W	1,209
8--W, 84, 29, 27, 30, 37, W	1,222
9--W, 87, 89, 53, 49, 48, 52, 60, 57, 62, 58, 56, 61, 59, 40, W	1,284
10--W, 45, 44, 46, 67, 65, 70, 66, 68, 64, 69, 63, 42, 106, W	1,220
11--W, 75, 77, 79, 74, 76, 88, W	1,160
12--W, 80, 72, 55, 47, 41, W	1,245
13--W, 82, 83, 2, 28, 33, W	1,270
14--W, 85, 81, 90, 92, W	1,116
15--W, 96, 93, 95, 54, 50, 94, 51, 98, 97, 91, W	1,243
16--W, 105, 104, 101, 43, 99, 86, W	1,182
17--W, 60, W	1,296

Total Variable Distribution Cost $3,062.00

Total Miles: 6,124

Lansing First Half Year

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 18, 16, 14, 24, 35, W	1,098
2--W, 21, 28, 29, 26, 3, 2, 77, 38, W	1,281
3--W, 22, 105, 101, 99, W	1,102
4--W, 30, 20, 36, W	1,275
5--W, 92, 82, 83, 33, W	1,046
6--W, 19, 17, 15, 9, 12, 10, 13, 8, 11, 34, W	1,265
7--W, 25, 84, 31, 32, 27, 37, W	1,272
8--W, 5, 23, 6, 7, 42, 39, W	1,207
9--W, 80, 73, 74, 79, 40, W	1,269
10--W, 45, 98, 50, 51, 94, 54, 53, 55, 47, 41, W	1,263
11--W, 43, 44, 46, 67, 65, 70, 66, 68, 64, 69, 63, 106, W	1,288
12--W, 86, 96, 89, 87, 85, W	1,224
13--W, 88, 76, 4, 1, 78, 107, W	1,286
14--W, 90, 59, 61, 56, 58, 62, 57, 60, 52, 48, 49, 95, 93, 97, 104, W	1,230
15--W, 91, 81, 72, 71, 75, W	1,147
16--W, 60, W	1,296

Total Variable Distribution Cost $3,101.50

Total Miles: 6,203

Lansing Second Half Year

1--W, 2, 77, 76, 83, 82, W	1,191
2--W, 19, 24, 14, 35, W	1,246
3--W, 21, 11, 8, 13, 10, 12, 9, 15, 17, 23, 39, W	1,263
4--W, 25, 30, 20, W	991
5--W, 5, 33, W	392
6--W, 18, 7, 6, 16, 36, W	1,209
7--W, 78, 1, 4, 37, W	1,232
8--W, 48, 52, 60, 57, 62, 58, 56, 61, 59, 53, 55, 41, W	1,273
9--W, 50, 94, 51, 98, 97, 93, 95, 54, 49, 47, 40, W	1,276
10--W, 80, 84, 26, 3, 32, 31, 38, W	1,280
11--W, 85, 81, 72, 87, W	1,288
12--W, 86, 96, 89, 91, 90, 92, W	1,264
13--W, 88, 28, 29, 27, 34, W	1,271
14--W, 104, 45, 44, 46, 67, 65, 70, 66, 68, 64, 69, 63, 42, 106, W	1,228
15--W, 105, 99, 101, 43, 22, W	1,189
16--W, 75, 71, 73, 74, 79, 107, W	1,262
17--W, 60, W	

Total Variable Distribution Cost $3,072.50

Total Miles: 6,145

Ionia First Half Year

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 2, 78, 4, 38, W	1,252
2--W, 20, 5, 36, W	1,048
3--W, 21, 19, 105, 104, 101, 99, 86, W	1,291
4--W, 24, 14, 17, 15, 16, 35, W	1,286
5--W, 26, 1, 79, 74, 76, 77, W	1,256
6--W, 84, 27, 31, 32, 3, 37, W	1,268
7--W, 80, 72, 73, 9, 12, 10, 13, 11, 33, W	1,273
8--W, 22, 6, 7, 42, 18, 23, 39, W	1,185
9--W, 45, 97, 98, 51, 94, 50, 54, 95, 93, 96, 40, W	1,212
10--W, 83, 29, 28, W	1,184
11--W, 90, 59, 61, 56, 58, 62, 57, 60, 52, 48, 49, 89, 87, 41, W	1,263
12--W, 91, 85, 81, 82, W	1,185
13--W, 92, 30, 8, 34, W	1,214
14--W, 25, 63, 69, 64, 68, 66, 70, 65, 67, 46, 44, 43, 106, W	1,295
15--W, 88, 47, 53, 55, 71, 75, 107, W	1,041
16--W, 60, W	1,296

Total Variable Distribution Cost $3,099.00

Total Miles: 6,198

Ionia Second Half Year

1--W, 21, 23, 18, 7, 6, 5, 36, W	1,269
2--W, 22, 19, 20, W	1,146
3--W, 29, 27, 30, 39, W	1,127
4--W, 11, 14, 24, 34, W	1,156
5--W, 8, 13, 15, 17, 16, 35, W	1,163
6--W, 84, 26, 3, 32, 31, 37, W	1,224
7--W, 97, 98, 51, 94, 50, 54, 95, 93, 96, 40, W	1,173
8--W, 87, 89, 53, 49, 48, 52, 60, 57, 62, 58, 56, 61, 59, 41, W	1,284
9--W, 45, 44, 46, 67, 65, 70, 66, 68, 64, 69, 63, 42, 25, W	1,254
10--W, 75, 76, 4, 38, W	1,237
11--W, 80, 72, 55, 47, 88, W	1,262
12--W, 83, 28, 33, W	745
13--W, 92, 91, 85, 81, 90, W	1,186
14--W, 86, 99, 43, 101, 104, 105, W	1,182
15--W, 1, 79, 74, 73, 9, 12, 10, 106, W	1,285
16--W, 2, 77, 78, 71, 82, 107, W	1,162
17--W, 60, W	1,296

Total Variable Distribution Cost $3,147.50

Total Miles: 6,295

Alma First Half Year

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 19, 24, 14, 5, 106, W	1,281
2--W, 22, 42, 7, 6, 23, 18, 36, W	1,185
3--W, 84, 27, 31, 32, 3, 38, W	1,268
4--W, 28, 30, 11, 34, W	1,294
5--W, 71, 76, 2, 26, 29, 33, W	1,132
6--W, 44, 46, 63, 64, 68, 66, 70, 65, 67, 69, 43, 35, W	1,288
7--W, 87, 96, 97, 98, 50, 51, 94, 54, 95, 93, 39, W	1,222
8--W, 47, 53, 55, 72, 41, W	1,202
9--W, 59, 61, 56, 58, 62, 57, 60, 52, 48, 49, 89, W	1,214
10--W, 75, 79, 4, 1, 78, 77, 37, W	1,260
11--W, 80, 74, 73, 40, W	1,173
12--W, 82, 85, 81, W	1,094
13--W, 88, 105, 104, 101, 45, 99, 86, 91, 90, W	1,150
14--W, 92, 25, 20, 21, 83, W	1,212
15--W, 8, 13, 10, 9, 12, 15, 17, 16, 107, W	1,278
16--W, 60, W	1,296

Total Variable Distribution Cost $3,127.00

Total Miles: 6,354

Alma Second Half Year

1--W, 25, 20, 5, 22, 106, W	1,273
2--W, 28, 30, 27, 34, W	1,274
3--W, 83, 76, 77, 2, 29, 33, W	1,293
4--W, 45, 44, 46, 63, 64, 68, 66, 70, 65, 67, 69, 42, 35, W	1,220
5--W, 11, 8, 13, 10, 9, 12, 15, 17, 23, 36, W	1,224
6--W, 78, 1, 4, 37, W	1,232
7--W, 84, 26, 3, 32, 31, 38, W	1,224
8--W, 21, 14, 24, 19, 39, W	1,285
9--W, 89, 53, 49, 48, 52, 60, 57, 62, 58, 56, 61, 59, 41, W	1,255
10--W, 75, 79, 74, 73, 71, W	1,262
11--W, 80, 72, 55, 47, 40, W	1,245
12--W, 88, 105, 104, 101, 43, 99, 86, 91, 90, W	1,293
13--W, 92, 85, 81, W	1,092
14--W, 93, 95, 54, 94, 51, 50, 98, 97, 96, 87, W	1,202
15--W, 18, 7, 6, 16, 107, W	1,209
16--W, 60, W	1,296
17--W, 82, W	272

Total Variable Distribution Cost $3,079.50

Total Miles: 6,159

Climax First Half Year

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 1, 79, 74, 73, 80, 107, W	1,287
2--W, 5, 16, 6, 34, W	1,295
3--W, 11, 30, 27, 24, W	1,239
4--W, 20, 19, 39, W	881
5--W, 25, 84, 29, 26, 3, 32, 31, 37, W	1,245
6--W, 17, 15, 9, 12, 10, 13, 8, 33, W	898
7--W, 23, 18, 7, 42, 22, 99, 35, W	1,205
8--W, 86, 96, 97, 101, 105, 36, W	1,106
9--W, 93, 95, 49, 48, 52, 60, 57, 62, 58, 56, 61, 59, 89, 87, 40, W	1,295
10--W, 104, 45, 98, 50, 51, 94, 54, 53, 55, 47, 41, W	1,265
11--W, 78, 76, 4, 38, W	1,258
12--W, 83, 82, 81, 91, 90, W	1,157
13--W, 88, 72, 71, 75, 77, 2, W	1,071
14--W, 92, 85, 28, 21, W	1,158
15--W, 43, 44, 46, 63, 64, 68, 66, 70, 65, 67, 69, 106, W	1,288
16--W, 60, W	1,296
17--W, 14, W	605

Total Variable Distribution Cost $3,273.00

Total Miles: 6,546

Climax Second Half Year

1--W, 1, 79, 74, 73, 71, 107, W	1,257
2--W, 21, 84, 26, 3, 84, 32, 31, 37, W	1,263
3--W, 23, 18, 22, 19, 20, W	1,239
4--W, 24, 30, 11, 8, 33, W	967
5--W, 25, 28, 29, 27, W	1,288
6--W, 5, 17, 15, 9, 12, 10, 13, 34, W	1,057
7--W, 16, 6, 7, 39, W	1,121
8--W, 44, 45, 93, 49, 48, 52, 60, 57, 62, 58, 56, 61, 59, 53, 40, W	1,294
9--W, 43, 46, 69, 67, 65, 70, 66, 68, 64, 63, 42, 106, W	1,284
10--W, 80, 72, 55, 47, 41, W	1,245
11--W, 83, 82, 2, 78, 77, W	1,191
12--W, 87, 89, 96, 95, 54, 94, 51, 50, 98, 97, 35, W	1,278
13--W, 88, 75, 76, 4, 38, W	1,254
14--W, 90, 85, 81, 91, 86, W	1,117
15--W, 92, 105, 104, 101, 99, 36, W	1,072
16--W, 60, W	1,296
17--W, 14, W	605

Total Variable Distribution Cost $3,225.00

Total Miles: 6,450

Jenison First Half Year

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 2, 75, 71, 76, 78, 77, 3, W	1,067
2--W, 14, 17, 15, 12, 9, 10, 13, 34, W	1,207
3--W, 21, 22, 19, 5, 24, 8, 33, W	1,296
4--W, 25, 43, 44, 46, 67, 65, 70, 66, 68, 64, 69, 63, 106, W	1,295
5--W, 26, 4, 83, W	1,095
6--W, 84, 27, 32, 31, 38, W	1,265
7--W, 29, 28, W	918
8--W, 30, 11, W	761
9--W, 16, 6, 7, 42, 18, 23, 36, W	1,293
10--W, 80, 73, 74, 79, 1, 37, W	1,287
11--W, 92, 86, 99, 101, 105, 39, W	1,283
12--W, 91, 97, 93, 49, 48, 52, 60, 57, 62, 58, 56, 61, 59, 40, W	1,295
13--W, 47, 53, 55, 72, 41, W	1,202
14--W, 88, 85, 81, 82, 107, W	1,104
15--W, 90, 87, 89, 96, 95, 54, 94, 51, 50, 98, 45, 104, 35, W	1,273
16--W, 60, W	1,296
17--W, 20, W	632

Total Variable Distribution Cost $3,250.50

Total Miles: 6,501

Jenison Second Half Year

1--W, 2, 77, 79, 78, 76, 1, W	1,125
2--W, 3, 75, 71, 74, 73, 9, 34, W	1,282
3--W, 14, 11, W	1,137
4--W, 24, 5, 15, 12, 10, 13, 8, 33, W	1,174
5--W, 26, 4, 38, W	1,040
6--W, 28, 29, 27, W	1,254
7--W, 20, 30, W	957
8--W, 25, 42, 63, 69, 64, 68, 66, 70, 65, 67, 46, 44, 35, W	1,233
9--W, 17, 16, 6, 7, 18, 23, 36, W	1,280
10--W, 87, 89, 53, 49, 48, 52, 60, 57, 62, 58, 56, 61, 59, 41, W	1,284
11--W, 80, 72, 55, 47, 40, W	1,245
12--W, 84, 32, 31, 37, W	1,147
13--W, 90, 86, 99, 101, 43, 105, 39, W	1,198
14--W, 91, 96, 97, 93, 95, 54, 94, 51, 50, 98, 45, 104, 106, W	1,272
15--W, 92, 22, 19, 21, W	960
16--W, 83, 82, 81, 85, 88, 107, W	1,267
17--W, 60, W	1,296

Total Variable Distribution Cost $3,254.50

Total Miles: 6,509

Zilwaukee First Half Year

ROUTE NUMBER AND COMPONENTS	Route Demand in Cubic Feet
1--W, 76, 83, 2, 26, 29, 34, W	1,133
2--W, 45, 67, 66, 70, 64, 63, 65, 69, 68, 42, 43, 44, 36, W	1,258
3--W, 75, 77, 78, 1, 4, 79, 37, W	1,260
4--W, 84, 3, 32, 31, 27, 38, W	1,268
5--W, 90, 92, 21, 20, 25, 22, 39, W	1,262
6--W, 5, 23, 6, 7, 18, 105, 40, W	1,269
7--W, 87, 96, 97, 98, 50, 51, 94, 54, 95, 93, 41, W	1,222
8--W, 55, 53, 47, W	724
9--W, 59, 61, 56, 58, 62, 57, 60, 52, 48, 49, 89, W	1,214
10--W, 73, 72, W	839
11--W, 74, 71, W	1,073
12--W, 80, 30, 28, 35, W	1,180
13--W, 85, 82, 81, W	1,094
14--W, 86, 104, 101, 99, 91, 33, W	1,015
15--W, 88, 11, 8, 13, 10, 12, 9, 15, 17, 46, 106, W	1,197
16--W, 19, 24, 14, 16, 107, W	1,245
17--W, 60, W	1,296

Total Variable Distribution Cost $3,258.50

Total Miles: 6,517

Zilwaukee Second Half Year

1--W, 3, 31, 32, 26, 84, 34, W	1,224
2--W, 11, 8, 13, 10, 12, 9, 15, 17, 23, 36, W	1,224
3--W, 21, 24, 14, 19, 39, W	1,285
4--W, 28, 30, 27, 37, W	1,274
5--W, 87, 96, 97, 98, 50, 51, 94, 54, 95, 93, 41, W	1,202
6--W, 45, 46, 68, 69, 65, 63, 64, 70, 66, 67, 43, 104, 40, W	1,279
7--W, 59, 61, 56, 58, 62, 57, 60, 52, 48, 49, 53, 89, W	1,255
8--W, 72, 55, 47, W	1,189
9--W, 73, 74, 71, W	1,088
10--W, 75, 4, 1, 78, 38, W	1,244
11--W, 79, 77, 76, 83, 29, 80, W	1,258
12--W, 81, 82, 2, 33, W	756
13--W, 86, 85, W	792
14--W, 88, 25, 20, 5, 22, 35, W	1,290
15--W, 91, 92, 90, 105, 99, 101, 44, 106, W	1,252
16--W, 42, 18, 7, 6, 16, 107, W	1,243
17--W, 60, W	1,296

Total Variable Distribution Cost $3,263.50

Total Miles: 6,527

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