SUPPLY AREA OPTIMIZATION
IN THE
WESTERN CANADIAN HOG MARKET

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Growing interest in the teletype marketing system of selling hogs, following the implementation of such a system in Ontario and Manitoba, and the possibility of an integrated Western Canadian system, prompted the initiation of this study. The object of the study was to determine the optimum number, size, and location of assembly yard facilities in the prairie provinces in order to minimize the cost of marketing the region's hogs. It was felt this would provide a good basis for the extension of the existing systems and the implementation of any additional systems into the region.

Data for the study was obtained from the Manitoba Hog Marketing Commission, the Western Tariff Bureau, the Ontario Hog Producers Co-operative, as well as the 1961 Census of Agriculture and other Dominion Bureau of Statistics publications.

The approach in this study included the obtaining of the functional cost of transporting hogs from available data by different types of trucks and the application of these functions to a matrix of distances between points on the Prairies. Using the known distribution of production, the volume handled by the various plants, and the cost of operating assembly yards from the Ontario

system, this matrix, which was based on the transhipment model was solved on the computer. Two solutions were obtained, one considering the three provinces as a single region and a second which restricted the assembly function to the hogs within each province. These results showed the flow patterns of hogs from producing regions to designated assembly yards and then to final plants as well as the costs associated with the system.

The results showed:

1. The choice of 26 assembly yards
    a. In the three province model: 3 in Manitoba, 9 in Saskatchewan, and 14 in Alberta.

    b. In the separate province model: 2 in Manitoba, 10 in Saskatchewan, and 14 in Alberta.

2. Back-hauling in eastern Saskatchewan when the assembly function is restricted to within the province hogs.

3. A slight increase in total cost when assembly is restricted to within the province hogs.

4. Efficiency would be increased by reducing the number of assembly yards presently operating in Alberta and Saskatchewan.

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CHAPTER I

INTRODUCTION

> ". . .We are interested not only in understanding . . .how the present system functions, but also, more fundamentally, in how we as students of marketing can take advantage of that knowledge to bring about a more efficient system, no matter who derives the benefit from such efficiency. In fact it is impossible to study marketing properly by clinging to a biased point of view, whether it be that of the farmer, consumer, or middleman."[1]

This is the goal of this paper. In relation to Western Canadian hogs, what is the most efficient system of marketing them? In other words, what is the least cost method--the most efficient--of transferring the hogs produced in Western Canada from the points of production to the points of processing?

The approach to be taken in this paper to determine the most efficient marketing system is the one of the dialectic expressed above. A study will be made of past and present marketing systems and various limitations present in each. The efficient system will evolve from the understanding and extending of former systems. This paper will proceed to develop a relevant model, and thus system of marketing, after a review of relevant history and theory.

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[1] M. E. Brunk and L. B. Darrah, Marketing of Agricultural Products (New York: The Ronald Press, 1955), p. 8.

THE HISTORICAL SETTING

This century has seen the development of many changes in the institutions which influence the interrelationships of social beings. The social, political, and economic institutions which were prevalent following the Industrial Revolution have been subjected to examination, criticism, violent revolution, and gradual evolution and redirection. These processes of changing institutions have been influenced by, and have had influences upon, forces internal to each process respectively, forces of mutual effect, as well as forces of other aspects of the world.

The situation in North America in the recent past has witnessed influences upon and within the agricultural section that may be considered analogous to the influences that led to the decline of the feudal system in the analysis initiated by Marx and Engels.[2] The failure of the existing economic institutions to deal with the needs, either real or imagined, of the members of this sector has led to re-evaluation and changes in a sector of society the members of which were previously thought to be the greatest advocates of the status quo.[3] However, more complete and/or broader theories of social change have indicated that one of the main causes for changing institutions has been dissatisfaction with existing conditions.

In support of these theories of social change, note that the trends in the agricultural movements in North America during this century have been based upon the farmer's feeling of mistreatment at the hands of the other sectors

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[2] K. Marx and F. Engels, The Communist Manifesto, ed. Samuel H. Beer (New York: Appleton-Century-Crofts, 1955).

[3] J. C. Gilson, "A National Food and Farm Policy.", (paper read at Farm Conference Week, Winnipeg, Manitoba, 2 March 1967).

of the economy. The great co-operative movemant near the turn of the century,[4] the creation of various other farm organizations, such as the Grange[5] and the Farmer's Union, and the phenomena which are described by the concept of countervailing power[6] have emerged from dissatisfaction with the contemporary situation.

THE CANADIAN EXPERIENCE

The basis for social change expressed above may be considered to have been operative within the Canadian livestock marketing systems. There have been and presently are, many different types of institutions within Canada concerned with the marketing of agricultural products--and, of more specific concern to this paper, with the marketing of hogs. The situation that previously existed in Ontario may be considered similar, in most respects, to the situation throughout Canada, so a review of developments in Ontario will have implementions for the entire country. Furthermore, the present system of hog marketing in Ontario is unique and can only be studied within the context of that province.

Prior to the introduction of the present system of hog marketing in Ontario, the organization of the producers went through several stages. With a few large buyers and producers who were still acting as individual agents, "marketing practices existed which denied the farmer bargaining power to such an extent as to be most unbelievable."[7] This allegation, which was based on a

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[4] K. L. Robinson, "Government and Agriculture in the United States", (unpublished paper, Cornell University, Ithaca, 1965).

[5] S. J. Buck, The Granger Movement: A Study of Agricultural Organization and its Political, Economic, and Social Manifestations (Cambridge: Harvard University Press, 1933).

[6] J. K. Galbraith, American Capitalism, the Concept of Countervailing Power (Boston: Houghton Mifflin Company, 1956) pp. 108-165.

[7] Dr. Lattimer of MacDonald College as quoted in: J. R. Kohler, "The Changing Pattern of Hog Marketing in Ontario" (paper read at Ninth Agricultural Marketing Clinic, Kellogg Center, Michigan State University, East Lansing, 12 March 1963).

study of export and domestic market conditions in 1959, was the opinion of Dr. Lattimer of MacDonald College, an economist examining the situation. Thus, producer dissatisfactions were reinforced by the appraisal of a professional economist. The marketing practices in question were of three types.

Direct Deliveries. Farmers could deliver their hogs directly to the packers' plants and receive the going price or the price agreed upon at the time. Several factors made this method detrimental to the farmer's bargaining position. The farmer, in many if not most cases, did not have the ability to bargain that the professional buying agent did; the buyer could quote low prices because the farmer did not have sufficient information to know he could obtain higher prices elsewhere; and, as is shown to be the case to a greater degree in low income countries with a less modern marketing system,[8] once the farmer has brought his product to market he tends to accept a low price rather than incur the expense and inconvenience of going to another market or returning home and selling his product at a later date. All of these factors are conditioned by the lack of information available to farmers on market conditions and prices.

Truckers and Drovers. Secondly, farmers could deal with truckers and drovers, of whom many were alledged to have received bonuses from certain packers to deliver the hogs to their plants. This policy resulted in an even flow of hogs through the plants of the large processors, eliminating much idle time and increasing the efficiency of labor. This method of obtaining

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[8] J. W. Mellor, The Economics of Agricultural Development (Ithaca: Cornell University Press, 1966) Chaps. 14 & 18.

a supply of hogs, although increasing the returns of processors and truckers, was alleged by the producers to have resulted in the delivery of producers' hogs to plants which were at a greater distance from the producer's farm than other plants, and which reflected a lower return to the producer than could have been obtained at a different plant. The weaknesses of this method of marketing, which include many of the ills of the method of direct delivery, account for the dissatisfaction of the farmers with their subjectively "unsatisfactory" position.

Auction Sales. A third method of marketing, once widely used in Ontario, is a system of country auction sales. This involves sales barns, operated on a regular or irregualr basis, where the local producer brings his hogs to be auctioned to both local and more distance buyers. Although this method provided a greater degree of competition than the others, certain abuses were alleged to be present. These included collusion among the larger buyers to keep the prices low, or to bid higher to force smaller firms, which obtained a much larger percentage of their supply at these sales than did the larger firms, into an untenable profit position. Although this behavior is impossible to verify, various people have commented on it, and a Kentucky study mentioned it as a moot problem of that state's marketing system.[9]

In the aggregate, none of these methods of marketing gave the producers a significant amount of control over the method by which the prices they received were determined. In addition, all the methods seem to indicate that the farmer's lack of market information contributes to his "unsatisfactory" position.

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[9] E. C. Johnson, Kentucky Livestock Auction Sales Organizations, Kentucky Agricultural Experiment Station Bulletin No. 270, (Lexington, April 1926).

ONTARIO HOG PRODUCERS' CO-OPERATIVE (OHPC)[10]

Against this background of producer dissatisfaction were initiated certain activities designed to improve the producers' bargaining position. The Ontario Hog Producers' Association attempted, with no success, to negotiate a minimum price with the processors, negotiated with the federal government on bacon contracts with Britan, introduced condemnation insurance, and forced the initiation of bankruptcy proceedings against an insolvent buyer of hogs. These latter actions met with greater success than the futile negotiations with the processors.

In 1946 the Ontario Hog Producers Marketing Board was set up with the purpose of selling producers' hogs under the Ontario Farm Products Marketing Act, after a favourable vote from hog producers. Initially, the board acted as a negotiating committee to reach agreements with the packers concerning minimum prices, conditions of sale, forms of contracts and other matters. It was limited in effect since it did not have control over the delivery of hogs and thus had no means by which to enforce the price agreements.

In 1952-53 a central selling agency, United Livestock Sales Company, was organized and operated in Toronto as the selling agent for the Marketing Board. This enterprise had the authority to divert hogs from a plant when it received an unsatisfactory bid, partly alleviating the alleged ills caused by payments to truckers by the processors.

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[10] This section is drawn from: Kohler, op. cit.; J. R. Kohler (report given to OHPC annual meeting, Toronto, 14 September 1961); J. A. Brown, A. A. Heidt, and R. H. D. Phillips, Hog Marketing in Saskatchewan (a preliminary report prepared for the Saskatchewan Advisory Swine Council, Saskatoon, June 1966); and G. F. Perkins, Marketing Milestones in Ontario, 1935-1960 (Ontario Department of Agriculture, Toronto, 1962) pp. 50-65.

In addition, this agency established the basis of the hog price for the province through the price determined in their transactions. This provided the farmers with better information on the prevailing prices. The central agency insured more competitive bidding partly through assuring the smaller processors of being able to bid on the same animals as the larger processors. The agency alleviated in part the large gap in bargaining ability previously existing when the farmer dealt directly with the buying agent by performing some of the bargaining through its own professional agents. The establishment of an increasing number of marketing yards throughout the province resulted in the central agency controlling more hogs so the processors had to increasingly rely on the agency for their supplies.

In 1955 the Marketing Board set up the Ontario Hog Producers Cooperative as its marketing agency replacing United Livestock Sales Company. The new agency was granted the power to control the sale of all hogs in Ontario unlike the former agency which could only control those hogs delivered to it. Compulsory direction through the control agency's yards was then gradually initiated as more assembly yards were established until at present all hogs in the province with the exception of those in Haliburton and the Northern districts are handled by OHPC, the central agency.

THE TELETYPE SELLING SYSTEM

The method of selling initially employed by the OHPC involved telephone contact and soliciting of bids. This system, which lacked mechanical records, was attacked with accusations of favoritism, allocation of hogs between yards and plants in an inefficient manner resulting in higher transportation costs and more travel time, and other more minor complaints. The need for a system which would be more acceptable to all parties was recognized by the OHPC as a result of these complaints. A mechanical system of keeping records was considered most desirable. Further, a method which assured processors they were receiving the hogs they bid for and not ones from a more distant yard, was considered imperative in light of their complaints alleging the existence of this practice under the previous system. These factors led to the introduction of the teletype system presently in operation.

The teletype system offers hogs to the buyers through buying machines in their offices. The buying machine shows the number of hogs in an offering and the yard at which they are located. The buyer thus knows what charges he will have to pay for transportation and when he can have the hogs at his plant. Using the Dutch auction principle of a declining scale of prices, the electronic equipment ensures that the first processor to bid, and therefore the one offering the highest price, receives the hogs. The equipment also ensures that the identity of the buyer is shown only on the particular buyer's machine and the selling machine. The remaining buyers' machines merely show that a sale was completed and at what price. Thus, the identity of the buyer can be kept secret. The system may be regarded as having reduced human involvement and bias to a minimal level.

Against this historical background of a changing marketing system, the question arises as to what type of marketing system would be desirable. The dissatisfaction that was evident with the existing systems must have had a basis which reflected certain criteria of what a marketing system should be. In relation to this question it will be informative to explore various outlooks.

CHAPTER II

CONSIDERATIONS RELEVANT TO A MARKET FOR HOGS

There has been an abundance of literature dealing with marketing and with a definition of what marketing is. Similarly, the definition of what a market is, or should be, encompasses a broad spectrum of views. It would be a fruitless exercise to review all the possible definitions here. I shall take a more constructive, if abbreviated, approach and pursue a minimum number of views to develop a conceptual framework in which to analyse a market.

One of the more concise, if naive, definitions of a livestock market has been given by Miller and Henning:

> "The most important function of a livestock market is to bring the seller and buyer of livestock together and satisfy the needs of each more efficiently than either can do separately."[1]

Any attempt to add to this simple definition risks confusing technique with function--there is little functional difference between a slave market in Istanbul, the Halles in Paris, or the New York Stock Exchange--, obscuring the description with professional jargon, or both. This does not mean that the stated role is a simple one. The needs of the parties must be determined and the various techniques must be evaluated regarding their relative efficiencies.

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[1] R. A. Miller and G. F. Henning, Suggested Location of Ohio Livestock Markets to Reduce Total Marketing Costs, Ohio Agricultural Research and Development Centre, Research Bulletin 981, (Wooster, February 1966) p. 3.

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These assumed goals are also described in the Ohio article:

> "The buyer wants an adequate supply of livestock, with the desired weight, grade, and quality required by his trade, from a few sources relatively close to his base of operations. The seller wants a strong conveniently located market with enough competition to insure a good market price and reasonably low market costs."[2]

Within this framework of the functions which a livestock market should perform and the needs of the parties involved in that market, various techniques, or type of markets, can be examined and evaluated. I will attempt to show that a system of assembly yards throughout the prairies together with a central selling agency can fulfill the above requirements.

QUALITY

The first need to be dealt with, and the simplest to analyse, is the one concerning quality. The present system of rail grading of hog carcasses, besided being considered as given, eliminates the subjective element previously involved in determining the price to pay when the hogs were graded on a live basis. This system ensures that the buyer will not make the mistake of bidding too high for hogs merely because he thinks they are of higher quality than they actually are. The differentials for quality are determined by formulae, so his bidding is based on a standard and he pays more, or less, depending on the quality index established by inspection.

While this system determines the differential for various grades, further research would be necessary to determine if it encourages the production of those grades desired by the consumer or processor.

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[2] Ibid.

SUPPLY

The needs of the buyer for an adequate supply is met by his being able to bid on all hogs offered throughout the system. In the case where all hogs must be sold through the teletype system no other type of system could ensure such a large number of hogs being available to each buyer, other than the direction of all hogs through one central market, which would entail back-hauling of hogs and greater procurement costs resulting in a less efficient system. Where use of the teletype system is voluntary, as in Manitoba, those hogs not delivered directly to packing plants are offered to all packers resulting in the largest uncommited supply possible.

COMPETITIVENESS

In the list of the needs of the seller, it was pointed out that the existence of competition was an important consideration. There have been two studies[3,4] done showing that the teletype system as implemented has been more competitive as shown by higher on-farm hog prices. In addition there are certain analytical reasons for assuming there would be stronger competition.

It should be pointed out that there is no one definition of competition that will be accepted by all parties. One can propose any definition ranging from "perfect" or "pure" competition to "workable" competition. All these definitions have their limitations. Perfect and pure competition are hypothetical abstractions, or even propositions, and being based on unreality can have only arbitrary value which may not be applicable to reality. Workable competition also has a similar problem as it is based on a standard drawn from pure competition.

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[3] W. F. Lu, "Effects on Regional Price Levels of Selling Hogs by Teletype", (unpublished M.Sc. thesis, University of Manitoba, Winnipeg, 1968).

[4] S. C. Lowe, "An Economic Analysis of the Teletype Hog Marketing System in Manitoba, Canada", (unpublished M.Sc. thesis, University of Wisconsin, Madison, 1968).

With the above considerations in mind, I shall proceed to set down a perspective and subsequent framework within which to view competition that will be relevant to this work. As has been pointed out by various people, including A. W. Wood, in an article in The Country Guide,[5] one of the main concerns of the producer is the ability of the buyers of his livestock to collude and decide to pay "less than fair value" for livestock. The relating of the concept of fair value to the economic concept of "value of marginal product" does not add any clarity to the understanding of the market as it merely plays semantic games and begs the question. In addition, as all definitions of "value" are circular tautologies, there is no recourse in that direction that would grant perspective for a definition.

With the above limitations in mind, all of which involve circularity, an alternative view can be proposed. For purposes of this presentation, competitiveness will be identified with the absence of collusion and the presence of enough buyers such that there is actual conflicting interest, viz., they would bid against each other for supplies. With this definition the test for competition will have to be found in examining the structure of the market and industry. Although there may be difficulties with this approach, the discussion above should justify its use.

Previously there were large differences between the buying and selling sides of the hog market in Ontario. A few large buyers, with a fringe of smaller buyers, faced atomistic producer-sellers. Organization theory

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[5] A. W. Wood, "Bargaining Power in the Livestock Market", The Country Guide, May 1962.

hypothesizes that this type of structure is conducive to collusion. "Such concurrence may be obtained whether by agreement or by buying price leadership, whereby one of the buyers sets a low buying price which others follow."[6] At the same time the atomistic sellers are price takers. As Bain points out:

> "Where the (oligopsonist) buys from a competitive industry or groups of sellers...it is almost certain that the short-run supply curve will show increasing cost, and it is very probable that the long-run supply curve will also slope upward to the right. This is generally true of agricultural industries, from which concentrated buying is most common.
>
> Thus, the probable tendency in (oligopsonistic) buying from competitive suppliers is for restricted output, increased price to consumers, lowered price to the basic suppliers, and excess buying profits to the (oligopsonist).[7]

The above statement by Bain is strong in including so many practices as probable tendencies. Many combinations of these tendencies may be possible in the market place. The teletype system should eliminate all but the most concerted collusion. With the identity of the buyer known only to himself and the central agency, only direct control could ensure such knowledge. This type of action is precluded by its very nature which is non-secretive and thus easily detected. In addition this type of collusion would appear to be an impossibility because of the presence in the market of a fringe of smaller buyers which precludes any large buyer from knowing whether or not a hypothetical partner in collusion was the buyer who had bid higher than the price agreed upon. Thus, collusion under this system is all but impossible.

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[6] J. S. Bain, Pricing, Distribution, and Employment Economics of an Enterprise System, (New York: Henry Holt and Company, 1958), p. 393.

[7] Ibid., pp. 387-388.

The fringe of smaller buyers in this market ensures that the only possible form of collusion that has a "chance" of succeeding is the most blatant and easily detected type. In addition, this type of collusion can only succeed if the fringe of smaller buyers do not buy as large amounts as would reduce supplies to the level where the large buyers could not obtain their requirements at their low agreed upon price. This would also mean that any expansion by the smaller buyers or the entrance into the market of additional buyers would render the collusion unstable. Competitiveness is thus ensured by the fringe of smaller buyers participating in the market at the same time as the large buyers. All buyers must bid against all other buyers in the market unitl they obtain their required supplies.

Another problem which previously impaired the competitiveness of the market was differing bargaining abilities of various sellers permitting price discrimination. The teletype system eliminates this problem. There is no personal contact and bargaining between buyer and seller and the system dictates that the buyers compete in buying practices against each other. Thus, the relevant bargaining abilities are only those of the buyers.

The complete hiding of identity of buyer and seller under the teletype system prevents any selective bidding-up eliminating the possibility of hurting any particular buyer without forcing the price of all lots of hogs in the market to a higher level.

It should be noted that this system, while ensuring the maximum amount of competitiveness within the market, does not give the producers monopolistic control over what is marketed. The central selling agency performs only the functions of an agent and does not restrict marketings. There is the possibility of manipulation through timing of the use of the buying machine in the selling office, however, with public and industry scrutiny there is little possibility of restrictive marketings from the selling side of the market being created by this particular system.

EFFICIENCY

The question of efficiency is the most important criterion to be evaluated, and is the immediate question to be considered by this study. At the same time the "convenient" location of the "market" will be seen to be closely related to the efficiency ceiterion.

The structure of the model to be used (see Page 37) guarantees that the final solution is at least as efficient as direct deliveries from the producing regions to the plants. There will be no assembly yard designated in the solution unless it entails lower costs than are incurred by shipping directly from producing regions to the final point of demand for live hogs. The total cost of the system must be, analytically, at least as low as is now possible without the system.

The individual producer could, in some cases, find that the solution, if strictly adhered to, would be less beneficial than an alternative. This would be the case if the model did not select a yard at the locations of the plant centres, precluding any possibility of direct delivery. It also could be a result in those cases where a region's hogs are shipped to a plant centre further away from the region than the nearest plant centre. In this case, a producer may incur a net increase in his marketing costs as opposed to his shipping direct to the nearest plant. Many of these limitations are caused by the model dealing with producing regions which are areas and not the single points which the model appears to use. Those producers near the outer boundaries could have alternatives significantly different than those facing producers near the center of the region. The smaller the producing region, the less likely is this limitation to occur. The limit would be where the producing regions become identical with each individual producer of hogs, but this is a practical impossibility due to data limitations.

The concept of a "convenient market" is related to the efficiency of the system. The producer wants to deliver his hogs into the marketing system in such a manner as to minimize his inconvenience, especially related to time, and to minimize his net marketing costs. His criteria relating to his time input can be satisfied by having a location near by to which to deliver his hogs thus requiring only a little time, or by having truck service readily available to deliver the hogs for him. The latter alternative is presently available in almost all regions in the prairies and can be assumed to be the choice of most producers as the former alternative would increase net marketing costs in the aggregate and thus for most producers.[8]

In order to show that the system of marketing being considered will result in a system of "most convenient markets", the following proof will be considered:

> Given two farms, A and B, A is located in the supply area, designated by the model, of plant X, while B is located in the supply area of plant Y. This means that the price at X less the cost of transfer to X from A is greater than the price at Y less the cost of transfer from A to Y. $P_x - t_{ax} > P_y - t_{ay}$ Similarly, the price at Y less the cost of transfer from B to Y is greater than the price at X less the cost of transfer from B to X. $P_y - t_{by} > P_x - t_{bx}$ To determine if there can be any change in the supply areas which incurs no additional costs, reassign one unit of production at A to plant Y,

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[8]The "most convenient market" concept as it relates to the individual producer may vary under similar systems. In Alberta for example the assembly function is independent of the teletype selling system and the producer pays directly for the cost of assembling his hogs. In Ontario the assembly yards are operated as part of the teletype system and the costs pooled or shared by all producers. The Ontario producer could find his net marketing cost decreasing if a yard were located near by despite an increase in aggregate costs. This is because the added cost resulting from that yard is paid for predominantly by those producers not using it. The individual producer or regional groups of producers can improve their relative position as they do not pay the full cost added by their new yard. Alberta producers, however, because they pay directly for any increase in the cost of the facility they use, will tend to select assembly facilities which reflect lower individual as well as aggregate costs.

and, in order to maintain market equilibrium, one unit from B to X. The change in transfer cost will be as follows:
For A: transfer cost from A to Y less the transfer cost from A to X must be greater than the price at Y less the price at X. Thus the change in transfer cost is greater than the amount by which the price at Y exceeds the price at X. If this were not true A would have been in Y's area initially rather than in X's.

$$t_{ay} - t_{ax} > P_y - P_x$$
$$\Delta t_a > P_y - P_x$$

Similarly, the change in transfer cost from reassigning one unit of production at B from Y to X is the transfer cost from B to X less the transfer cost from B to Y which is greater than the price at X less the price at Y. Thus, the combined change in transfer cost is the transfer cost from A to Y less the transfer cost from A to X plus the transfer cost from B to X less the transfer cost from B to Y. This change is, and tautologically must be, greater than zero.[9]

$$t_{bx} - t_{by} > P_x - P_y$$
$$\Delta t_b > P_x - P_y$$
$$t_{ay} - t_{ax} + t_{bx} - t_{by} > 0$$

At the limit, the system of market areas minimizes the total cost and results in the best economic position for the producers collectively, as well as for the processors. Thus, the model results in the most efficient allocation of hogs, subject to the limitations mentioned above.

This chapter has dealt with those factors which must be considered in a marketing system. Several of these factors are subject to normative judgment and difficult to evaluate. Others must be examined analytically due to data limitations while some can be examined more objectively. The following chapter will consider the models developed to analyse the spatial aspects of economic activity and the model to be used in this study.

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[9] drawn from class lectures by Om P. Tangri, (Winnipeg, University of Manitoba, Fall 1966).

CHAPTER III

THE THEORETICAL MODELS

The mainstream of neo-classical economics has neglected the space dimension of economic processes, assuming for convenience, a single point of production and consumption. The development of location theory and spatial equilibrium analysis has met this void to relate neo-classical theory to the real world in a manner which is more realistic than that provided by conventional theory.

Although the development of the spatial aspects of economic processes took place in other fields, great interest in this field has been shown by those economists dealing with agricultural problems. This interest in the locational aspects of economics has been necessitated by the dispersion of agricultural production and its separation from the processing and distributing functions.

This project is concerned with a spatial model relating production, which is dispersed throughout an area, to assembly, located at points to be determined, and to processing, which is located at given points in space. In this section several theories and models which preceded the spatial equilibrium model, or are modifications of that model, will be reviewed. The model to be used in this study will then be developed.

LOSCHIAN ANALYSIS

The depiction of the supply or market area as a system of hexagonal area around each plant has been the traditional analysis as initiated by August Losch.[1] The hexagon proves to be the most economical shape in the division of market areas because it eliminates any areas that would not be included in a circular set of supply areas, and it is sufficiently similar to a circle to minimize the transportation costs. Other possible shapes which would not exclude any area, the square and triangle, entail higher costs of transportation over a given area because of a greater difference in distance between center to apex and center to nearest side.

Although this analysis holds only under ideal conditions with identical cost functions faced by all firms, uniformity of production densities, and uniformity of transportation facilities, it can be extended to include many other conditions. Thus, differing densities of production can be introduced to yield an economic hexagon which is a different shape on a geographical plane. Differing transportation facilities may also be introduced stretching the hexagon toward regions of improved facilities. The result may be an economic hexagon which displays only remotely that shape on the geographical plane.

Olson, in an article on milk processing plants,[2] develops the costs of assembly based on the density of production and the firm's production function. Using these factors, the supply area is determined since the costs of processing, the costs of assembly, and the selling price of the

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[1] August Losch, The Economics of Location, Woglom, translator, (New Haven: Yale University Press, 1954,)ch. 10.

[2] F. F. Olson, "Location Theory as Applied to Milk Processing Plants", Journal of Farm Economics, Dec. 1959, pp. 1546-1559.

commodity will, when combined with the density, determine the area which will be used to secure the necessary inputs to maximize the firm's profits.

The development of the model involves the factors mentioned above and may be presented as follows:

> r = the distance from the plant which encompasses the supply area and is related to the volume of the plant and the density of production in the surrounding area.
>
> V (Volume) = D (Density) πr^2
>
> $r = \sqrt{V/D\pi}$

Assuming equal cost functions to all points in the area and the full utilization of the supply area r must be modified since the area will be divided into hexagonal supply areas at equilibrium. The r involved will be the distance to the apex of the hexagon which has the relationship r' = h/cos. 30, where h is the shortest distance from the center to the side of the hexagon. This r' must be larger than the previous r since the area of a hexagon with a given radius is less than the area of a circle with the same radius. The upper limit of r' is where the original r is equal to h. Since this is too large, a good estimate would be the apex which is halfway between r and r', <u>viz.</u> r" = r/.933015. This is the estimate used by Olson and may be considered as a good approximation. In Figure I, r is the radius of the circle that would give the necessary volume. However, the hexagon of radius r is circumscribed by the circle and has a smaller area. The relationship r' = h/cos. 30, h = r generates a second hexagon which circumscribes the circle and has a larger area. As in Olson's article[3] the best estimate is assumed to be the hexagon with the distance to the apex which is halfway between r and r'; in this case r".

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[3] <u>Ibid.</u>, p. 1551

A more accurate and complex analysis is given by J. C. Williamson Jr.[4] which involves the integration of the conical section of a hexagon. For the presentation of the basic system of markets the estimate of Olson is sufficiently accurate as the additional effort required to integrate a complex function involving equilibrium volume and costs may not be justified.

This simple analysis, considering only the perfectly homogenous case can be extended to show the effects of decreasing density of production, or consumtion, away from th. plant or final market. In Figure II, the hexagonal shape is divergent toward the less dense areas of production. With a continuously decreasing density, refined mathematical analysis could develop such a system of stretched hexagons.

Less regular differences in homogeneity, such as differences in the transportation facilities in various directions, may result in supply areas similar to the one in Figure III. Techniques for the systematic development of systems such as this are lacking, but appear to involve a combination of mathematics and graphics. The more irregular the conditions prevailing, the stronger the emphasis on graphics as mathematics becomes very cumbersome when dealing with the complex functions which result. The existence of a transportation system in the prairies that displays a great deal of irregularity, especially in the north-south directions, highlights the need for more work in this complex field.

THE TRANSPORTATION MODELS[5]

The transportation model, which was originally developed for naval scheduling of cargo vessels, has since been applied to transportation problems involving air and land transfer as well as certain production and allocation problems. The simple transportation model minimizes the transportation costs

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[4]J. C. Williamson, Jr., "The Equilibrium Size of Marketing Plants in a Spatial Market", Journal of Farm Economics, Nov. 1962, pp. 953-967.

[5]The basic description of the transportation model and its solution is taken from: E. O. Heady, and W. Candler, Linear Programming Methods, Ames: The Iowa State University Press, 1966, ch. 10.

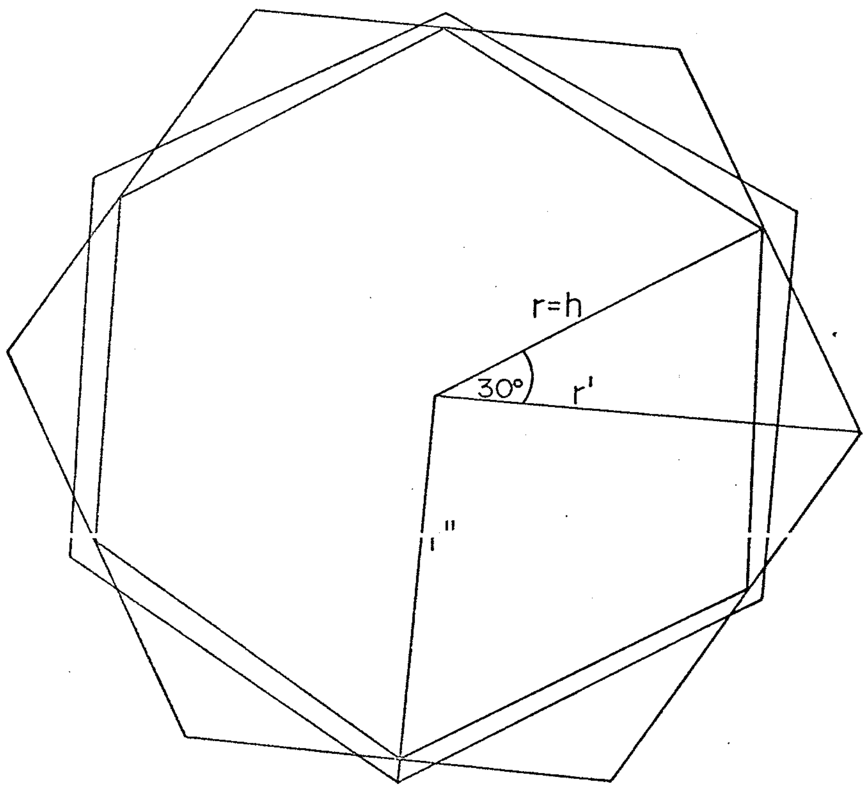


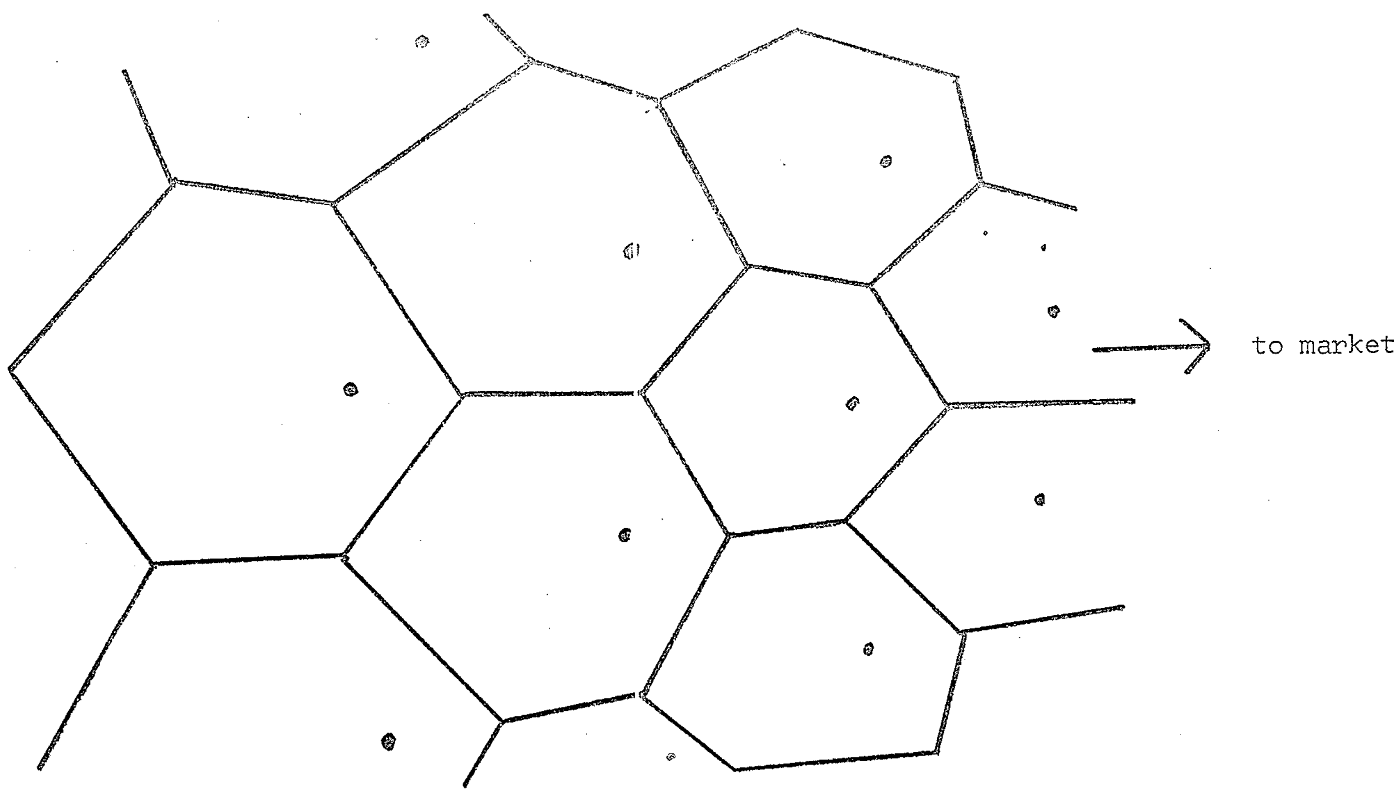
Figure I

Determination of Radius of Supply Area Under Perfect Homogeneity.

(From: Olson, F. L., "Location Theory as Applied to Milk Processing Plants", Journal of Farm Economics, Dec. 1959, p.1552.)

FIGURE II

SYSTEM OF MODIFIED HEXAGONAL SUPPLY AREAS



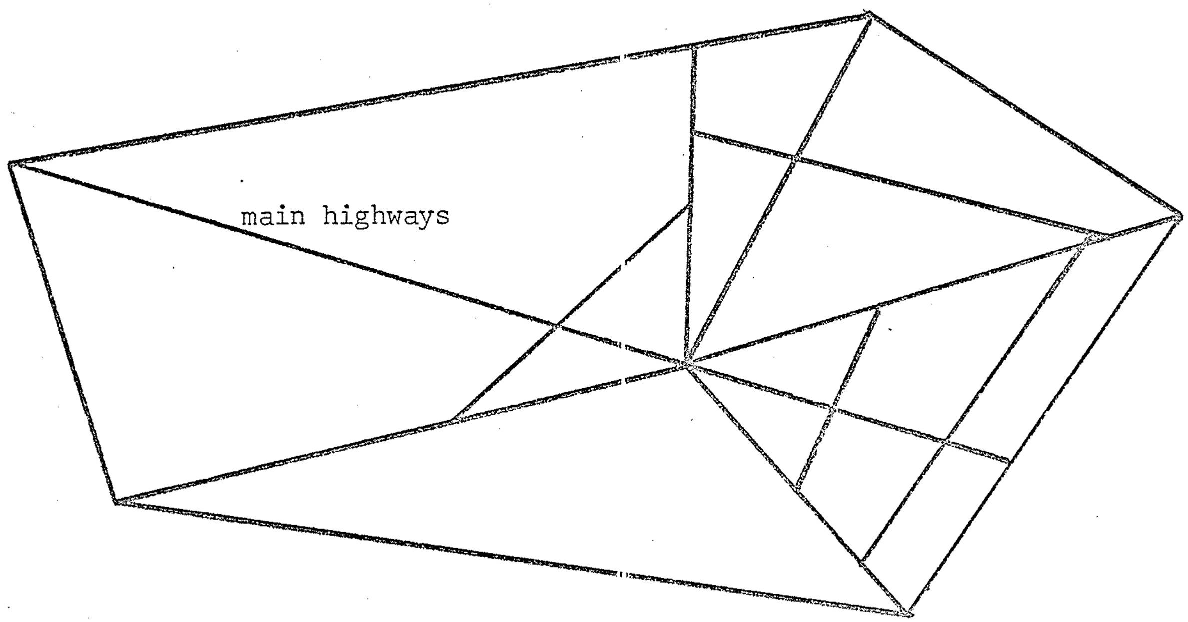
Source: Class notes under Om P. Tangri, University of Manitoba, Winnipeg, 1967.

FIGURE III

POSSIBLE SUPPLY AREA

WITH

NON-HOMOGENEOUS TRANSPORTATION FACILITIES



involved in transferring homogeneous commodities from various origins to various destinations. Although this type of problem can be solved by the simplex technique, the transportation model is a more efficient method for solving problems which fulfill its more restrictive assumptions.

These assumptions are:

1. Homogeneity of the commodity transferred, i.e., the supply at any point can be used to satisfy the demand at any point.

2. Supplies of the commodity available at the various origins and demands at the various destinations are known and are equal in the aggregate.

3. The cost of transferring a unit of commodity from each origin to each destination is constant and independent of the number of units transferred.

4. There is an objective function to be optimized.

5. Transfer between points is non-negative.

The last three assumptions are quite similar to the assumptions of general linear programming. The first two assumptions, however, are what make the transportation model more restrictive than the simplex technique.

Mathematically the model can be expressed as follows:

Minimize: $$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}x_{ij}$$

subject to: $$\sum_{j=1}^{n} x_{ij} = b_i \text{ (supply at origin i)}$$

$$\sum_{i=1}^{m} x_{ij} = y_j \text{ (amount required by destination j)}$$

$$\sum_{j=1}^{n} y_j = \sum_{i=1}^{m} b_i \text{ (total supply equals total demand)}$$

$x_{ij} \neq 0$ (non-negative transfers)

where:

c_{ij} = the transfer cost per unit from origin i to destination j

x_{ij} = the amount transferred from origin i to destination j

b_i = supply at origin i

y_j = demand at destination j

Solution of the Model

As with other linear programming methods, the solution of the transportation model involves beginning with a feasible plan, applying some criterion to determine if the original plan can be improved, and modifying the plan. In determining a first feasible solution, the north-west corner rule is used. This merely means that, given a set of origins and destinations in a matrix, the requirements of the destinations in the first column is met with supplies in the first row, the upper left, or north-west corner. Then the procedure is to the right or lower cell, east or south, depending on whether there is a net surplus or deficit in the supply row. This is shown in the matrix depicted in Figure IV.

There are two major means of changing the plan. The first, the stepping stone method, gives a path which compensates the entire matrix for a unit increase in an inactive cell. At the same time it provides a criterion for judging the possibility of improving the program. If, in Figure IV, we wished to supply Point 9 from Point A with one unit, there would have to be some adjustment in the entire matrix since Point A would otherwise be supplying more than it has, and Point 9 would be receiving more than it needs.

Stepping Stone Method

In order to balance Row A we now allocate one less unit to Cell A6. Now Column 6 is imbalanced so one unit is added to Cell B6. Similarly: Cell B7 -1, C7 +1, C9 -1, until all the rows and columns are balanced.

There are costs associated with the transfer of units of the commodity from each origin to each destination. These are shown in Figure V. In the change of plan presented above each of the increases in the amount shipped to a destination from an origin incurs an expense, while a saving is realized where less is shipped. This is outlined below:

Increase by 1 - cost			Decrease by 1 - saving	
Cell	A9	1	A6	3
	B6	6	B7	5
	C7	2	C9	2
Total		9		10
				9
Net Saving				1

This represents the saving that would result if one unit were to be shipped from A to 9. Each possible change has a cost or saving associated with it, so each starting inactive state will have a value as is depicted in Figure VI.

The selection of the inactive cell with the largest saving for increasing the flow on the next iteration leads to a plan which entails less cost than the first feasible solution. The cell selected on this basis should receive an increase equal to the smaller of either the supply available at the relevant origin or the demand at the relevant destination. By successively applying this technique, an optimum plan is reached where none of the cells represents a saving. If a starting plan has a value of zero, the use of that cell obtains a plan as good as, but no better than, the former plan.

FIGURE IV

STEPPING STONE MATRIX

origins	destinations									total volume
	1	2	3	4	5	6	7	8	9	
A	200	75	75	200	175	25(-5)			(+5)	750
B						475 (+5)	25(-5)			500
C							75(+5)	125	50(-5)	250
total	200	75	75	200	175	500	100	125	50	1500

Source: E. O. Heady, and W. Candler, Linear Programming Methods (Ames: The Iowa State University Press, 1966), ch. 10.

FIGURE V

TRANSPORTATION COST MATRIX

origins	destinations									total volume
	1	2	3	4	5	6	7	8	9	
A	5	1	4	2	1	3	7	4	1	750
B	2	3	2	6	4	6	5	4	3	500
C	1	2	1	1	5	7	2	2	2	250
total	200	75	75	200	175	500	100	125	50	1500

Source: E. O. Heady, and W. Candler, <u>Linear Programming Methods</u> (Ames: The Iowa State University Press, 1966), ch. 10.

FIGURE VI

NET CHANGE MATRIX

origins	destinations									total volume
	1	2	3	4	5	6	7	8	9	
A							5	7	1	750
B	-6	-1	-5	1	0			-1	-2	500
C	-4	1	-3	-1	4	4				250
total	200	75	75	200	175	500	100	125	50	1500

Source: E. O. Heady, and W. Candler, Linear Programming MEthods (Ames: The Iowa State University Press, 1966), ch. 10.

<u>The MODI Method</u>

The second method of solving the transportation model, the MODI method, begins with an initial feasible solution and proceeds to select cell values associated with the active cells. After the values for the active cells are in a matrix, an arbitrary number is selected for the value of a row or column. At this point, since cell value = row value + column value, the values of the remaining cells, rows, and columns are automatically determined.

This matrix of values is then compared with the matrix of the original transfer costs. The cells with a cost less than their MODI value are the ones to be activated in the next iteration. By choosing the cell with the largest difference between actual and MODI values, and successively applying this technique until no values are less than their MODI value, an optimum is reached.

The similarity of the two methods of solution is evidenced by the values obtained in the comparison of the MODI and transportation matrices. The difference between the cell values is the value of the path, and thus the cell value of the matrix in the stepping stone method.

Due to the inadequacies of the computer facilities at the University of Manitoba, the transportation model as such could not be used to solve the problem in this project. Instead, a linear programming revised simplex format was used under the Mathematical Programming System (MPS) of the IBM 360-65 computer system.

In order to understand the relationship between the two formats, it will be necessary to show the matrix analogous to that shown in Figure V as it would appear in the simplex format. This is done in Figure VII with the most notable feature being that each cell value in Figure V now requires an entire column of activity. The transportation costs become a separate row heading each column. The matrix entries are all unity, the supplies and demands become activity levels--right hand sides (RHS). There are diagonals of unity to transfer the RHS of the columns of the matrix in Figure V to the rows. The size of the matrix is increased substantially, viz., rows increase by the number of columns while the columns increase by a factor of the number of rows becoming the product of the two. Consequently, the density of the matrix decreases.

The solution of the problem is not changed as the simplex method changes activity levels to reach an optimum. In the simplex method these activity levels are reflected as column vectors, whereas they were cell values under the transportation model format.

FIGURE VII

LP MATRIX FORMAT

	A1	A2	A3	A4	A5	A6	A7	A8	A9	B1	B2	B3	B4	B5	B6	B7	B8	B9	C1	C2	C3	C4	C5	C6	C7	C8	C9	Cost / level
	5	1	4	2	1	3	7	4	1	2	3	2	6	4	6	5	4	3	1	2	1	1	5	7	2	2	2	
A	1	1	1	1	1	1	1	1	1																			750=
B										1	1	1	1	1	1	1	1	1										500=
C																			1	1	1	1	1	1	1	1	1	250=
1	1									1									1									200=
2		1									1									1								75=
3			1									1									1							75=
4				1									1									1						200=
5					1									1									1					175=
6						1									1									1				500=
7							1									1									1			100=
8								1									1									1		125=
9									1									1									1	50=

THE RELATIONSHIP BETWEEN THE LOSCHIAN APPROACH AND THE TRANSPORTATION MODELS

The Loschian approach to the study of market areas may be compared to the transportation models, although the restrictions of the two approaches are different. The Loschian approach deals with the completely homogeneous case where the firms have identical cost functions and thus identical volumes. On the other hand, the transportation models use real world values which give differing volumes indicating that cost functions are not identical and/or other assumptions of complete homogeneity do not hold. Density of production is assumed to be homogeneous in the Loschian analysis, while the other approach deals with explicit volumes for given points or regions.

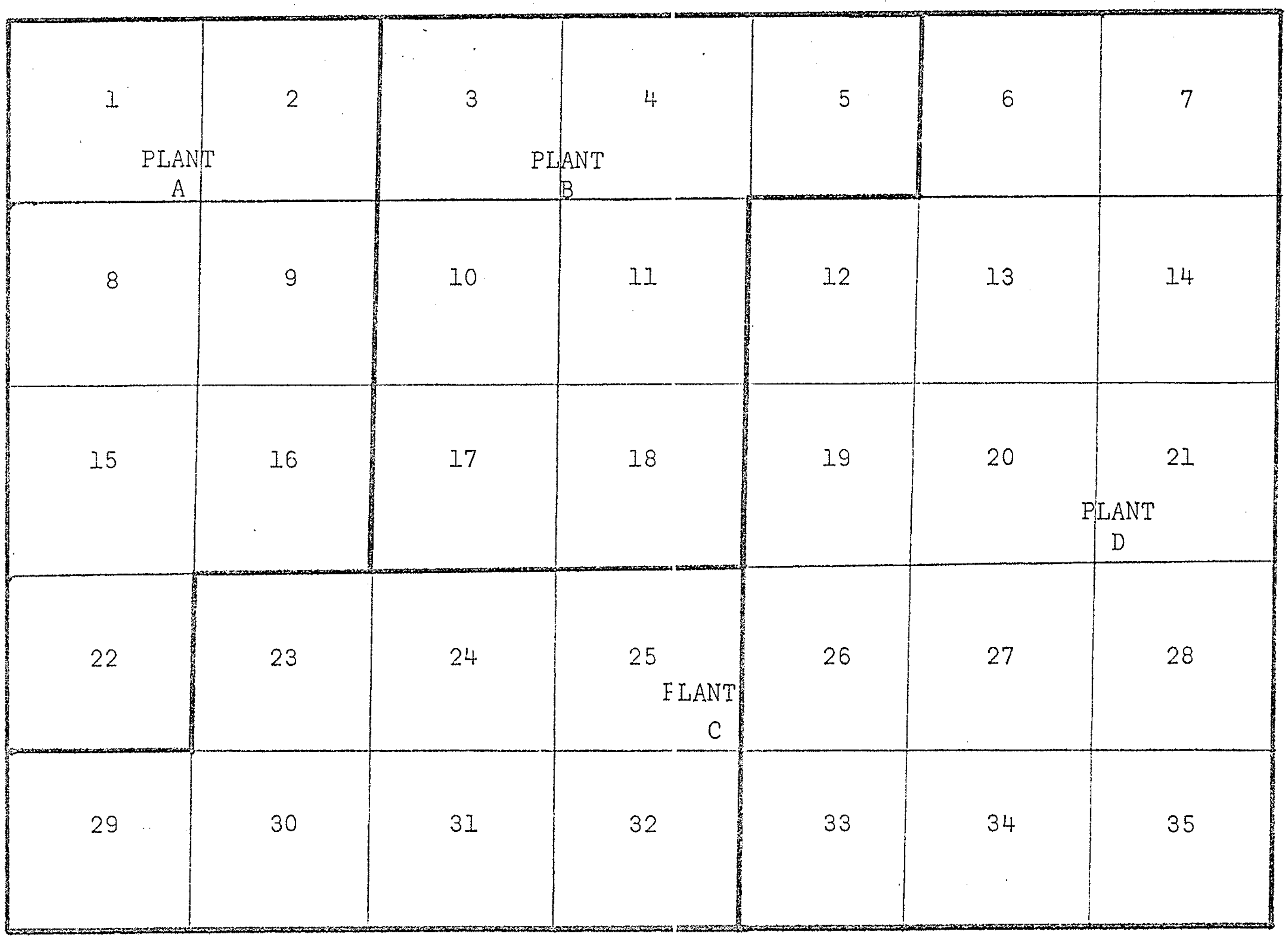
The relationship may be shown by considering the following example. In a plane, as in Figure VIII, the transportation model can be viewed as dividing a supply area between plants in such a manner as to approximate the ideal shape of a Loschian system. Production in this case is depicted as occurring at one point, viz., the centre of a census subdivision, which approximates the aggregate distance involved in transporting a commodity within the subdivision.

If in Figure VIII, squares 1 to 35 represent the centres of the sub-division, each producing 100 units, eg., hogs; and A to D represent Plants A, B, and C requiring 700 hogs and D requiring 1,400 hogs, then the minimization procedure may allocate subdivision production as shown by the boundaries. The supply areas for each plant will be as outlined by the heavy lines.

Although the supply areas are not hexagons, the logical extension of this approach, if there were homogeneity of production density and requirements, and a large number of small producing regions, would be a distribution of areas in a hexagonal pattern. Another way of expressing this is: at the limit, as

FIGURE VIII

POSSIBLE SUPPLY AREAS



the number of producing regions approaches infinity and their size approaches zero, the transportation model solution approaches the solution of the Loschian analysis, viz., a system of hexagonal market areas. This can easily be seen by comparing the concepts of the integral and the summation, which also approach each other at the same limit. Since the Loschian analysis uses a double integral function and the transportation model uses a double summation, the similarity is apparent.

Using a linear model, a single point must be used as the source of production, and the resulting shape of the market area must be a figure made up of the original forms involved. Thus, in southern Saskatchewan, the shapes depicted in Figure VIII might result, while in Manitoba or Alberta less regular shapes reflecting the boundaries of rivers, lakes, etc., may result.

In dealing with real world data, where production levels, transportation facilities, plant cost function, etc. are not homogeneous, a method for approximating the actual incurred cost must be utilized. More refined and complex theories, including allowances for varying densities of production, biases in the transportation system, etc. could be employed. With the introduction of these more complex techniques, the additional accuracy of representation of the real situation may not justify the extra time and effort required. An exception may be the results obtained through the use of simulation[6] techniques where the various parameters, e.g., transfer cost, plant operating cost, supplies, demands, etc., can be varied easily within the program to indicate the effects of such changes. In large distribution problems their use may be justified.

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[6] M.L. Gerson, and R.B. Maffei, "Technical Characteristics of Distribution Simulators", Management Science, October 1963, pp. 62-69.

MODEL FOR THE DETERMINATION OF THE OPTIMUM NUMBER, SIZE, AND LOCATION OF HOG ASSEMBLY YARDS

The basic transportation model can be modified to deal with shipments to and from intermediate points.[7,8] The transhipment model as used by King and Logan[9] and modified by Hurt and Tramel,[10] is readily amenable, with certain restrictions and changes dictated by the particular circumstances, to the problem presented in this thesis. The model is not one dealing entirely with transhipment, but allows for the points where transhipment could occur by considering those points as both origins and destinations.

The model may be presented as follows:

Minimize: $Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}$; $m = p+y$, $n = y+f$

Z = total cost of transfer of hogs from producing regions to assembly yards and from the yards to plant centres including the operating costs of the yards.

subject to: $c_{ij} \geqq 0$

$c_{ij} = 0$ for $i-p = j$ where $i = p+1, \ldots m$ and $j = 1, \ldots y$

$= \infty$ for $i-p \neq j$ where $i = p+1, \ldots m$ and $j = 1, \ldots y$

$= \infty$ for $i = 1, \ldots p$ and $j = y+1, \ldots n$

$= t_{ij} + H_i$ for $i = 1, \ldots p$ and $j = 1, \ldots y$

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[7] A. Orden, "The Transhipment Problem", Management Science, April 1956, pp. 276-286.

[8] C. H. Kriebal, "Warehousing with Transhipment Under Seasonal Demand", Journal of Regional Science, Summer 1961, pp. 57-69.

[9] G. A. King, and S. H. Logan, "Optimum Location, Number, and Size of Processing Plants with Raw Product and Final Product Shipments", Journal of Farm Economics, Feb. 1964, pp. 94-108.

[10] V. G. Hurt, and T. E. Tramel, "Alternative Formulations of the Transhipment Problem," Journal of Farm Economics, Aug. 1965, pp. 763-773.

$$\sum_{i=1}^{p} x_{ij} = \sum_{i=p+1}^{m} x_{ij} = \sum_{j=y+1}^{n} x_{ij}$$

total deliveries to plants = volume handled by assembly yards = all hogs marketed.

Where: c_{ij} is the transfer cost per hog from region j to assembly yard i; i = p+1, ...m and j = y+1, ...n

is the transfer cost per hog from yard j to plant centre i plus the operating cost per hog of assembly yard j; i = 1, ...p and j = 1, ...y

x_{ij} is the number of hogs transferred from region j to yard i, i = p+1, ...m and j = y+1, ...n

is the number of hogs transferred from yard j to plant centre i; i = 1, ...p and j = 1, ...y

t_{ij} is the transfer cost per hog from yard j to plant centre i; i = 1, ...p and j = 1, ...y

H_i is the operating cost per hog of yard j;

is a function of $\sum_{i=1}^{p} x_{ij}$; j = 1, ...y

f is the number of producing regions

y is the number of possible assembly yards

p is the number of plant centres

Matrix Format

The matrix format for the model presented above is given in Figure IX. Figure IX-A gives the format for the solution, while Figure IX-B gives the format for the cost matrix. There are four submatrices as is shown. Submatrix A shows the shipments of hogs from assembly yards to plant centres in the solution, and shows the transfer costs between those points plus the operating cost per hog of the assembly yards. Submatrix B has no relevance to the problem and high cost entries preclude any entries in the final solution. Submatrix C has a zero value diagonal in the cost matrix to allow the entry of excess yard capacity in the solution. The remaining cells in the submatrix have no relevance to the problem and again, high costs preclude entries in the solution. Submatrix D contains shipments from the producing regions to the assembly yards in the solution and transfer costs between those points in the cost matrix.

The actual costs and volumes of movement for the hog marketing system which the model was applied to will be dealt with in the following chapters. Chapter IV will deal with the costs involved in transfer and assembly, viz., the values for the cost matrix depicted in IX-B. Chapter V will then present the values associated with the solution, viz., the volume and direction of movements as depicted in Figure IX-A, and the overall cost involved in the system or the minimized Z of the model.

FIGURE IX - A

MATRIX FORMAT

SOLUTION

Demands at Plant Centres	A Hog Shipments from Yards to Plant Centres	B No Relevance to Problem
Yard Capacities	C Excess Yard Capacity on Diagonal	D Hog Shipments from Producing Regions to Yards
	Yard Capacities	Supplies of Producing Regions

FIGURE IX - B

MATRIX FORMAT

COST ENTRIES

Demands at Plant Centres	A $t_{ij} + H_i$ transfer costs from Yards to Plant Centres plus assembly costs	B ∞ No Relevance to Problem
Yard Capacities	C 0 Diagonal 0 has 0 zero 0 costs 0 Remainder of matrix ∞ to preclude entries	D c_{ij} Transfer costs from Producing Regions to Assembly Yards
	Yard Capacities	Supplies of Producing Regions

CHAPTER IV

TRANSFER COSTS

Location theory predicts that transfer functions will have certain properties. Given certain fixed costs of a transfer system and terminal costs, the transfer cost function should begin at a positive value at zero distance and increase with the distance travelled. The cost does not increase proportionally with distance. As Isard explains, "In industrialized areas modern transport media require large overhead expenditures and incur many costs and offer many services (especially terminal) which are unrelated to the distance covered in a given shipment. Typically, tariff per distance unit or zone is steep for the first zone and falls abruptly from the first to the second zone and considerably less abruptly between each succeeding zone (or set of zones) and the one after. Tariff structures are graduated, rates being less than proportional to distance."[1] This is reflected in Figure X where the cost function is increasing at a decreasing rate. The step-like horizontal lines reflect the zonal characteristic of modern rate structures. Isard also points out that realistic rate structures may reflect differing conditions in various directions through higher or lower cost, e.g., mountains in one direction from a point and level prairie in another.[2]

In addition to the points mentioned above, it will be worthy to note that the terminal costs may become more complicated than a simple single value. Figure XI depicts a hypothetical case of a trucker's cost in

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[1] W. Isard, Location and Space-Economy, (New York: John Wiley and Sons, Inc., 1969), p. 104.

[2] Ibid.

transporting hogs. If each point, A to D, represents various farms at which the trucker stops to collect hogs, there should be a terminal cost associated with each point. Thus, the total cost of transport from A to the market, M, is shown as TTC. If at the same time we show the cost of transporting the same number of hogs directly from A to M without other stops, it is apparent that this would be a lower cost, viz., TC_1. Therefore, it is possible to see the savings that could result from reducing the number of stops made in transporting hogs from producing units to markets.

Consideration of the type of trucks used should further illustrate the cost functions involved. It could be expected that large trucks, as compared to small trucks, should include a greater amount of fixed cost in their cost functions due to larger capital expenditures. In addition, as it requires more energy to move a larger truck, its variable cost should also be greater per unit distance. This is reflected in the comparison of operating costs of half ton and one and one-half ton trucks shown in Table I.[3]

Due to possible economies of scale, it would be expected that the larger trucks would have a lower per unit weight/distance cost. This is shown to be the case in the third line of Table I where the cost per half ton mile is shown for the one and one-half ton trucks. In each case the per unit cost is less than that for the half ton trucks.

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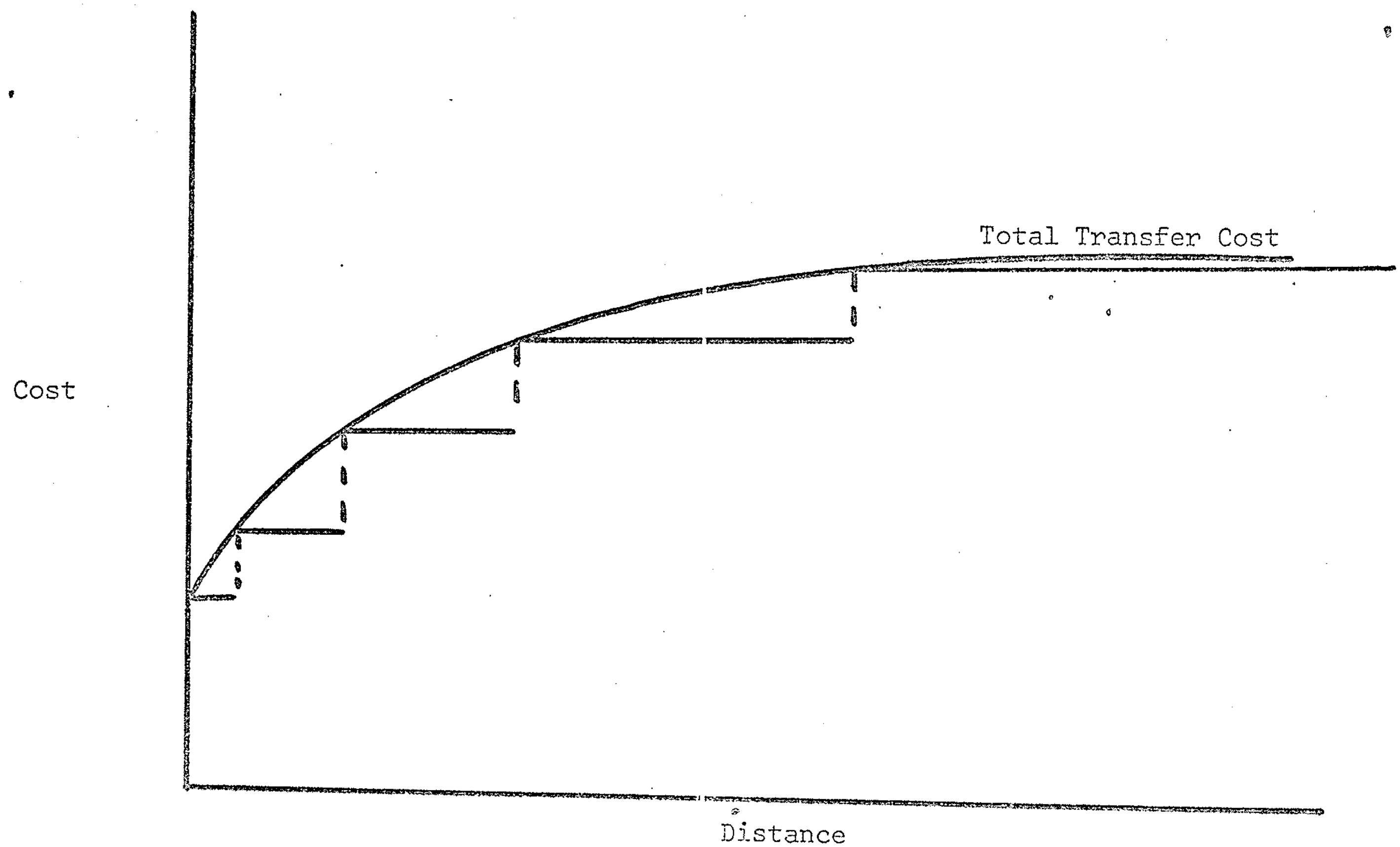
[3]C. F. Capstick, Cost of Owning and Operating Farm Trucks in Eastern Arkansas, Agricultural Experimental Station Bulletin, (Fayetteville, 1960), Tables I and II.

FIGURE X

TRANSFER COST FUNCTION



Source: E. M. Hoover, The Location of Economic Activity (New York: McGraw-Hill Book Company, Inc., 1967), p. 21.

FIGURE XI

COST OF TRANSFER FROM A TO M

WITH THREE INTERMEDIATE STOPS

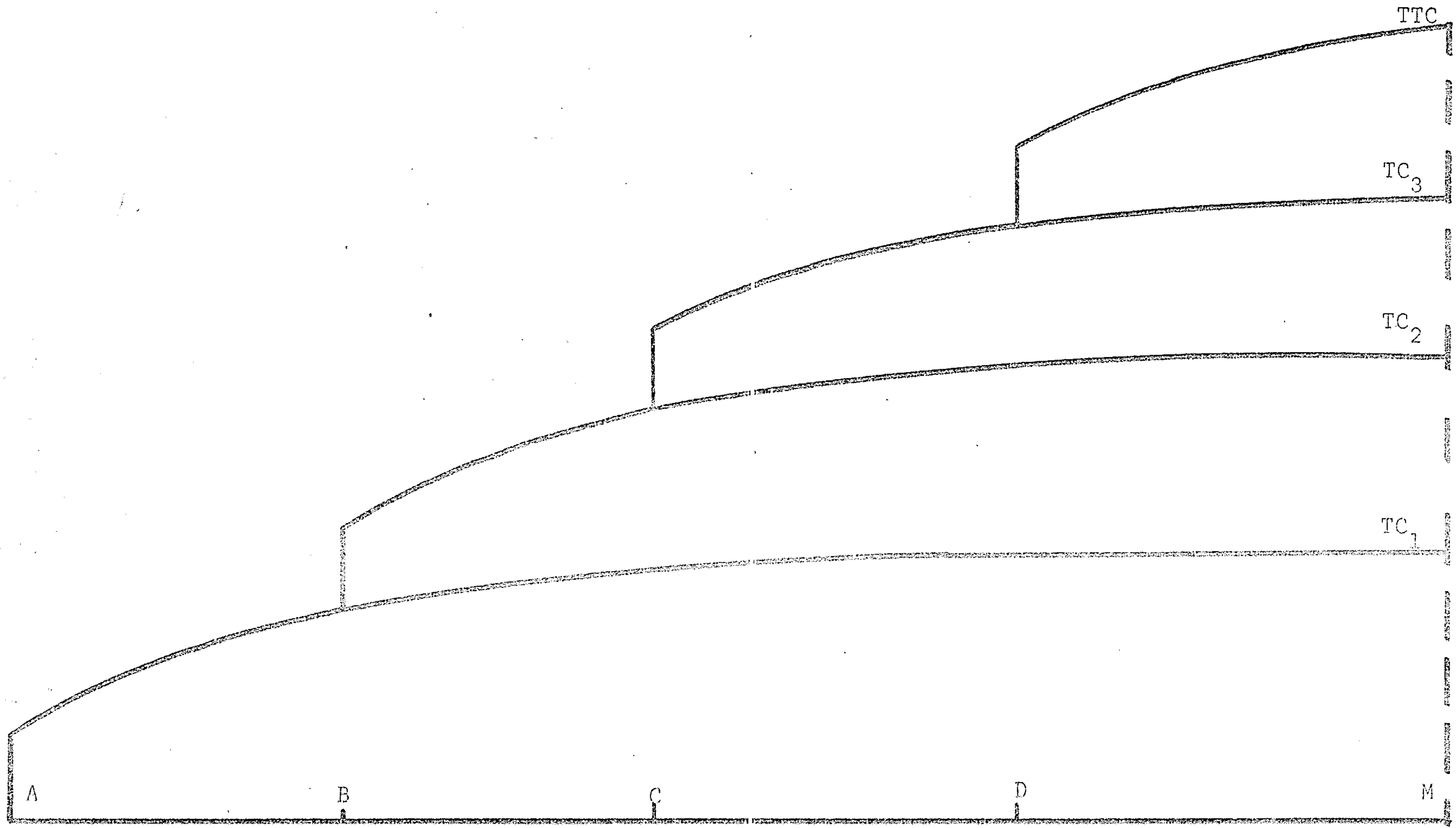


TABLE I

AVERAGE COST PER MILE FOR HALF TON
AND ONE AND ONE-HALF TON TRUCKS IN ARKANSAS
BY AGE AT 10,000 MILES PER ANNUM

	years of use						
	1	2	3	4	5	6	7
	(cents per mile)						
½ ton:	11.4	10.6	9.8	9.4	9.1	8.8	8.5
1½ ton:	16.7	15.6	14.7	14.8	14.2	14.0	13.5
per ½ ton:	5.6	5.2	4.9	4.9	4.7	4.7	4.5

Source: C. F. Capstick, Cost of Owning and Operating Farm Trucks in Eastern Arkansas, Arkansas Agricultural Experimental Station Bulletin, Fayetteville, 1960, Tables I and II.

THE EMPIRICAL TRANSFER COST FUNCTIONS

The above characteristics of transfer cost functions were borne-out by data used in this study. Regressions were performed on two sets of truck rates to determine the transfer costs to be used. Trucks were used as the mode of transportation in the study as a comparison of rail and truck rates for common points indicated that truck rates were less in most cases.[4] Although it would be more accurate in order to arrive at the minimum cost to determine the actual rates for all points in the model, compare the modal rates and select the lowest rate for use in the model, the method used in this study was to apply a functional relationship of distance and rate to a matrix of distances to develop the transfer cost matrix.

This technique was utilized as it represented a substantial saving of research time. Its accuracy is dependent upon the homogeneity of the highway network and the resulting trucking costs. Although there can be no realistic assumption of such homogeneity, the east-west network being more developed than the north-south network, additional government expenditures on highways should produce a greater homogeneity than that which presently exists.

In this project simple regressions were performed on two different sets of rate data. The first involved a questionnaire to truckers to the St. Boniface stock yards and was obtained through the Manitoba Hog Marketing Commission. As the data were not stratified by truck size, they include all

[4]In a comparison between Western Tariff Bureau, Tariff No. 501, and a private communication from Canadian National Railways; of 84 common points, 72 or about 86%, had a lower truck rate.

commercial vehicles hauling into the yards. With the 164 observations, there were two distinct trends in the data. The data were split at 105 miles and two straight line regressions were performed. The first regression performed on distances less than 105 miles included eighty-nine observations. The regression yields the functions Y = 66.0 + .60X where Y is the cost in cents of transporting one hog, including on farm pick-up and X is the distance travelled in miles. The regression had a coefficient of determination, r^2, of .47 and was significant at the 1% level using the F test. The regression coefficient was also significant at the 1% level as indicated by the Student t value.

For distances greater than 105 miles, the simple regression on seventy-five observations yields the function Y = 68.0 + .45X. The coefficient of determination, r^2, had a value of .49 and was significant at the 1% level as was the regression coefficient.

In the second set of data, two hundred seventy observations of trailer loads of not less than 20,000 pounds from points in Saskatchewan to the St. Boniface yards, taken from Western Tariff Bureau, Tariff No. 501, Section 3, there was no definite break in the observations. The straight line regression of these data yields a cost function of Y = 70.0 + .32X which included only one pick-up. The coefficient of determination, r^2, had a value of .80 and was significant at the 1% level as was the regression coefficient.

It may be observed from these regression values that the larger trucks which do not stop at a large number of farms incur a lower transfer cost at distances greater than 14.3 miles. Although this seems an unrealistically low distance for this economy to occur, which may be partially explained by the small number of observations at short distances, it does indicate that there should be some point at which it would be less expensive to aggregate farmer's hogs and then transport them in larger lots using larger trucks. It is worthy of note that the high per mile cost of the survey involving smaller trucks includes a few larger units with large loads similar to those in the second set of data.[5] These larger units would normally be included in the mixture of trucks which operate at distances greater than 105 miles. Their presence is reflected in the lower cost function for that range of distance.

These cost functions are shown in Figure XII. The functions which included on farm pick-up, apply to transfer from producing region to assembly yard. In Figure IX-B, these are represented by the c_{ij}'s in submatrix D and can be stated as:

$$c_{ij} = 66 + .60D_{ij};\ 0 < D_{ij} \leq 105$$

$$c_{ij} = 68 + .45D_{ij};\ 105 > D_{ij}$$

where: c_{ij} is the cost of transferring one hog from i to j including on farm pick up and

D_{ij} is the distance from i to j.

The function obtained from the data using 20,000 pound loads applies to the transfer from assembly yard to plant centre. This is represented by the t_{ij}'s of submatrix A in Figure IX-B and can be stated as:

$$t_{ij} = 70 + .32\ D_{ij}$$

where: t_{ij} is the cost of transferring one hog from i to j, and

D_{ij} is the distance from i to j

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[5] drawn from conversation with Mr. L. Sedgwick and others at the Manitoba Hog Marketing Commission, May 1967.

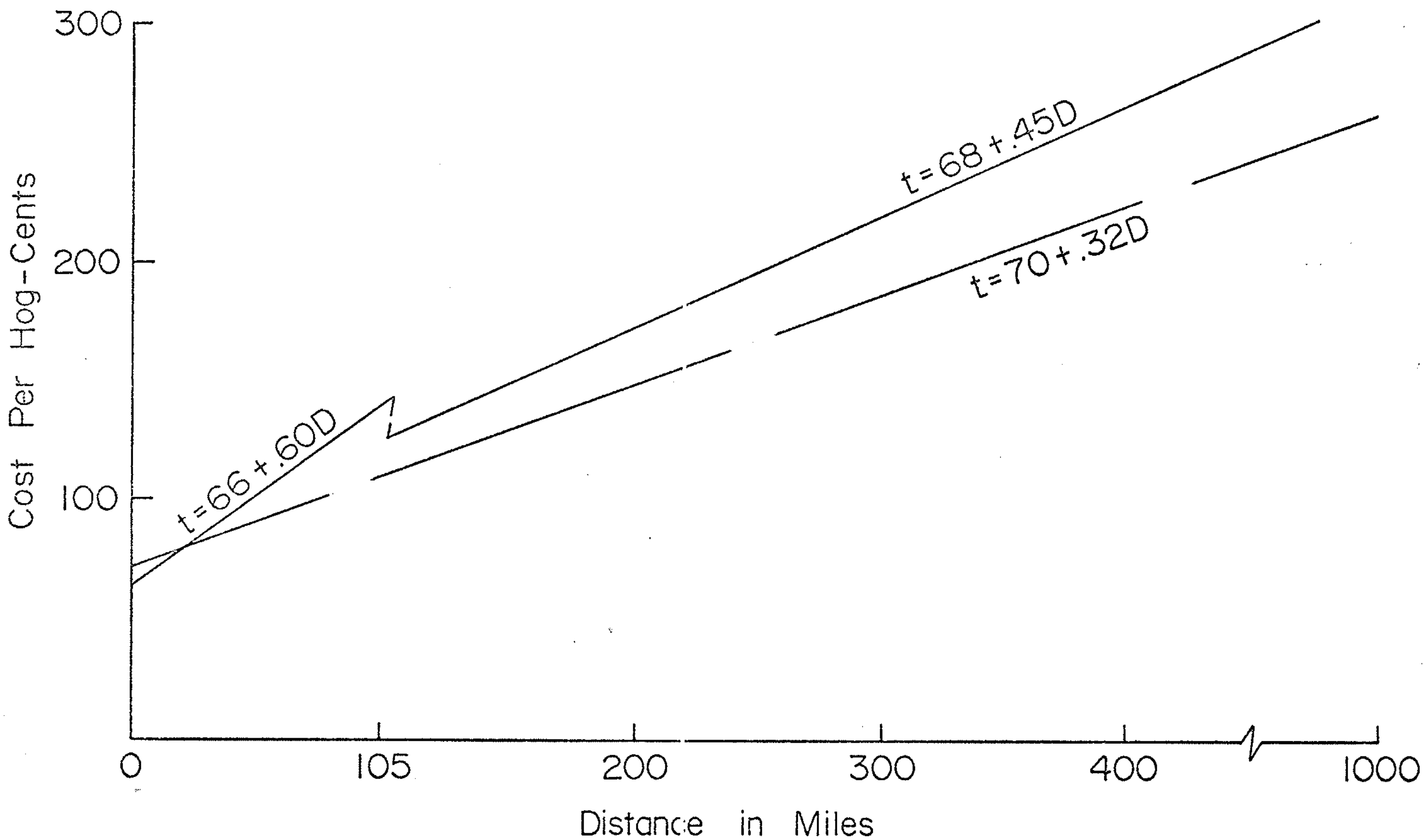

Figure XII
Transfer Cost Functions

ASSEMBLY COST FUNCTIONS

In the derivation of assembly cost we could expect that the average cost per hog would decrease with the increase in the number of hogs handled through any facility, due to the possibility of economies of scale. Although classical theory predicts that the average cost curve will be U shaped, empirical studies have indicated that, at least for the range under consideration, the average cost does not rise at larger volumes.[6,7]

The derivation of the actual cost functions used in this project was made from cost data drawn from the system operating in Ontario.[8] Depicted in Figure XIII is the actual average cost per hog-volume handled at various points. The line connecting the minimum points may be considered as the envelope of the data and, thus, the economies of the scale curve.[9] Although it may be considered unrealistic that an envelope curve exists in the real world, the use of one is reasonable because in addition to the limitations created by a lack of sufficient, suitable data, a functional relationship derived from a limited number of observations is both available and manageable whereas an infinite series of points is not. In this project, the function obtained from the data, the straight line segments in Figure XIV is as follows: Where X is the volume of the yard in terms of the number of hogs handled per year and H_i is the operating cost per hog expressed in terms of 1/100 cents:

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[6] H. B. Howell, "Economies of Scale in Livestock Production", Journal of Farm Economics, Dec. 1961, pp. 1229-1236.

[7] J. D. Faris, "Economies of Scale in Crop Production", Journal of Farm Economics, Dec. 1961, pp. 1219-1228

[8] Information provided by OHPMB to Select Committee of the Legislative Assembly of Manitoba to Enquire into all Phases of the Livestock Marketing System in Manitoba, Winnipeg, 1963.

[9] R. G. Bressler, "Research Determination of Economies of Scale" Journal of Farm Economics, Aug. 1945, pp. 526-539.

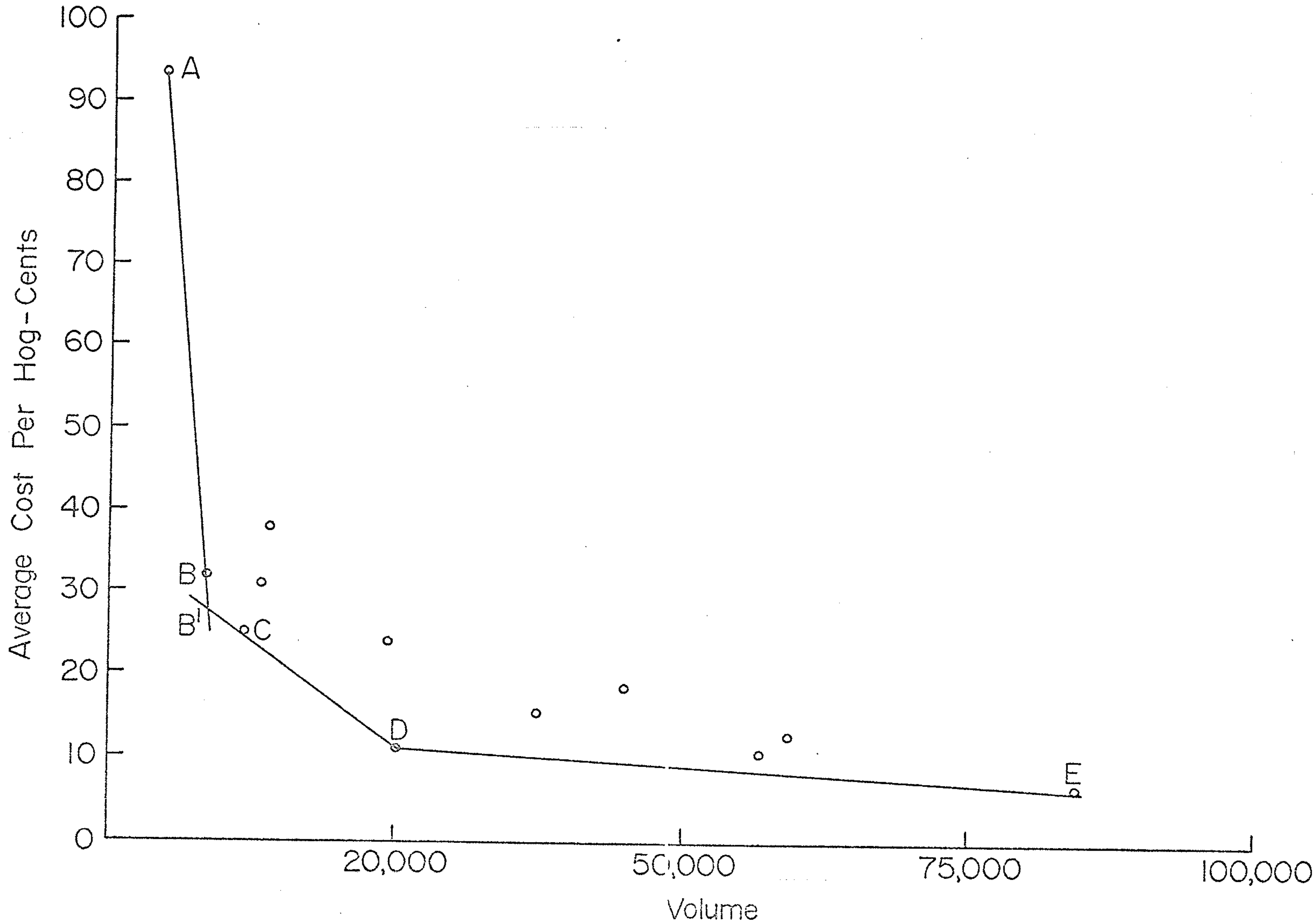

Figure XIII
Assembly Yard Operating Costs

$H_i = 10938 - 0.817X ; X \leq 10626$

$H_i = 3361 - 0.104X ; 10627 \leq X \leq 23422$

$H_i = 1089 - 0.007X ; 23423 \leq X \leq 84000$

$H_i = 500 ; X > 84000$

These values are included in the H_i values in submatrix A, Figure IX-B.

The plotted data shows a close relationship when depicted as average annual volume per day. This was used because annual volume as such showed large divergence between the operating costs of similar sized yards where the yards in question operated different numbers of days per week. The data themselves suggested the average annual volume per day as there were no variable costs associated with the non-operating days and comparisons between yards operating one or two days per week and those operating four or five days per week were of little value.

The costs derived, the transfer costs and assembly costs were applied to the hog marketing situation in the prairie provinces. The application of the model is described in the following chapter.

CHAPTER V

APPLICATION OF THE MODEL

With the determination of the cost function completed, the model was then applied to the hog marketing setting in Western Canada.

The matrix was set up as in Figure IX with submatrix A being 9 (plant centres) by 140 (possible assembly yards, one being void); submatrix C being 140 (assembly yards) by 140 (assembly yards); and submatrix D being 140 (assembly yards) by 149 (production regions). Total matrix size was 149 rows by 289 columns (one row and one column were void.)

The nine plant centres were obtained by discovering where hogs were slaughtered, excluding small, local abattoirs.

The 139 possible assembly yards were selected by limiting the size of population centres that would be considered to those centres with over 1,000 inhabitants. This arbitrary figure reflects a viable sized prairie town especially when considering the desirability of having many services close together in rural communities as indicated in other studies.[1,2,3] In addition, the pattern of possible assembly yards was such that the maximum distance that any producer would be from a yard was approximately sixty miles. Although this was the upper limit, most producers were considerably closer.

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[1] P. Woroby, "Service Centres", (unpublished M.Sc. Thesis, University of Manitoba, Winnipeg, 1957).

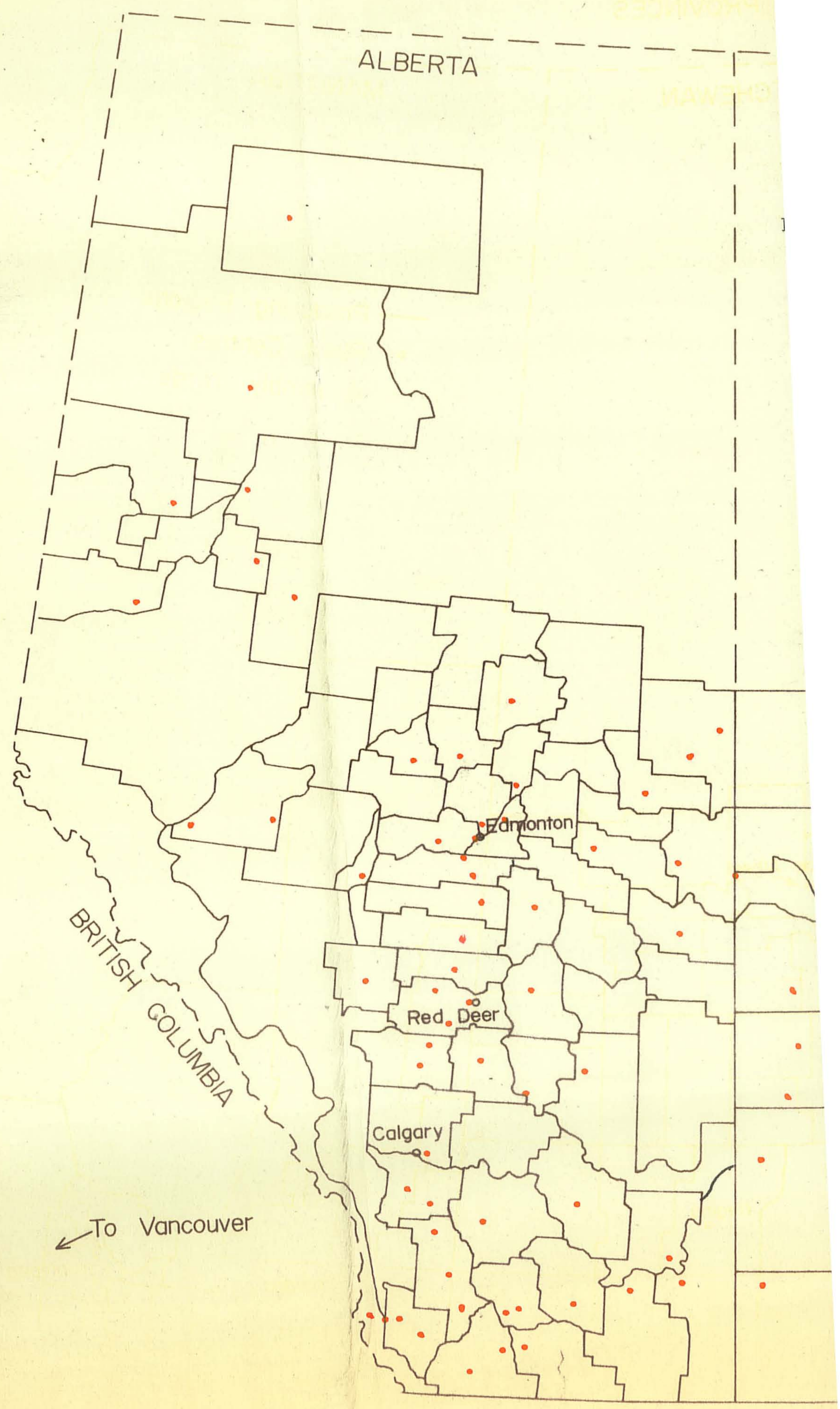
[2] E. B. Riordan, "Spatial Competition and Division of Grain Receipts Between Country Elevators", (unpublished M.Sc. Thesis, University of Manitoba, Winnipeg, 1964).

[3] Manitoba to 1980, report of Committee on Targets for Economic Development, Winnipeg, 1969.

The 149 producing regions were more difficult to arrive at as the three provinces have differing systems of division. Census divisions and subdivisions in Saskatchewan are more uniform in size and shape than the analogous unit in either Manitoba or Alberta. Thus, the aggregation of certain units or the splitting up of others was done in an attempt to create a more uniform division of both area and production. The supply areas, possible assembly yards and plant centres are shown in Figure XIV. Although the particular divisions and aggregations performed did not result in a homogeneous production plane, some improvement was made and the resulting units were more adaptable to the computer format.

The supplies and the demand for hogs were assumed to be equal, viz., all production was processed. Further, it was assumed that the relevant plants used were the only plants to use that production. The volumes handled by the particular plants and, therefore, plant centres were obtained from industry sources and the proportion of total production slaughtered in each city determined.

The supplies in each region were obtained by assuming that marketings from the regions would be in the same proportion as hog population in these regions. The latest hog population figures at the time the matrix was developed were from the 1961 Census and these were therefore used. The total supply derived from these data was then allocated as demands at the plant centres in the same proportions as obtained earlier. Therefore, total supply equalled total demand. While this resulted in a greater supply than existed in 1961, the proportion in the various regions was more important in determining supply areas. There does remain the relevant question of whether the pattern of production in 1961 has remained the same and will remain the same in the future. If not, then more recent data should be used.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URE XIV

S, PLANT CENTRES AND
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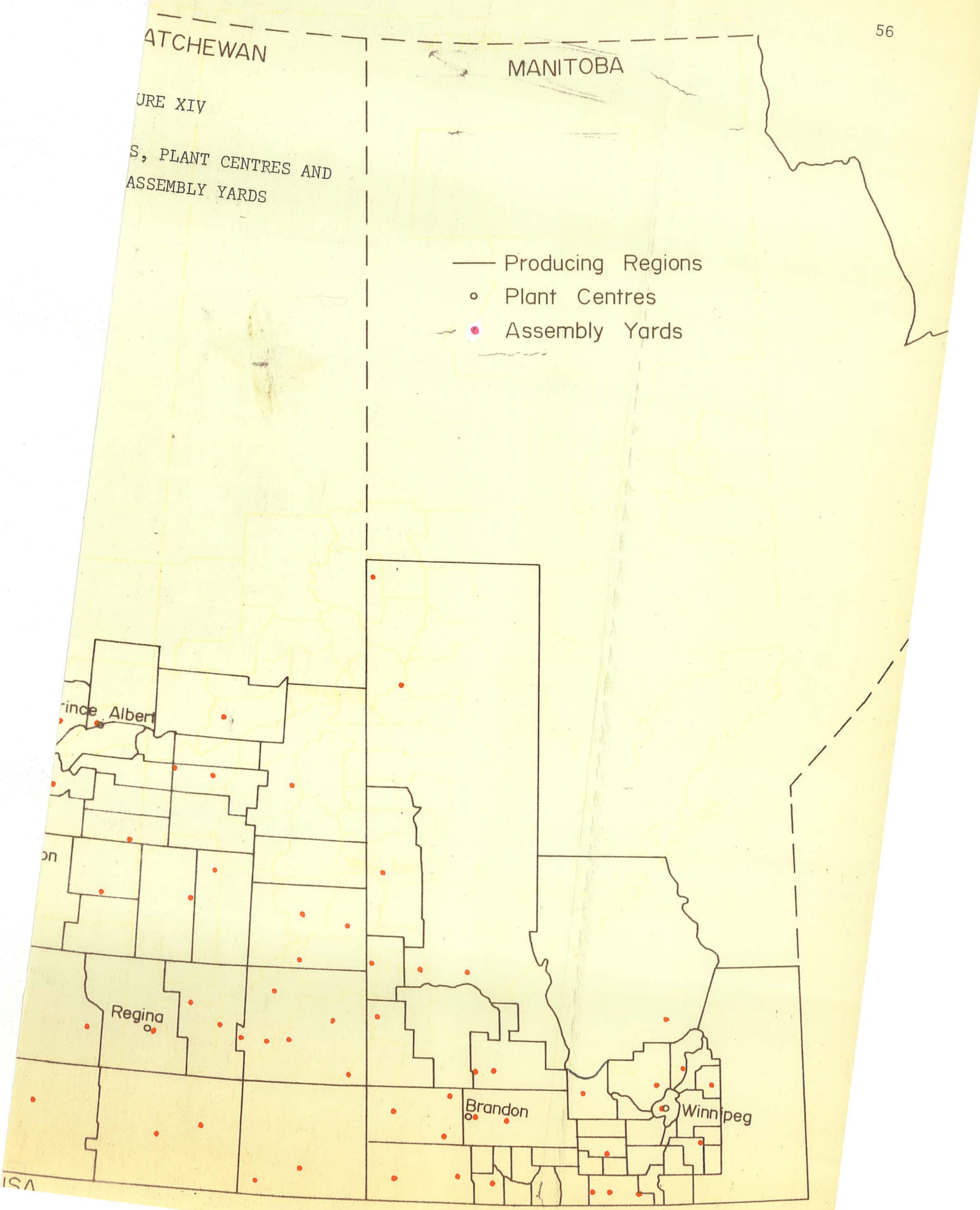


The model was then solved in several stages. Originally, it was solved using a matrix containing the distances between the points as determined by main highway routes. Next, the transfer cost functions were applied to those distances and a new matrix was generated with the costs of transfer as entries. This matrix was subsequently solved. Using this solution, volumes for the various assembly yards were obtained and the cost functions for operating costs of the assembly yards were applied to the volumes and a cost per hog, H_i, to be added to the cost of transfer for each cell in submatrix A was obtained. Several iterations were performed after each of which the operating costs of the assembly yards were altered. Finally, an iteration was performed which had no changes from the preceding one. This was the optimum, thus lowest cost solution, and an analysis of this result could be performed.

This procedure was repeated for each of the provinces separately as well as the three provinces together. These results will be presented in the next section and a comparison made of the separate and aggregate solutions.

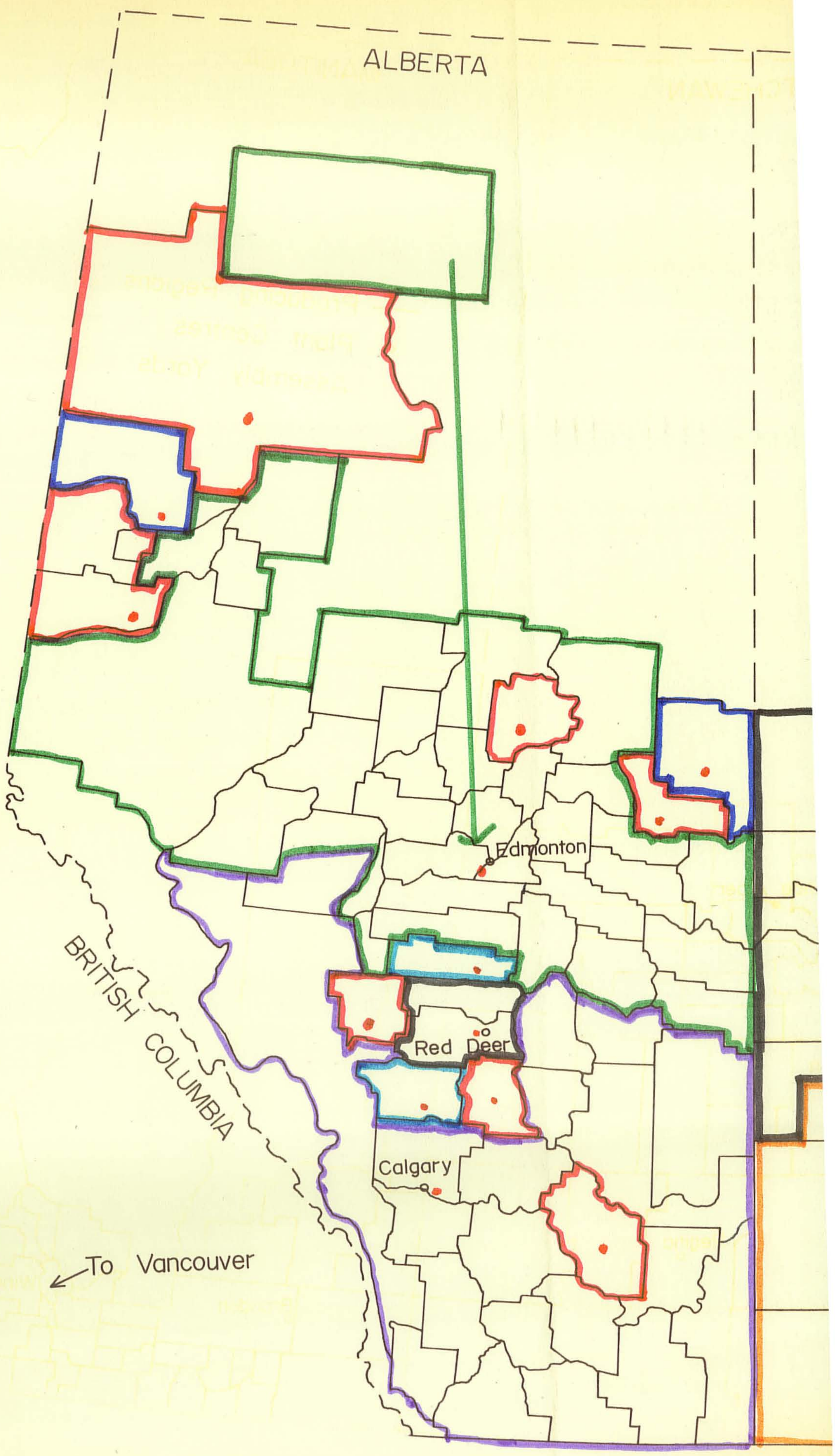
THE SOLUTIONS

The solutions of the model in selection of possible assembly yards were similar both when the model was solved for the three provinces together and when each of the provinces was solved separately. Twenty-six yards were selected in the three province model, three in Manitoba, nine in Saskatchewan, and fourteen in Alberta.

When the provinces were solved separately, twenty-six yards were again selected, although not all were the same as in the three province model. Manitoba solution Brandon receives hogs from Manitoba CD 4, CD 8, CD 14, and part CD 5 and R. M. of Riverside. All were direct from producing region to the yard and then to the plant.

The only other major differences between the two solutions also involved Manitoba and Eastern Saskatchewan. In the three province solution Dauphin was selected as an assembly point for Manitoba CD 16, CD 17, and CD 18 while in the separate province solution, this area shipped to Winnipeg yard. The other changes in the separate province solution, especially the shipments from CD 14 and CD 15 to Brandon, may have countered the seventeen cents per hog advantage the Dauphin yard displayed over direct delivery from the region to Winnipeg.

The result in Eastern Saskatchewan of restricting assembly to the province was, in addition to the back-hauling mentioned, the selection of one additional assembly point with slight variation in boundaries. In the separate province solution, Yorkton and Wadena replaced Canora which was selected in the larger model. The difference in supply areas for these yards can best be seen by comparing Figure XV with XVI and Figure XVII with XVIII. The slight differences in the supply areas for Saskatoon and Regina plant centres are of minor concern as the model indicated the possibility of alternate activities which would not affect the cost of the solution. The slight difference in distribution from the assembly yards in Alberta to Vancouver and Calgary reflects a similar situation. The plant centres had very similar supply areas in both solutions. The only major difference was the area supplying the Brandon plant. The area serving Brandon and Winnipeg combined, however, displayed only minor changes similar to the slight variations for the other plants. Figures XVII and XVIII show the respective supply areas for the plants in the two solutions.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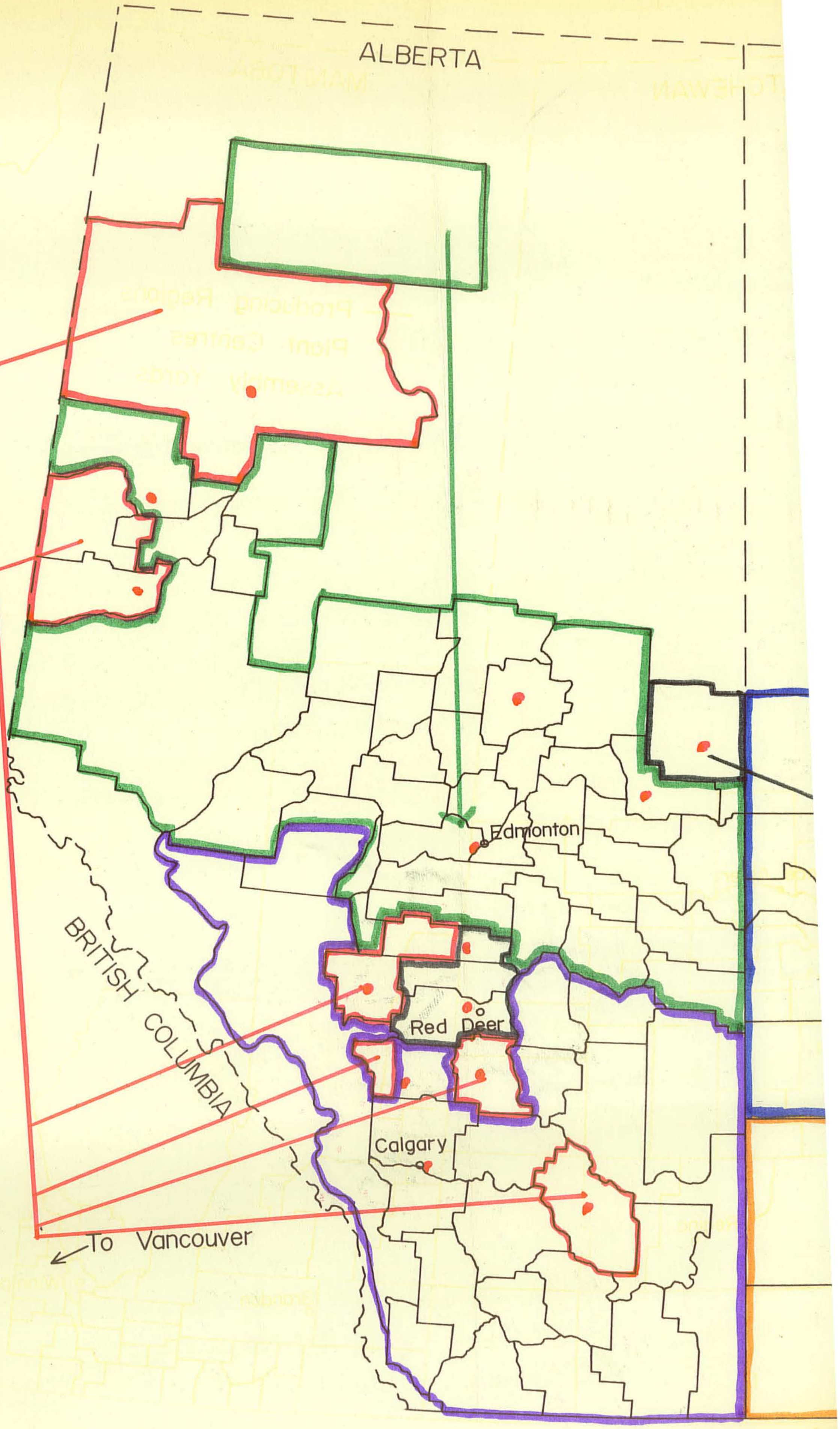

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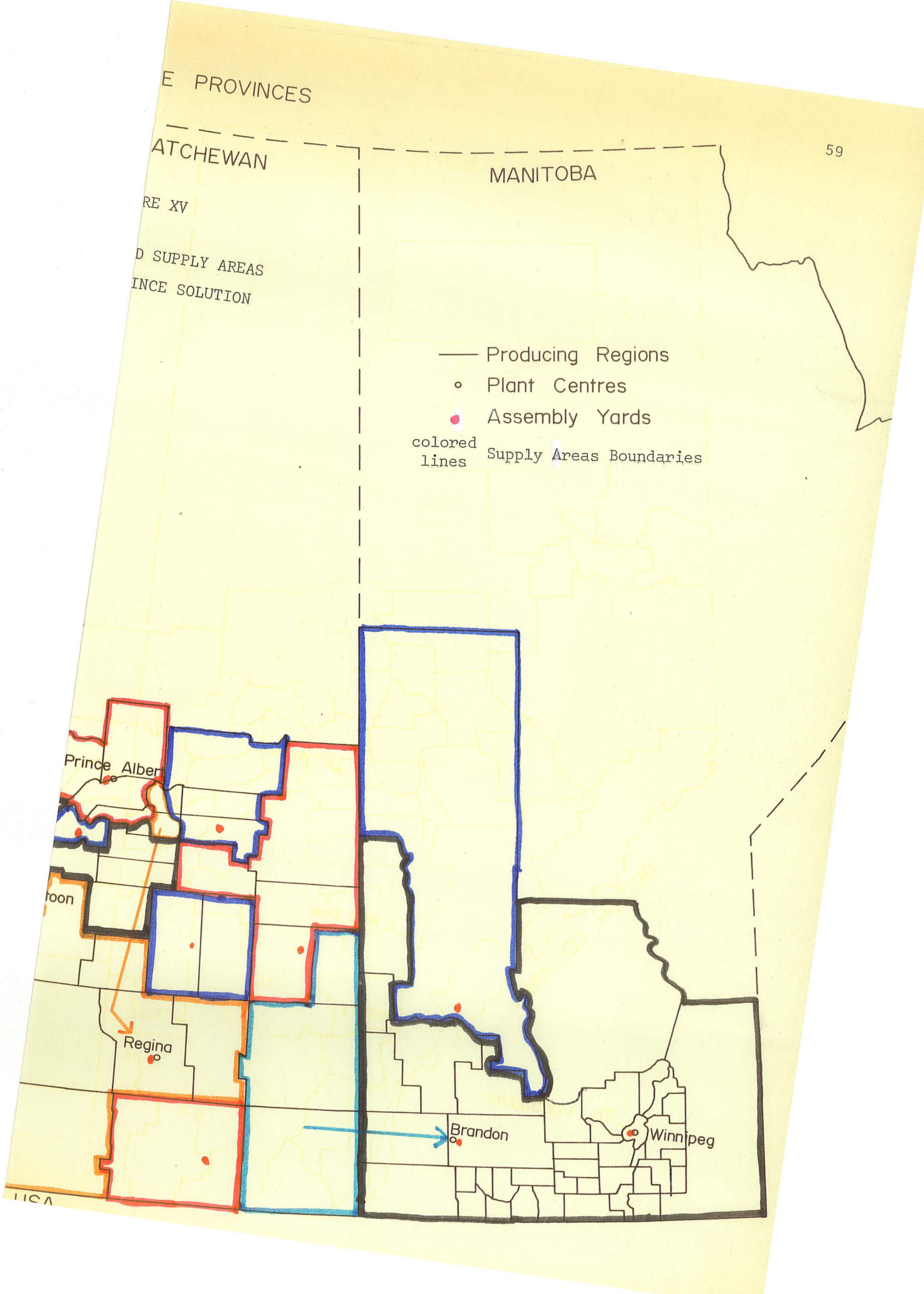
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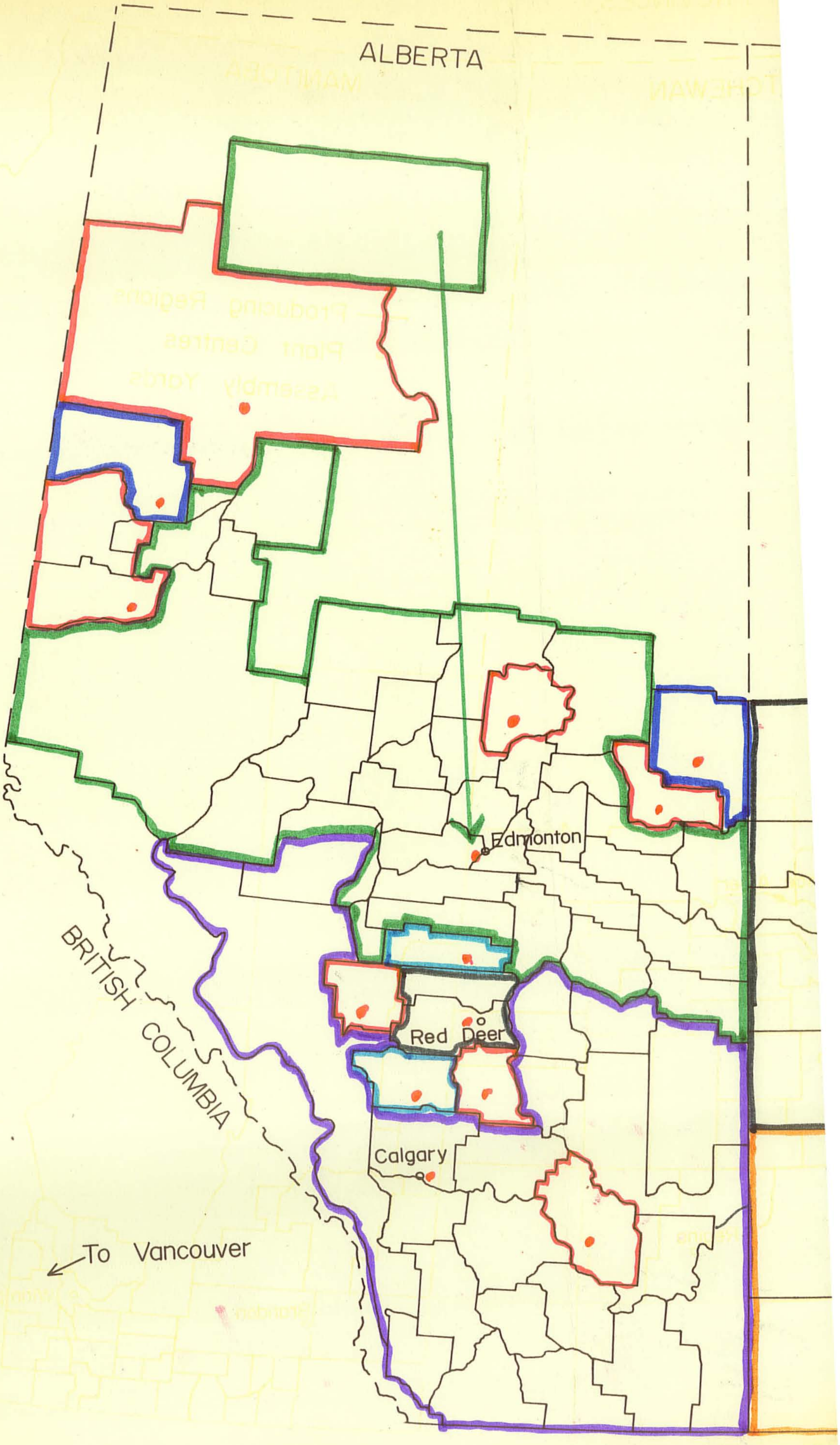
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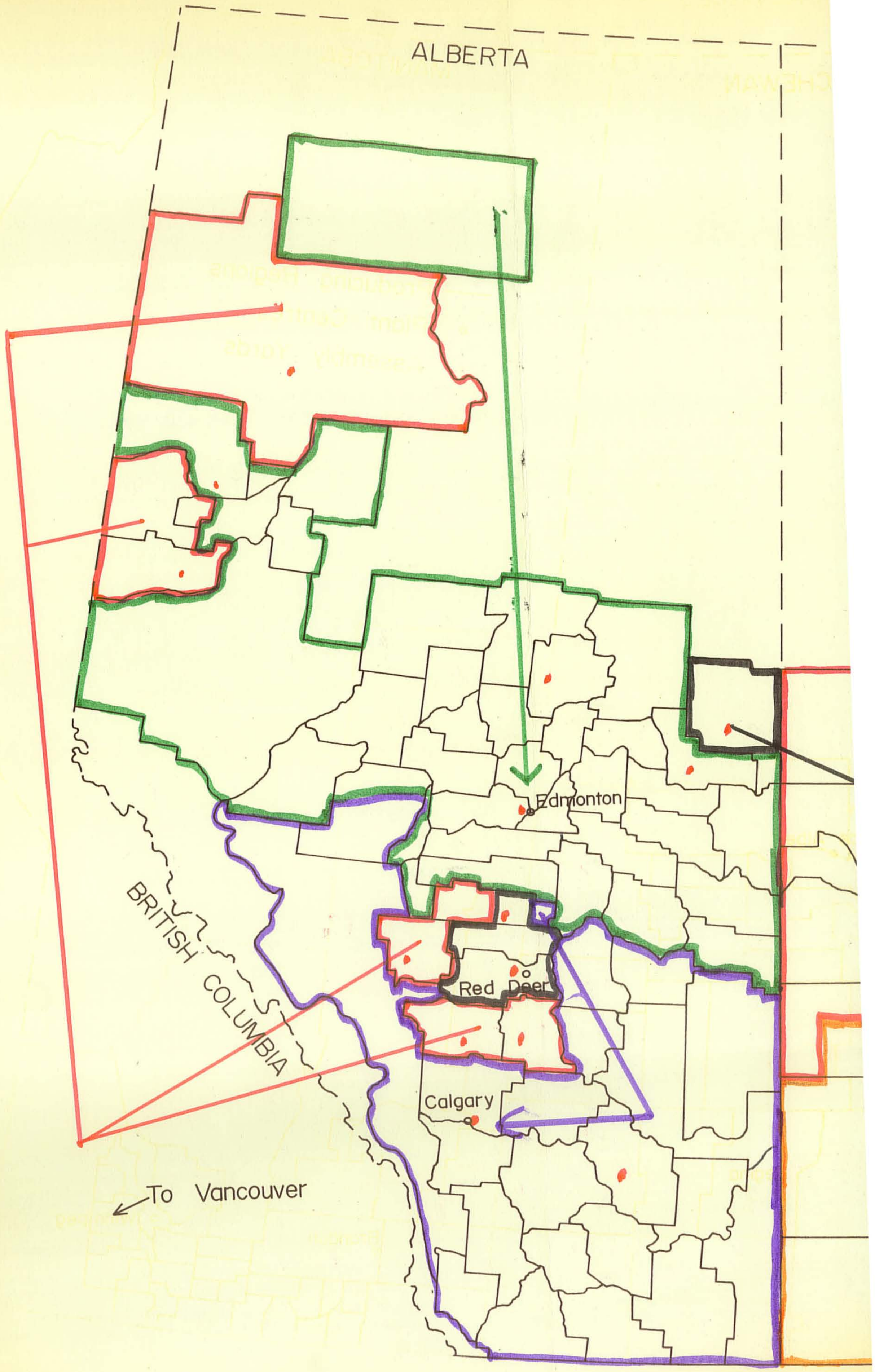
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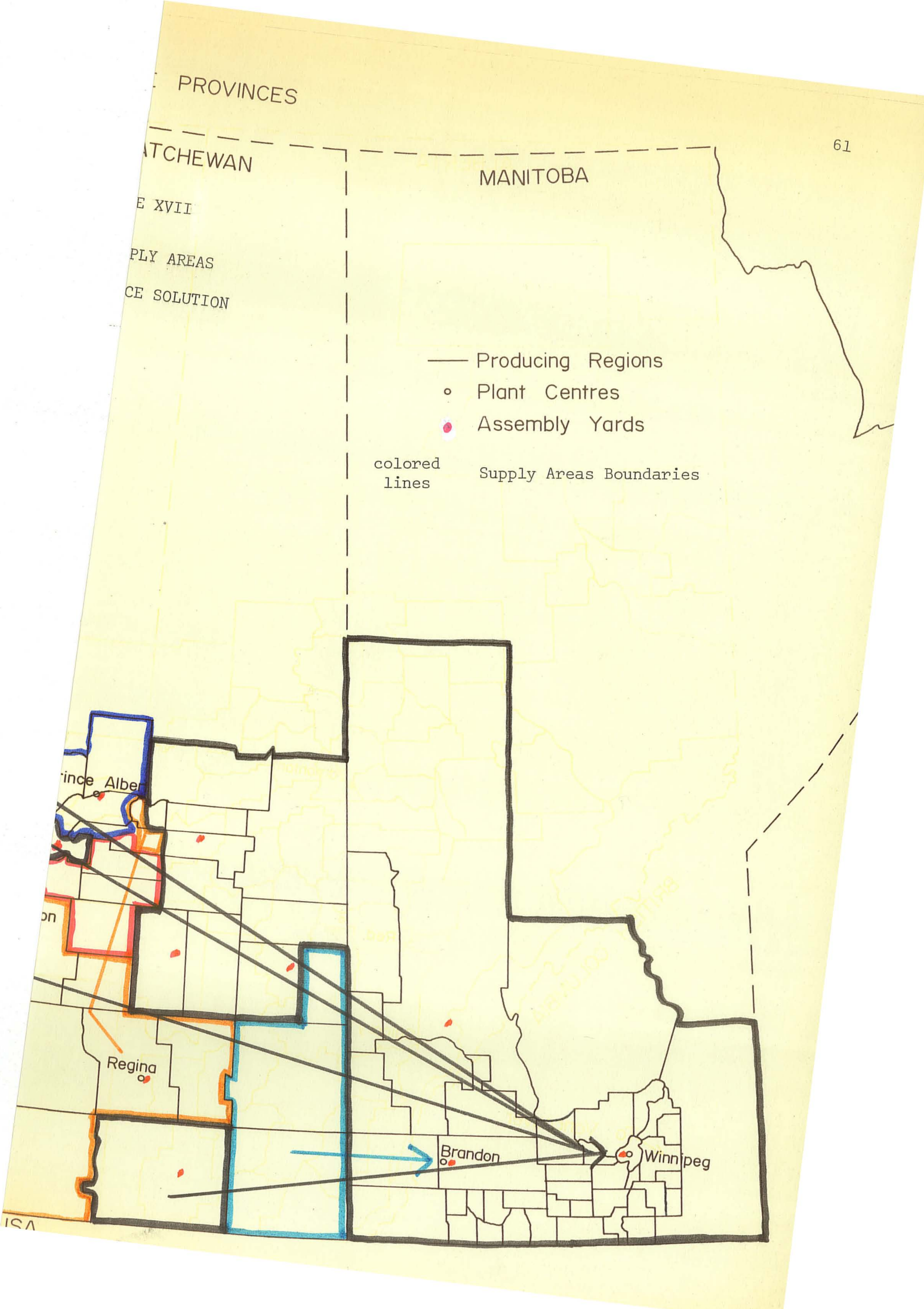
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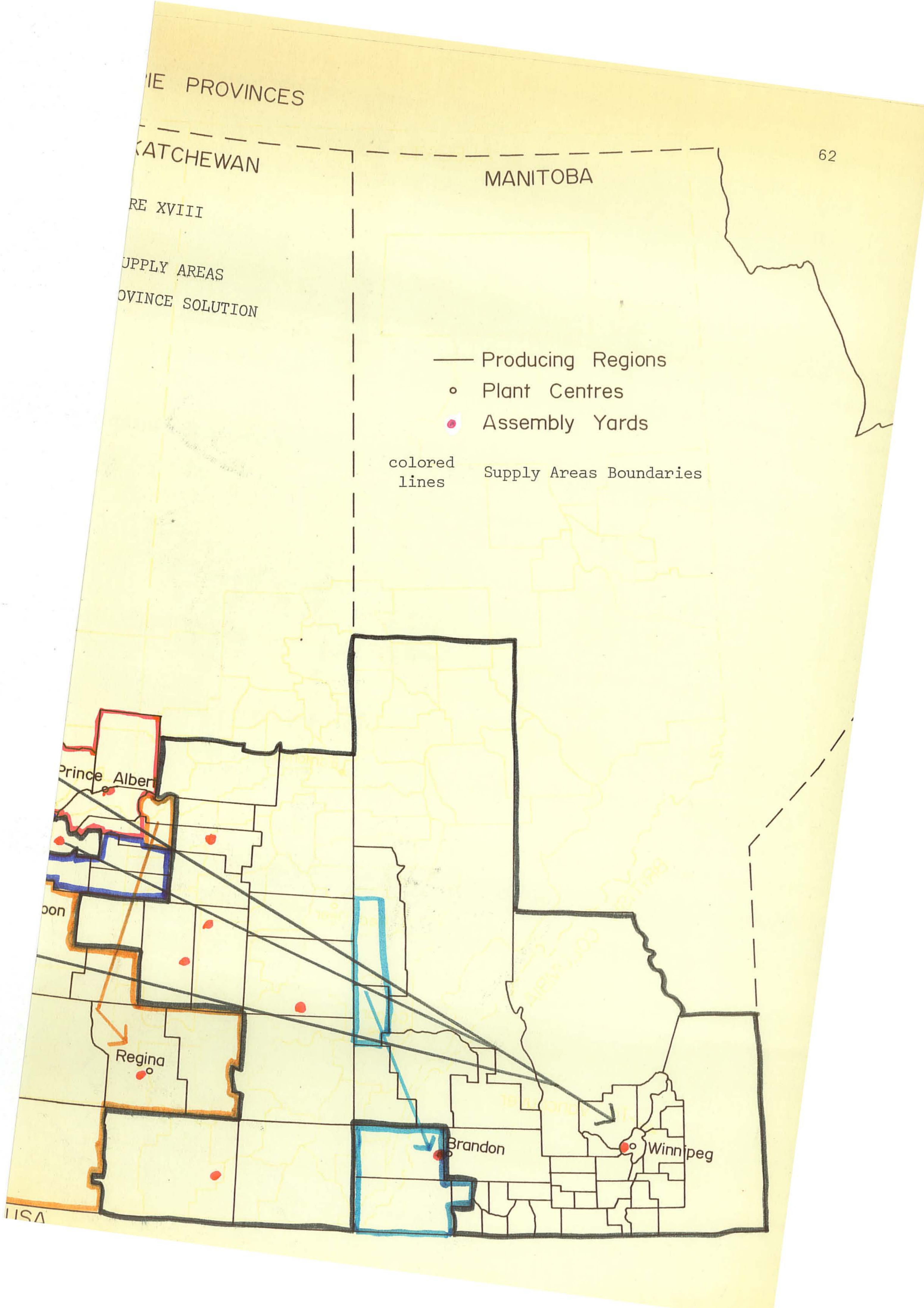
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There are several items in the solutions which appear out of place. These are the remote assembly yards selected to ship to Winnipeg. These include Bonnyville, Alberta, and Rosetown and Rosthern, Saskatchewan. Bonnyville supplies Winnipeg with the surplus of Alberta production which moves east rather than west to Vancouver. In Saskatchewan, Rosetown and Rosthern yards represent areas where the cost of assembly plus the transfer cost to Winnipeg is likely less than that which would accrue if areas further east were to ship to Winnipeg and these areas ship to Saskatoon, Regina or Prince Albert. These apparent inconsistencies may be due to limitations caused by the data used. These limitations will be discussed in a later section.

COSTS

The costs derived from the solutions of the model indicate lower cost for an integrated unit than for the separate province model. Total cost for the three province solution was $3,810,093.20 or $1.50 per hog. The three provinces separately yield a combined cost of $3,894,008.60 or $1.53 per hog. These costs reflect transfer costs from producing regions to assembly yards to final plants plus the cost of operating the assembly yards.

Assembly yard operating costs represent only a small proportion of total costs while transfer costs are responsible for the bulk of the costs. Assembly yard costs were only $143,373.49 or $.05 per hog for the three province solution. The solution by separate provinces yielded combined assembly yard costs of $154,186.88 or $.06 per hog.

These costs highlight the savings which accure to the overall marketing system from the assembly function as well as the impossibility of considering the various marketing components separately. The total cost of the marketing system when the provinces are separated increases by only 2.1% while assembly yard operating costs increase by 7.6%. The much larger transfer cost component had increased by only 1.9%.

The most note worthy aspect of this increase is that it results almost exclusively from the changes in eastern Saskatchewan. This fact must be borne in mind when considering any similar system for Saskatchewan.

The results, both flow patterns and costs, are shown in more detail in the appendix. These results are reflective of the limitations created by the data used and the assumptions within the model. These limitations have been indicated previously, but they will be reviewed in the next chapter.

CHAPTER VI

SUMMARY

This study was initiated in 1966 at a time when significant changes were occurring in the Canadian hog marketing system. The evolution in Ontario of a compulsory teletype selling system with a network of assembly yards had led to interest in similar systems in the prairie provinces. Manitoba had only recently initiated a voluntary teletype system with only two assembly yards, avoiding the strongly contentious issue of compulsory direction. Saskatchewan and Alberta were studying both the Ontario and Manitoba systems as well as others, including an interprovincially integrated system. In addition several research projects were being initiated to study the effects of these systems.

This study was undertaken in order to determine the optimal location and size of assembly yards throughout the prairie provinces under a marketing system with a central selling and buying mechanism. This was considered important in order to reduce the possibility of the establishment of assembly yards at locations which would be inefficient. The urgency of this need for an economic determination of these locations was highlighted by the recent study of the Ontario system by Wiggan[1] which had demonstrated that other considerations had led to inefficiencies. The most notable aspect of that study was the importance of local producer pressure in determining the location of many of the smaller and less efficient yards. It was felt that in

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[1] Michael J. Wiggan, "A Spatial Equilibrium Model of Swine Marketed Under the Ontario Hog Producers Marketing Scheme" (unpublished M.Sc. thesis, University of Guelph, Guelph 1963).

light of the serious consideration being given to the establishment of similar marketing systems in the prairie provinces, the prior determination of optimal locations for assembly yards would partially alleviate the possibility of an inefficient network of assembly yards being developed if similar systems were initiated.

The approach taken in this project was to study the evolution of the marketing system in Ontario--identifying the forces involved and comparing this process with the literature relating to marketing and marketing systems. The review of the literature on marketing revealed a wide variety of definitions of marketing, a market, and marketing systems, as well as more diverse views of what each should be. The approach in this study was to identify those aspects of conventional literature which were amenable to the marketing of hogs in the prairie provinces.

From this review a framework evolved which assumed "The most important function of a livestock market is to bring the seller and buyer of livestock together and satisfy the needs of each more efficiently than either can do separately."[2] The framework further identified as important factors, the quality and supply of livestock and the competitiveness and efficiency of the marketing system.

The framework was then used to evaluate how a teletype marketing system would perform in relation to the identified important factors. This exercise demonstrated that the teletype system could best meet the criteria relating to supply, competitiveness and efficiency. Quality was considered independent of the marketing system used as the railgrading of hog carcasses was considered as given. The question of the competitiveness of the teletype

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[2]Miller and Henning, loc. cit.

system has been the subject of other studies[3,4] which have demonstrated that the system has increased competition from that existing under the previous systems, in effect in Ontario and Manitoba.

The theoretical models relating to the locational aspects of economic activity were then reviewed. This section considered the early theories, particularly the Loschian type analysis[5,6], the transportation and transhipment models which are adaptable to computer solution and analysed the relationships between these different techniques of locational analysis. From these models the model to be used in this study was then developed. This model was developed to determine the optimum number, size, and location of assembly yards for hogs in the prairie provinces.

The theoretical nature of transfer cost functions was studied prior to the derivation of the empirical cost functions derived for this study. The transportation cost functions were derived from data relating to different types of trucks. The distinction was made between trucks which would be delivering hogs from the farms to assembly yards and those which would be shipping truck load lots from the assembly yards to the plants. The former function was split between trucks hauling less than 105 miles, which included many small farm trucks and those operating at a greater distance. These derived costs were then utilized in the solution of the model.

The costs of operating the assembly yards were obtained from the Ontario operation which provided the only data available at that time. These cost functions were also used in the model.

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[3]Lu, *loc. cit.* [4]Lowe, *loc. cit.* [5]Losch, *loc. cit.*

[6]Olson, *loc. cit.*

The model was solved using the MPS system on an IBM 360 computer. The model was originally solved using a matrix of distances between points. The transportation cost functions were then applied to this solution and subsequently solved. The assembly yard operating cost functions were then applied to the selected yards. Successive runs were solved until there were no changes from the previous solution. This last solution represented the optimal or least cost solution of the model. This model was solved both as a model representing one large region and as a set of models representing the provinces separately. The separate province solution entails the assembly of a provinces's hogs at an assembly point within the province.

The two models yielded different solutions which were then compared. The most notable similarities were the selection of the same number, 26, of assembly yards in both models; with, in most cases, the same supply areas. The outstanding differences involved the choice of assembly yards and their supply areas in Manitoba and eastern Saskatchewan. These changes included the selection of one additional assembly yard in Saskatchewan in the separate province solution which entailed the back-hauling of hogs from the eastern portions of the province for assembly and then shipment to Winnipeg. This entailed a reassignment of supply areas for those yards in eastern Saskatchewan, as Yorkton and Wadena replaced Canora which was selected in the larger model. In Manitoba, Dauphin was not selected in the separate province model and the region which shipped to the Dauphin yard in the larger model shipped directly to the yard at Winnipeg.

The difference in costs between the two solutions was slight. The overall cost as determined by the model increased by only 2.1% when the assembly function is separated by provinces. This is true despite the 7.6%

increase in the operating costs of the assembly yards because the much larger transportation cost component had increased by only 1.9%. This discrepancy highlights the interdependence of the various functions within the marketing system.

COMPARISON WITH PRESENT SYSTEMS

The purpose of the study had been completed at this time, viz., the determination of the optimum number, size, and location of assembly yards and their respective supply areas. A further comparison was then made between the model results, which show the supply areas for the plants and yards and thus, the flow pattern for the region's hogs, and the existing systems.

At present there is a voluntary teletype marketing system in operation in Manitoba, a compulsory teletype system in Alberta, and no formal system in Saskatchewan. The Manitoba system includes two assembly yards located at Winnipeg and Brandon which are operated by the Manitoba Hog Marketing Commission. Further descriptions of the Manitoba operation can be found in other theses.[7,8]

The Alberta system was implemented in November 1969, and involves only the teletype system for buying and selling as the existing handlers, agents, etc., were allowed to become recognized assemblers. The buying stations that did exist prior to implementation of the Alberta system could operate under the system only as assemblers. In Alberta there are 224 assemblers presently operating.[9]

In Saskatchewan there are a large number of handlers or assemblers and various means of marketing.[10] The Saskatchewan situation is similar to that

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[7]Lu, loc. cit. [8]Lowe, loc. cit.

[9]Orval Anderson, General Manager, Alberta Hog Producers Marketing Board, personal correspondence, August 1970.

[10]Brown, Heidt, Phillips, loc. cit.

described earlier in Ontario prior to the introduction of the teletype marketing system. There are direct delivery by farmers, commercial truck delivery, on-farm sales to livestock buyers, assemblers shipping carload or truckload lots, commission sales agents, and public auction sales. There are an estimated thirty-three points that presently operate assembly yards. This number includes public and local markets as well as Saskatchewan Wheat Pool facilities. With these figures in mind, the solution may be compared with the present situation.

In Manitoba the present system closely resembles that of the solution. The two existing assembly yards, Winnipeg and Brandon, are common to the two solutions. Dauphin was selected in the three province solution, but not in the separate province solution. The Manitoba Hog Marketing Commission suggests that if another yard were considered it would most likely be at Dauphin.[11] The location of existing assembly points can be seen in Figure XIX.

In Saskatchewan the present number of assembly points is much greater than that in the solution. There are, however, eight major assembly points in Saskatchewan most of which entered into the model solution. Those that were not in common with the model include yards at centres which have small plants which were not considered in the model. In addition there are fewer existing yards in the eastern portion of the province. There is presently one yard at Yorkton, but none either in the northern portion, as represented by Tisdale in the model, or in the southern portion, as represented by Weyburn in the model. The small yards selected by the model at Rosetown and Rosthern do not exist and probably would not have been selected with better data as is pointed out in a later section.

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[11] W. B. Munro, Manager Director, Manitoba Hog Marketing Commission, personal interview, May 1970.

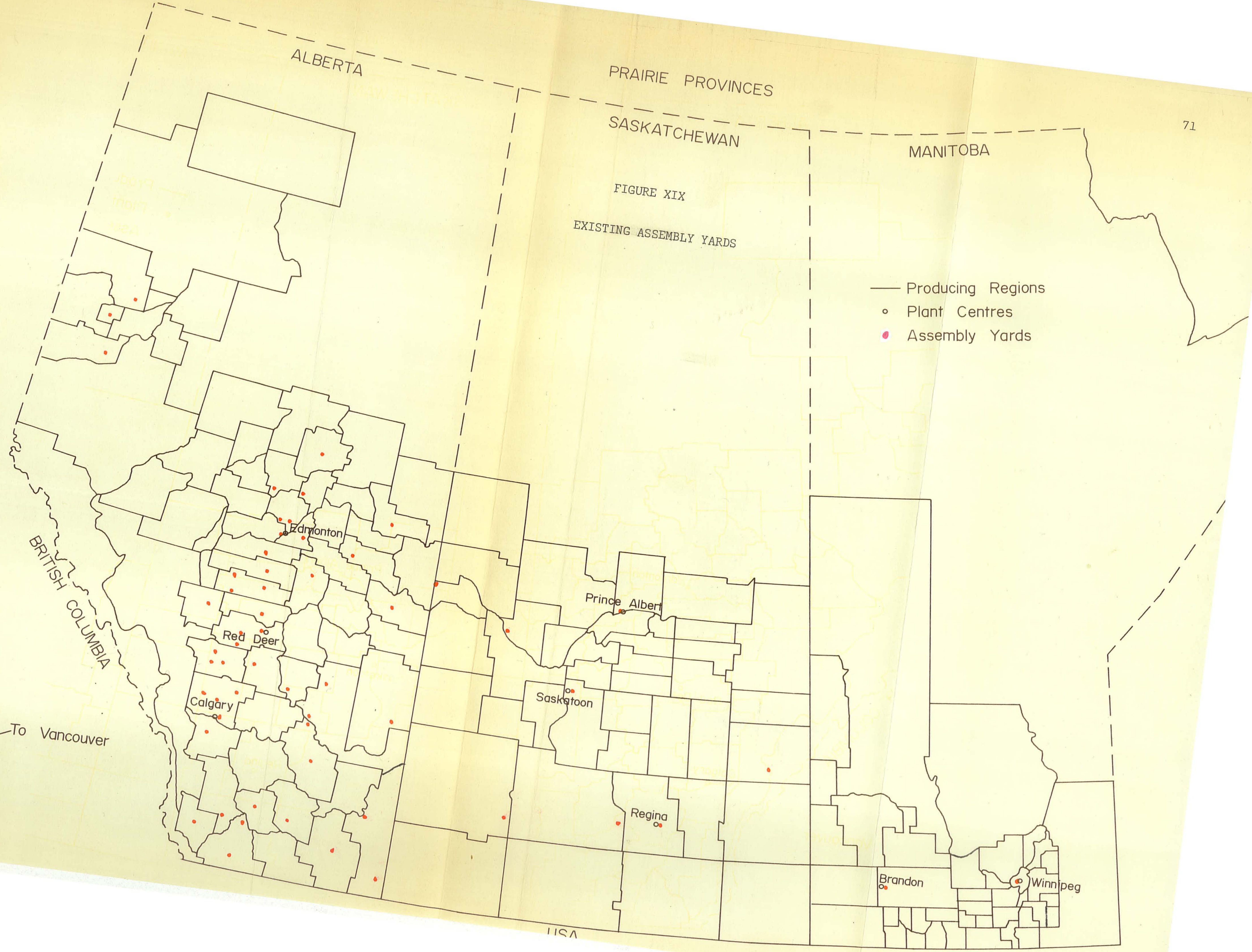

FIGURE XIX

EXISTING ASSEMBLY YARDS

The Saskatchewan situation cannot merely be compared with the model by considering yard locations because the major yards serve a price determining function as auctions. This additional function may create the demand by producers for a more localized auction or price determining facility. With a centralized auction facility encompassing all producers as in the teletype system, there may be less demand for the more localized facilities as the competitive nature of the teletype auction could satisfy this aspect of producer demands.

The Alberta situation is the most complex of the three provinces. Alberta's production moves east and west as well as within the province. The presence of such a large number of assemblers, 224, seems inefficient when compared with the model selection of fourteen. While the location and size of this large number of assemblers is not available, a comparison can be made with the location of pre-teletype livestock auction.[12] Most of these became assembly points under the teletype system now in operation. The number of these locations is fifty which while much less than the 224 assemblers, should give a description of the areas served.

The comparison of the former auction sites with the yards selected by the model indicates a much greater number in the present situation. There is at least one in each county, between Edmonton and Calgary which seems unrealistically high for the distances involved. The southern portion of the province also has a much larger number than selected by the model. While this also seems inefficient, the density appears to be less than that between Edmonton and Calgary.

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[12] W. Manning, Country Livestock Auctions and Market Performance, Agricultural Economics Technical Bulletin 1 (Edmonton: Department of Extension, University of Alberta, 1966) p. 4.

The present number and density of assemblers in Alberta results, therefore, in a less efficient marketing system than would be the case if fewer assemblers were strategically located as determined by the model. The Alberta Hog Producers Marketing Board has expressed the view that there will be a reduction in the number of assembly yards and assemblers.[13] The experience in Ontario has shown that producer pressure for more localized assembly yards tends to increase the number of yards to a greater than optimum number.[14] In Alberta, however, the adjustment should come closer to the optimum because, unlike the Ontario situation where an increase in costs from a particular assembly yard is spread over all producers, Alberta producers directly pay for the assembly function. Thus, the users of a particular assembly facility will pay for any increase in costs related to it.

The existing situation other than in Manitoba is characterized by an excess of assembly yards probably of small size. In Saskatchewan, because these yards also determine price, they cannot be judged on only their distributive efficiency. In Alberta with the newly introduced teletype selling system, the excess is clearly inefficient as shown in the comparisons with the model solutions.

LIMITATIONS OF THE RESULT AND THE NEED FOR FURTHER RESEARCH

Throughout the thesis it has been pointed out that there were limitations to be considered. The first point to be considered as a limitation was the assumption of homogeneity in the transportation system. There are vast differences in the highway network, and most likely differing operating costs for trucks throughout the region. The highway differences could not be eliminated in the data, although routes used were predominately major highways

[13]Orval Anderson, General Manager, Alberta Hog Producers Marketing Board, personal correspondence, July 1970

[14]Wiggan, loc. cit.

represented by the same point. While eliminating the zero transfer cost element, this method is still subject to the assumption of homogeneous production density within the region. This latter assumption can only be eliminated if one reduces the producing region to the individual farm as the shipping point.

The limitations related to transfer costs, both as a result of the highway network and the lack of within the region transfer costs, could be alleviated by the development of a suitable transfer component matrix. Such a matrix could provide the standard for research in the region involving locational aspects. This matrix would include the distance between all census subdivisions and the larger towns and cities, as well as between producing regions and between the towns and cities. In addition, a suitable value for within the region travel could be included. This matrix could be utilized in all further studies involving locational aspects within the region by applying the relevant functions to the distance matrix. Changes in the matrix would become necessary only when subdivision boundaries changed or when the highway network changed significantly. It would ensure the use of the same spatial relationships in future studies and facilitate the comparison of results.

Another limitation is the dated data used in the solution. The distribution of production was based on the 1961 Census and the assembly yard operating costs were derived from 1963 Ontario data. The updating of this data would increase the relevance of the solution.

The results of this study, while subject to the limitations mentioned above, would be of practical use in the design of a marketing system for the prairie provinces. The implementation of new marketing systems or changes in the present ones should be made in light of the results of this study along with other factors. The determination of the location and size of assembly yards and their supply areas reflect an efficient distribution for the region.

The results of this study are most relevant to hog producers and policy formulation in Western Canada. The model can be used to identify differences between alternative proposed systems or between proposed systems and the existing system. It can also be used to determine the effects of changes in these systems. To make the model more useful it should be re-run with the most recent data. Improved data are required particularly on assembly yard operating costs and location and volume of all significant slaughter points. Particular attention should be paid to developing a distance or transportation matrix for the region utilizing the smallest practical units, probably census subdivisions or townships. This would provide greater accuracy for not only this model but for all regional research in the prairies. The model could be further refined to take account of the differences in price levels between plant centres. This could entail the use of the spatial equilibrium model which allows for more variables or activities.

In any case the model provides a tool for the evaluation of the Western Canadian hog market and the effects of various policies. It provides the means ". . .To bring about a more efficient system, no matter who derives the benefit from such efficiency."[15]

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[15] Brunk and Darrah, loc. cit.

APPENDIX

The appendix contains details concerning the model. It contains six tables.

Table A-I -- Demands at Plant Centres, lists the location of the plant centres and the demand at each location. These demands are based on the total supply being utilized in the same proportion at each plant centre as that obtained from industry sources in 1967 as described on Page 55.

Table A-II -- Possible Assembly Yards in the Model, provides a list by province of the locations at which assembly yards could be chosen in the model. There were a total of 139 possible yards; 29 in Manitoba, 50 in Saskatchewan, and 60 in Alberta. For the criteria used to select these points, see Page 54.

Table A-III -- Destinations and Volumes of Hog Shipments from the Assembly Yards Selected, gives the flow patterns from the assembly yards selected by the model to the Plant Centres. As can be seen, an assembly yard may ship to more than one plant centre. The results are given for both the separate province solution - Volume I and the three province solution - Volume II.

Table A-IV -- Producing Regions, Total Supplies and Volumes & Destinations of Shipments, lists the 149 producing regions showing their hog population according to the 1961 census which was considered to be the market supply (see page 55). In addition, the assembly yard(s) to which each region ships and the volume of these shipments in both solutions is also shown.

Table A-V -- Operating Costs of Assembly Yards Selected, lists the assembly yards selected and shows the total and per hog cost of operating each assembly yard in the two solutions. For a derivation of the cost functions, see page 51.

Table A-VI -- Summary of Costs, provides a breakdown of total costs as well as the per hog cost of the marketing system depicted in the model. These costs are given on a provincial basis for the separate province solution as well as in total and for the entire region in the three province solution.

TABLE A-I

DEMANDS AT PLANT CENTRES

Plant Centre	Demand Number of Hogs	
Winnipeg	648,000	
Brandon	69,700	
TOTAL MANITOBA		717,700
Saskatoon	172,600	
Prince Albert	70,700	
Regina	140,500	
TOTAL SASKATCHEWAN		383,800
Edmonton	864,573	
Red Deer	133,000	
Calgary	289,500	
TOTAL ALBERTA		1,287,073
Vancouver		150,100
TOTAL DEMAND		2,538,673

TABLE A-II

POSSIBLE ASSEMBLY YARDS IN THE MODEL

Manitoba	Saskatchewan	Alberta
Winnipeg	Saskatoon	Edmonton
Brandon	Prince Albert	Red Deer
Altona	Regina	Calgary
Beausejour	Assiniboia	Athabasca
Boissevain	Battleford	Barrhead
Carberry	Biggar	Bellevue
Carman	Broadview	Black Diamond
Dauphin	Canora	Blairmore
Flin Flon	Esterhazy	Bonnyville
Gimli	Estevan	Bow Island
Grandview	Eston	Brooks
Killarney	Fort Qu' Appelle	Camrose
Melita	Gravelbourg	Cardston
Minnedosa	Grenfell	Claresholm
Morden	Gull Lake	Coaldale
Morris	Herbert	Cold Lake
Neepawa	Hudson Bay	Coleman
Portage la Prairie	Humboldt	Devon
Rivers	Indian Head	Didsbury
Roblin	Kamsack	Drayton Valley
Russell	Kerrobert	Drumheller
Selkirk	Kindersley	Edson
Souris	Leader	Fairview
Steinback	Lloydminster	Fort MacLeod
Stonewall	Maple Creek	Fort Saskatchewan
Swan River	Meadow Lake	Grande Prairie

TABLE A-II, Con't.

Manitoba	Saskatchewan	Alberta
The Pas	Melfort	Hanna
Virden	Melville	High Level
Winkler	Moose Jaw	High Prairie
	Moosomin	High River
29 TOTAL	Nipawin	Hinton
	North Battleford	Innisfail
	Outlook	Lacombe
	Oxbow	Leduc
	Radville	Lethbridge
	Rosetown	Magrath
	Rosthern	Manning
	Shaunavon	McLennan
	Shellbrook	Medicine Hat
	Swift Current	Nanton
	Tisdale	Olds
	Unity	Peace River
	Wadena	Pincher Creek
	Watrous	Ponoka
	Weyburn	Raymond
	Wilkie	Redcliff
	Wolseley	Redwater
	Wynyard	Rocky Mt. House
	Yorkton	St. Albert
		St. Paul
	49 TOTAL	Stettler
		Stony Plain

TABLE A-II, Con't

Manitoba	Saskatchewan	Alberta
		Sylvan Lake
29 TOTAL	49 TOTAL	Taber
		Three Hills
		Vegreville
		Vermilion
		Vulcan
		Wainwright
		Westlock
		Wetaskiwin
		61 TOTAL

139 GRAND TOTAL

TABLE A - III

Destinations and Volumes of Hog Shipments
From the Assembly Yards Selected

ASSEMBLY YARD	DESTINATION(S)	SEPARATE PROVINCES VOLUME I	THREE PROVINCE VOLUME II
Winnipeg	Winnipeg	361762	395041
Brandon	Brandon	69700	69700
Saskatoon	Saskatoon	172600	172600
Prince Albert	Prince Albert	70700	70700
Regina	Regina	140500	140500
Edmonton	Edmonton	769573	769573
Red Deer	Red Deer	121175	121175
Red Deer - Slack Supply	Winnipeg	286238	---
Calgary	Calgary	261901	261901
Yorkton	Winnipeg	100034	---
Weyburn	Winnipeg	47136	22993
Dauphin	Winnipeg	---	36421
Canora	Winnipeg	---	47886
Rosetown	Winnipeg	7244	7244

TABLE A - III, Con't.

ASSEMBLY YARD	DESTINATION(S)	SEPARATE PROVINCES VOLUME I	THREE PROVINCES VOLUME II
Tisdale	Winnipeg	36805	61307
Rosthern	Winnipeg	13390	13390
Wadena	Winnipeg	32831	---
Wynyard	Winnipeg	16973	31893
Ponaka	Red Deer	11825	11825
	Calgary	---	5424
	Vancouver	25717	20293
St. Paul	Edmonton	46663	46663
Brooks	Calgary	---	22175
	Vancouver	22175	---
Three Hills	Vancouver	25311	25311
Grande Prairie	Vancouver	34752	34752
Manning	Vancouver	10370	10370
Rocky Mt. House	Vancouver	18795	18795
Athabasca	Edmonton	29676	29676
Bonnyville	Edmonton	3098	3098
	Winnipeg	31825	31825
Didsbury	Vancouver	12980	40579
	Calgary	27599	---
Fairview	Edmonton	15563	15563

TABLE A-IV

PRODUCING REGIONS

TOTAL SUPPLIES AND VOLUME & DESTINATION (S) OF SHIPMENTS

PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Manitoba Census Division (CD) 20	6,002	Winnipeg	6,002	6,002
" CD 19	5,741	Winnipeg	5,741	5,741
" CD 16, 17, 18	36,421	Winnipeg	36,421	---
		Dauphin	---	36,421
" CD 15	26,503	Winnipeg	9,812	26,503
		Brandon	16,691	---
" CD 14	6,412	Winnipeg	---	6,412
		Brandon	6,412	---
" CD 13	14,186	Winnipeg	14,186	14,186
" CD 12	13,239	Winnipeg	13,239	13,239
" CD 11	14,570	Winnipeg	14,570	14,570
" CD 10	26,705	Winnipeg	26,705	26,705
" CD 9	22,609	Winnipeg	22,609	22,609
" CD 8	25,626	Winnipeg	---	25,626
		Brandon	25,626	---

TABLE A-IV, con't.

PRO	PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Manitoba	CD 7	27,678	Winnipeg	27,678	27,678
"	Cartier RM	12,093	Winnipeg	12,093	12,093
"	Grey RM	4,647	Winnipeg	4,647	4,647
"	Portage la Prairie RM	13,648	Winnipeg	13,648	13,648
"	Macdonald RM	6,626	Winnipeg	6,626	6,626
"	Brokenhead RM	5,437	Winnipeg	5,437	5,437
"	St. Andrews RM	6,551	Winnipeg	6,551	6,551
"	St. Clements RM	4,727	Winnipeg	4,727	4,727
"	Springfield	5,381	Winnipeg	5,381	5,381
"	CD 4	17,246	Winnipeg	---	17,246
			Brandon	17,246	---
"	Argyle RM	4,717	Winnipeg	4,717	4,717
"	Lorne RM	5,724	Winnipeg	5,724	5,724
"	Louise RM	10,020	Winnipeg	10,020	10,020
"	Pembina RM	13,506	Winnipeg	13,506	13,506
"	Riverside RM	3,725	Winnipeg	---	3,725
			Brandon	3,725	---
"	Roblin RM	3,595	Winnipeg	3,595	3,595

TABLE A-IV, con't

	PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Manitoba	Stratcona RM	3,557	Winnipeg	3,557	3,557
"	Turtle Mountain RM	4,414	Winnipeg	4,414	4,414
"	Dufferin RM	10,898	Winnipeg	10,898	10,898
"	Montcalm RM	3,633	Winnipeg	3,633	3,633
"	Morris RM	7,458	Winnipeg	7,458	7,458
"	Rhineland & Stanley RM	22,422	Winnipeg	22,422	22,422
"	Roland RM	2,825	Winnipeg	2,825	2,825
"	Thompson RM	4,623	Winnipeg	4,623	4,623
"	De Salabery RM	4,504	Winnipeg	4,504	4,504
"	Franklin RM	4,359	Winnipeg	4,359	4,359
"	Hanover RM	11,008	Winnipeg	11,008	11,008
"	La Broquery RM	857	Winnipeg	857	857
"	St. Anne RM	2,639	Winnipeg	2,639	2,639
"	Tache RM	4,930	Winnipeg	4,930	4,930
TOTAL MANITOBA		431,462			

TABLE IV, con't

PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Saskatchewan CS 493,494,496,974	21,839	Prince Albert	21,839	21,839
" CS 467,437,436,466,406	10,086	Saskatoon	10,086	10,086
" CS 405,434,435	8,145	Saskatoon	8,145	8,145
" CS 980,983,989	16,345	Saskatoon	16,345	16,345
" CS 501,502,529	9,149	Saskatoon	9,149	9,149
" CS 498,499,468,469	6,838	Saskatoon	6,838	6,838
" CS 470,471,472	7,927	Saskatoon	7,927	7,927
" CS 379-382,409-411, 439-442	14,087	Saskatoon	14,087	14,087
" CS 289-292,319-322, 349-352	15,981	Saskatoon	15,981	10,408
		Regina	---	5,573
" CS 347,375-378,408,438	11,082	Saskatoon	11,082	11,082
" CS 315,316,345,346,285	5,987	Saskatoon	5,987	5,987
" CS 280-288,316,318	7,244	Rosetown	7,244	7,244
" CS 395,944	5,988	Canora	---	5,988
		Yorkton	5,988	---
" CS 331-335	11,395	Canora	---	11,395
		Yorkton	11,395	---

TABLE A-IV, con't.

PRODUCING REGION		SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Saskatchewan	CS 366-368,397,398	16,492	Canora	---	16,492
			Wadena	16,492	---
"	CS 426-428	16,339	Tisdale	---	16,339
			Wadena	16,339	---
"	CS 446-458	18,774	Tisdale	18,774	18,774
"	CS 486-488	18,031	Tisdale	18,031	18,031
"	CS 490,491,959	11,476	Prince Albert	11,476	11,476
"	CS 460,461,463	15,443	Prince Albert	15,443	15,443
"	CS 459	10,952	Regina	10,952	2,789
			Tisdale	---	8,163
"	CS 429-431	25,926	Regina	1,394	3,984
			Prince Albert	21,942	21,942
			Saskatoon	2,590	---
"	CS 399-401	21,395	Saskatoon	21,395	21,395
"	CS 369,370	27,475	Saskatoon	27,475	27,475
"	CS 372-374	8,375	Saskatoon	8,375	8,375
"	CS 402-404	13,390	Rosthern	13,390	13,390

TABLE A-IV, con't.

PRODUCING REGION	SUPPLY	DESTINATION(S) - YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Saskatchewan CS 343,344,313,314, 282-284,253,254	16,589	Regina	16,589	16,589
" CS 340-342,310-312	15,301	Saskatoon	7,138	15,301
		Yorkton	8,163	---
" CS 250-252.280,281	8,040	Regina	8,040	8,040
" CS 248,278,279,308,309,338,339	16,973	Wynyard	16,973	16,973
" CS 246,247,276,277,307,336,337	14,920	Wynyard	---	14,920
		Yorkton	14,920	---
" CD 9	26,021	Yorkton	26,021	---
		Brandon	---	12,010
		Canora	---	14,011
" CD 8	19,945	Regina	19,945	19,945
" CD 7	20,539	Regina	20,539	20,539
" CS 126,127,156,157,186,187, 216-218	12,421	Regina	12,421	12,421
" CS 219-221,189,190,158-160, 128-130	13,086	Regina	13,086	13,086
" CD 5	33,547	Brandon	---	33,547
		Yorkton	33,547	---

TABLE A-IV, con't.

PRODUCING REGION	SUPPLY	DESTINATION(S) - YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Saskatchewan CD 4	15,640	Regina	15,640	15,640
" CD 3	21,894	Regina	21,894	21,894
" CD 2	22,993	Weyburn	22,993	22,993
" CD 1	24,143	Brandon	---	24,143
		Weyburn	24,143	---
TOTAL SASKATCHEWAN	638,213			
Alberta Improvement District (ID)				
" ID 124	2,568	Edmonton	2,568	2,568
" ID 125,129	7,627	Edmonton	7,627	7,627
" ID 126,110,111,574	5,643	Edmonton	5,643	5,643
" ID 130	13,588	Edmonton	13,588	13,588
" ID 131	5,163	Edmonton	5,163	5,163
" ID 132	6,741	Edmonton	6,741	6,741

TABLE A-IV, con't.

PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Alberta ID 133	2,710	Grande Prairie	2,710	2,710
" ID 134	5,203	Grande Prairie	5,203	5,203
" ID 135	6,215	Edmonton	6,215	6,215
" ID 136,139	15,563	Fairview	15,563	15,563
" ID 138,145,146	10,370	Manning	10,370	10,370
" ID 147	6,031	Edmonton	6,031	6,031
" Grande Prairie Co. #1	26,839	Grande Prairie	26,839	26,839
" ID 78	6,716	Edmonton Calgary	1,336 5,380	1,336 5,380
" ID 95	1,585	Edmonton	1,585	1,585
" ID 109	2,977	Edmonton	2,977	2,977
" ID 92 Westlock	44,736	Edmonton	44,736	44,736
" ID 93 Lac Ste. Anne	30,802	Edmonton	30,802	30,802
" ID 108	2,426	Edmonton	2,426	2,426
" ID 107,122	3,099	Edmonton	3,099	3,099
" Thorchild Co. #7	31,362	Edmonton	31,362	31,362

TABLE A-IV, con't.

PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Alberta Barrhead Co. #11	41,441	Edmonton	41,441	41,441
" Athabasca Co. #12	29,676	Athabasca	29,676	29,676
" ID 86 St. Paul	46,663	St. Paul	46,663	46,663
" ID 85,87,101	34,923	Bonnyville	34,923	34,923
" ID 102	12,538	Edmonton	12,538	12,538
" Smoky Lake Co. #13	34,265	Edmonton	34,265	34,265
" ID 75 Leduc	52,888	Edmonton	52,888	52,888
" ID 77	3,053	Edmonton	3,053	3,053
" ID 83 Strathcona	24,801	Edmonton	24,801	24,801
" ID 84 Stony Plain	37,489	Edmonton	37,489	37,489
" Wetashiwin Co. #10	49,987	Edmonton	49,987	49,987
" Sturgeon Co. #15	49,565	Edmonton	49,565	49,565
" ID 63 Camrose	57,859	Edmonton	57,859	57,859
" ID 71 Vermilion River	35,657	Edmonton	35,657	35,657
" ID 72 Minburn	36,776	Edmonton	36,776	36,776

TABLE A-IV, con't.

PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Alberta ID 81 Eagle	42,440	Edmonton	42,440	42,440
" ID 82 Lamont	47,921	Edmonton	47,921	47,921
" Beaver Co. #9	27,632	Edmonton	27,632	27,632
" ID 55 Red Deer	66,776	Red Deer	66,776	66,776
" Ponoka Co. #3	37,542	Ponoka	37,542	37,542
" ID 65	18,795	Rocky Mt. House	18,795	18,795
" Lacombe Co. #14	54,399	Red Deer	54,339	54,339
" ID 52 Provost	5,498	Edmonton	5,498	5,498
" ID 53	7,672	Calgary	7,672	7,672
" ID 61 Wainwright	14,348	Edmonton	14,348	14,348
" ID 62 Flagstaff	23,516	Edmonton	23,516	23,516
" Stettler Co. #6	19,549	Calgary	19,549	19,549
" ID 31 Foothills	18,810	Calgary	18,810	18,810
" ID 44 Rocky View	33,347	Calgary	33,347	33,347
" Mountain View Co. #17	40,579	Didsbury	40,579	40,579

TABLE A IV. con't

PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Alberta ID, 42,47	8,765	Calgary	8,765	8,765
" ID 48 Kneehill	25,311	Three Hills	25,311	25,311
" Vulcan Co. #2	14,684	Calgary	14,684	14,684
" Wheatland Co. #16	28,461	Calgary	28,461	28,461
" ID 34, Special Area #2	6,543	Calgary	6,543	6,543
" Special Area #3	4,485	Calgary	4,485	4,485
" ID 6 Cardston	14,881	Calgary	14,881	14,881
" ID 9 Pincher Creek	6,274	Calgary	6,274	6,274
" ID 26 Willow Creek	13,592	Calgary	13,592	13,592
" ID 14 Taber	18,880	Calgary	18,880	18,880
" ID 25 Lethbridge	29,140	Calgary	29,140	29,140
" Newell Co, #4	22,175	Brooks	22,175	22,175
" Warner Co. #5	15,885	Calgary	15,885	15,885

TABLE A-IV, con't.

PRODUCING REGION	SUPPLY	DESTINATION(S)-YARD(S)	SEPARATE PROVINCE VOLUME I	THREE PROVINCE VOLUME II
Alberta ID 11	5,789	Calgary	5,789	5,789
" ID 22	759	Calgary	759	759
" Forty Mile Co. # 8	9,005	Calgary	9,005	9,005
TOTAL ALBERTA	1,468,998			
TOTAL THREE PROVINCES	2,538,673			

TABLE A-V

OPERATING COSTS OF ASSEMBLY YARDS SELECTED

Assembly Yard	Separate Provinces-Volume I Yard Operating Costs		Three Province-Volume II Yard Operating Costs	
	Per Hog Dollars/10,000	Total Dollars	Per Hog Dollars/10,000	Total Dollars
Winnipeg	500	18,088.10	500	19,752.05
Brandon	601	4,188.97	601	4,188.97
Saskatoon	500	8,630.00	500	8,630.00
Prince Albert	594	4,199.58	594	4,199.58
Regina	500	7,025.00	500	7,025.00
Edmonton	500	38,478.65	500	38,478.65
Red Deer	500	6,058.75	500	6,058.75
Calgary	500	13,095.05	500	13,095.05
Yorkton	500	5,001.70	---	---
Weyburn	759	3,577.62	969	2,228.02
Dauphin	---	---	834	3,037.51

TABLE A-V. con't

Assembly Yard	Separate Provinces-Volume I Yard Operating Costs Per Hog Dollars/10,000	Separate Provinces-Volume I Yard Operating Costs Total Dollars	Three Province-Volume II Yard Operating Costs Per Hog Dollars/10,000	Three Province-Volume II Yard Operating Costs Total Dollars
Canora	----	---	754	3,610.60
Rosetown	5020	3,636.48	5020	3,636.48
Tisdale	831	3,056.49	660	4,046.26
Rosthern	1967	3,633.81	1967	2,633.81
Wadena	859	2,820.18	---	---
Wynyard	1596	2,708.89	886	2,761.93
Ponaka	826	3,100.96	826	3,100.96
St. Paul	762	3,555.72	762	3,555.72
Brooks	1054	2,337.24	1054	2,337.24
Three Hills	912	2,308.36	912	2,308.36
Grande Prairie	846	2,940.01	846	2,940.01
Manning	2466	2,557.24	2466	2,557.24
Rocky Mt. House	1407	2,644.45	1407	2,644.45

TABLE A-V, con't.

Assembly Yard	Separate Provinces-Volume I Yard Operating Costs Per Hog Dollars/10,000	Separate Provinces-Volume I Yard Operating Costs Total Dollars	Three Province-Volume II Yard Operating Costs Per Hog Dollars/10,000	Three Province-Volume II Yard Operating Costs Total Dollars
Athabasca	881	2,614.45	881	2,614.45
Bonnyville	845	2,950.99	845	2,950.99
Didsbury	805	3,266.60	805	3,266.60
Fairview	1741	2,709.51	1741	2,709.51
TOTAL MANITOBA	516	22,277.07		
TOTAL SASKATCHEWAN	678	43,291.77		
TOTAL ALBERTA	603	88,618.04		
TOTAL THREE PROVINCES	607	154,186.88	563	143,189.70

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