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THE BEEF DELIVERY SYSTEM:
OPTIMAL PLANT SIZES, LOCATIONS, AND PRODUCT FLOWS
FROM A NORMATIVE PERSPECTIVE

by

JOHN C. HAFER

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Lincoln, Nebraska

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TITLE

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AND PRODUCT FLOWS FROM A MORMATIVE PERSPECTIVE

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Table of Contents

List of Figures		i
List of Tables.		ii
Chapter I	Introduction	1
Chapter II	Problem.	5
	Objectives	5
Chapter III	Theory	6
Chapter IV	Review of Literature	14
Chapter V	The Model.	36
	Assumptions of the Model . . .	41
	The Grid System.	43
	Derivation of the Cj Cost Functions.	48
	Right Hand Side.	69
Chapter VI	The Optimal Solution	71
Chapter VII	Range Analysis of Activities . . .	119
	Net Exporting Regions.	120
Chapter VIII	Summary and Conclusions.	142
	Applications of this Research.	145
	Suggestions for Further Research	148
Appendices		150
Bibliography		158
Other Selected Information Sources.		162

List of Figures

Figure 1. Grid System of the United States 46

Figure 2. Goodwin and Crow's Optimal Beef Flows Under Full Adjustment. 84

Figure 3. Goodwin and Crow's Optimal Beef Flows Considering Existing Feeding and Slaughtering 86

Figure 4. Intrregional Movement-North Central. . . . 101

Figure 5. Intraregional Movement-South Central . . . 102

Figure 6. Intraregional Movement-Southeast 103

Figure 7. Intraregional Movement-Sothwest. 104

Figure 8. Intraregional Movement-Lake States 105

Figure 9. Intraregional Movement-Northeast 106

Figure 10. Intraregional Movement-South 107

Figure 11. Intraregional Movement-Northwest 108

Figure 12. Exports From Southwest Region. 109

Figure 13. Exportd From Southern Region 110

Figure 14. Exports Form Lake States 111

Figure 15. Exports From the Northwest Region. 112

Figure 16. Exports From the South Central Region. . . 113

Figure 17. Exports From the North Central Region. . . 114

List of Tables Continued

Table 26. Optimal Beef Flows and Costs 98

Table 27. Optimal Locations and Alternatives of Processing Centers with Cost Ranges . . . 121

Table 28. Optimal Activities with Flows and Activity Range, North Central Region 125

Table 29. Optimal Activities with Flows and Activity Range, South Central Region 129

Table 30. Optimal Activities with Flows and Activity Ranges, Southwestern Region 131

Table 31. Optimal Activities with Flows and Activity Range, Northwestern Region 133

Table 32. Optimal Activities with Flows and Activity Range, Lake State Region 135

Table 33. Optimal Activities with Flows and Activity Ranges, Northeastern Region 137

Table 34. Optimal Activities with Flows and Activity Ranges, Southern Region 138

Table 35. Optimal Activities with Flows and Activity Ranges, Southeastern Region 140

List of Tables

Table 1. Grid Strats and States 44
Table 1a. Regional Basing Points for Beef. 47
Table 2. Slaughter Volumes by Plant Size. 52
Table 3. Labor Expenditures per Head Slaughtered. . . 54
Table 4. Pollution Control Costs by Plant Size. . . . 56
Table 5. Total Building and Equipment Fixed Costs . . 56
Table 6. Total Slaughter Costs per Head 59
Table 7. Four Major Cost Catagories by Plant Size . . 60
Table 8. Summary of Processing Labor. 62
Table 9. Electrical Costs by Size of Operation. . . . 63
Table 10. Summary of "Other" Fixed Costs and Variable Cost of Processing 64
Table 11. Summary of Processing Costs by Size of Operation 65
Table 12. Summation of Slaughter + Processing Costs. . 67
Table 13. Regions of the United States 73
Table 14. Optimal Number, Size, and Efficiency of Plants Necessary to Achieve Optimal Solution 76
Table 15. Existing Plants in 1976 by Catagory and Grid 79
Table 16. Anthony's Projected Size Distributions of Cattle Slaughtering Firms 81
Table 17. Goodwin & Crow's Regional Basing Points for Beef Production and Consumption 85
Table 18. Beef Flows form North Central. 88
Table 19. Beef Flows from South Central. 89
Table 20. Beef Flows from Lake States 90
Table 21. Beef Flows from the Southwest. 91
Table 22. Beef Flows from the Northwes 94
Table 23. Beef Flows from the Southeast. 95
Table 24. Beef Flows from the South 96
Table 25. Beef Flows from the Northeat 97

INTRODUCTION

The beef packing industry has undergone pronounced changes in the last thirty years. The influence of the four major packers[1] has diminished with the growth of highly automated and specialized beef processors. The old gravity flow multiple specie packing houses are all but extinct, and with this extinction has come the abandonment of beef slaughtering activities by some of the traditional leaders.

The growth of technology has had its effects on the industry with respect to both location and plant operation. The adoption of capital intensive techniques has permitted greater output per production employee. It has also freed the slaughtering plants from locations where labor was a key factor. In other words, with plants requiring less labor to produce comparable amounts of meat, the plants found it more feasible to locate nearer the source of their raw material. This signalled the decline of terminal markets and the beef packing associated with those locations. This is evidenced particularly in the Plains states. The locational shifts have seen packing move from the traditional centers of Omaha, Kansas City and Fort Worth to more remote locations in the hinterlands.

Technology has affected the product. The adoption of fabricated beef processing has shifted much of the trimming, boning, and breaking that was the job of retail meat cutters to centralized assembly line plants where specialization of labor can be put to its fullest advantage. As a result, more pounds of salable meat are shipped per load, thus

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1 Armour, Swift, Cudahy, Wilson

utilizing transportation more effectively. The final produce is now boxed and sealed in air-tight containers permitting a longer storage life, requiring less storage space, and facilitating mechanized handling.

Beef marketing is not a static function. The conditions that influence long and short run decisions are changing as new information is gained and old information is updated. The primary function of marketing hasn't changed; its focus is on the customer. By making the customer sovereign, its purpose is to deliver satisfying products and services. The customer rewards the system by purchasing its product or service. When the system fails in its primary objective the consumer transmits his/her dissatisfaction by not purchasing or searching out more satisfying alternatives. The marketing function attempts to anticipate the demands of consumers and offer the right product, at the right time, in the right location and for the right price, so as to satisfy the time, place, form and possession utilities of that consumer. It is this marketing concept that must prevail in the minds of decision makers in the marketing system.

Firms also have a responsibility to themselves and their dependents and that responsibility is to generate a reasonable profit as a reward for their efforts and risk. These rewards have been small for meat packers. The 1925-1976 average of the earnings-percentage of total sales has been less than one percent,[2] and have ranged from a -.6% to 1.6% over that period. Compared to other industries in 1976, meat packing had a $311.5 MM income after taxes, while the forty industry

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2 Source: A.M.I. quoting Citibank. Monthly Economic Letter, April 1977.

average was $1345.4 MM.[3]

Competiton in the packing industry is a point of contention from both the product and input sides. The "Yellow Sheet", the traditional price and volume source of information, is being questioned with respect to its objectivity and charges of manipulation by major packers are not uncommon. Johnson (30) has questioned the degree of competition that exists in the marketing of livestock. He states, "Slaughter livestock marketing in the United States is not as efficient, competitive, or as equitable as one would reasonably expect, given existing technology, nor is it properly organized and structured to maximize the inherent benefits of a market-directed private enterprise economy ... marketing costs in 1975 were ... $298 MM higher than they needed to be ... (and) producer efficiency would ... improve by $3 billion by a pricing system that objectively equates product value and product price," (pg. 180). The accuracy of his figures and his hypotheses are not universally accepted. It is a fact that regardless of the competitive environment, profits result when revenues are greater than costs, and that by reducing total costs the profit potential is enhanced. This research will devote itself to cost minimization in the beef packing industry.

Marketing research is characterized by a systematic inquiry defining content - what the researcher is going to study, defining a method - a strategy of inquiry, and using a technique or tactic to implement the strategy. It is, in essence, a search for and analysis of, information relevant to identifying and solving of a problem related to

[3] Source: A.M.I. quoting Citibank. Monthly Economic Letter, April

the delivery of a product or service in order to satisfy the consumer's time, place, form and possession utility, and do so profitably. This research will address itself to the problem of plant size and location which will result in a minimal cost system of procurement, processing and distribution of beef cattle from selected supply points, through selected processing points and to the demand centers in the contiguous United States.

It is assumed that readers of this dissertation have an above average knowledge of the beef packing industry and all of its activities. Thus, what is considered widely known in the industry in terms of techniques, terminology, etc. will not be defined here. If this is not the case, numerous U.S.D.A. publications are available and easily accessible. In areas not in common knowledge of the above average reader, explanations will be either in the text or delegated to footnotes.

CHAPTER II

PROBLEM

The marketing of cattle and beef should be done as efficiently as possible, if the industry is striving for cost minimization, the assumed objective of this research. In the industry as it exists now, live cattle are trucked hundreds of miles and some beef slaughtered east of the Missouri River is shipped west, passing western beef bound for eastern markets. If slaughter plants were optimally located and least cost flows of cattle and beef established, then ideally this share of the marketing cost could be minimized without reducing services to consumers.

Objectives

1) To derive the necessary slaughter, processing, assembly, and shipping cost functions necessary to generate the objective function that will be used in an optimizing model
2) To build a normactive model capable of determining the optimal slaughter plant locations, by regions, and calculate the least cost flows of cattle and beef.
3) To examine the results of the model and the sensitivity of the solution with respect to the cost and activities
4) To consider a range of plant sizes and what influence size economies have on the plant locations and flow networks

CHAPTER III

THEORY

This chapter will state some of the basic assumptions dealing with the model employed. It will then discuss the elements of costs, revenues and profits from a mathematical perspective using the standard notation and basics of microeconomic theory. The problem of externalities in the real world is briefly discussed. The purpose of the theory discussion is to lay the foundation for the objectives of this study. The model chosen for the normitive research is a cost minimization transhipment model. Since individual plants are assumed to have little or no influence on the market price of either cattle or beef, a competitive structure is assumed.[4]

This model assumes that profit maximization is the firm's goal by looking at the dual situation, i.e., cost minimization. The theoretical discussion that follows should highlight the major points of the model.

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4 Johnson (27) has argued that there is a decided lack of competition in live animal marketing. His contention is that there are only a few buyers of cattle in any cattle producing area and that buyers representing the large slaughtering plants face little competition and thus have a degree of control over the price paid for live cattle. On the selling side the "Yellow Sheet" has been the traditional source of price and quantity information for the meat industry. Its purpose was to expose all traders to the same market information and provide an equal information base for their selling decisions. The effectiveness of the "Yellow Sheet" is widely questioned in the meat industry and charges of manipulation by large packers seems to have cast doubt upon the sheet's validity. Until a better method of information transfer is adopted or marketing practices and alternatives improve, this is the arena in which the meat industry operates.

Profits are the result of five elements. These are the cost factors representing processes that change the cattle into salable beef, the purchase price of the cattle, and the plant's total revenue.

The total cost of beef packing system, with reference to equations 1-5 below, is assumed to be the sum of (1) assembling cattle for slaughter from the possible points of origin, (2) slaughtering plus processing, (3) distributing beef from all possible packing locations to the possible demand centers, and (4) purchase price of the cattle. Profits are the difference between total revenue and total cost, and maximized where this difference is maximized, assuming a competitive market exists with known quantities of supply and demand.

1) $Cj = fj\ (Qj)^{*}$ = Cost of slaughter + processing

2) $\sum_{i=1}^{27} C_{ij}^{a} = \sum_{i=1}^{27} gij\ (Xij)^{*}$ = Cost of assembling live cattle

3) $\sum_{i=1}^{32} C_{jk}^{d} = \sum_{j=1}^{32} h_{jk}\ (Xjk)^{*}$ = Meat distribution

4) $C_{ij}^{o} = \sum_{i=1}^{27} P_{ij}\ (Xij)^{*}$ = Purchasing cost of live cattle

5) $TR_{j} = \sum_{k=1}^{32} Pk\ Xjk^{*}$ = Total revenue

---

* Notation:

Cj = Slaughter + processing at the "j[th]" plant location

"i" = Live cattle shipping points

"j" = Packing plant locations

"k" = Demand point locations

Thus, C_{ij}^{a} is the assembly cost from the "i[th]" point of origin to the "j[th]" packing plant location.

The fact that profit maximization occurs where added costs of production and delivery are offset by added revenues has an important bearing on the dynamics of the actual product flows. Temporary price imbalances serve to attract or repulse product flows. Thus, if regionalized supply and demand become imbalanced so as to push a local price higher and create a greater than "normal" spread between that region and others, product flows from packers will readjust toward this area.

This normitive model will assume that price spread imblances do not exist and that the product flows represent the "normal" situation that exists if the demand and supply are to be equalized.

Profits are:

6) $TCj = Cj + \sum_{i=1}^{27} C^{a}_{ij} + \sum_{i=1}^{27} C^{o}_{ij} + \sum_{g=1}^{32} C^{d}_{jk}$

7) $TRj = \sum_{k=1}^{32} Pk\ Xjk$

8) $\Pi_j = TRj - TCj$

9) $\Pi_j = \Sigma P_{jk} X_{jk} - f_j (Q_j) - \Sigma g_{ij} (Xij) - \Sigma P_{ij} (Xij) - \Sigma h_{jk} (Xjk)$

Assuming these to be continuous and twice differentiable functions, the first order conditions for profit maximization are:

10) $\frac{\partial \Pi j}{Xjk} = Pk - hjk\ (xjk) = 0$

11) $\frac{\partial \Pi j}{\partial Qj} = f_j'\ (Q_j) = 0$

12) $\frac{\partial \Pi j}{\partial Xij} = -g\ (Xij) - Pij = 0$

∴ $P_k = hjk\ (Xjk)$

$P_{ij} = g\ (Xij)$

If we constrain each plant to at least break even, then prices and costs would be equal or Pjk/cost = 1, or

13) $P_{jk} = f'(Qj) + \Sigma gij\ (Xij) + \Sigma Pij + h_{jk}'\ (Xjk)$

14) $$\frac{P_{j1}}{f_j'(Qj)+\Sigma gij(Xij)+\Sigma Pij+h_{j1}'(X_{j1})} = \ldots = \frac{P_{jk}}{f'(Qj)+\Sigma gij(Xij)+\Sigma Pij+h_{jk}'(Xjk)}$$

In the equilibrium state, equation 14), for a firm to sell beef into a sepcific region, the ratio of the price of beef in a market destination region to the added cost of a unit of beef sold into that region must be equal between markets. For the industry this means that each plant, if it were to optimally allocate its product flows, would do so to equate the margins of costs and revenues for all possible destinations and ship accordingly. All destination points are candidates but become receivers when the cost-price calculus is such that a breakeven or greater situation exists. At equilibrium there would be no abnormal profits with no firms entering or leaving the industry.

Looking at the state equilibrium we find that:

15) $$TC = TC\ (A,S,D,P)$$

A = Assembly
B = Slaughter + Processing
D = Distribution Cost
P = Prices

16) $$dTC = \frac{\partial TC}{\partial A}\, dA + \frac{\partial TC}{\partial S}\, dS + \frac{\partial TC}{\partial D}\, dD + \frac{\partial TC}{\partial P}\, dP$$

By assuming dP=0 as discussed previously,

17) $$dTC = \frac{\partial TC}{\partial A}\, dA + \frac{\partial TC}{\partial S}\, dS + \frac{\partial TC}{\partial D}\, dD$$

It is assumed management decisions cannot influence prices, the changes in total cost are the results of changes in the assembly, slaughter + processing, and distribution costs. In many plants where unions have a strong foothold, a firm can do little about the slaughter + processing cost. Output is measured in the time dimension, not rate, the chain speed remains constant and the production workers either work to match the chain or don't work. If guaranteed wages and annual work

day guarantees become the norm, the major portion of the slaughtering + processing costs will not be under management's control as these major variable cost items become more fixed in nature. If we can assume for discussion purposes, then, that dS=Ø, we are left with

18) $dTC = \frac{\partial TC}{\partial A} dA + \frac{\partial TC}{\partial D} dD$

If the firm is operating at minimal total cost, then dTC=Ø and

19) $\emptyset = \frac{\partial TC}{\partial A} dA + \frac{\partial TC}{\partial D} dD$

20) $\frac{-\partial TC}{\partial A} dA = \frac{\partial TC}{\partial D} dD$

21) $\frac{-\partial TC}{\partial A} \Big/ \frac{\partial TC}{\partial D} = dD/dA$

Proceeding through the equations terminating with 21) we have been building a normitive theoretical foundation. The purpose of the theory has been to state the generalized pristine environment that reflects the less than mathematically precise world. From a more pragmatic viewpoint, the analysis must explain "positively" rather than "normitively".

The impact of 19) - 21) is that a negative and inverse relationship exists between assembly and distribution if the firm is operating at dTC=Ø. Thus, if assembly costs increase, distribution costs must be lowered and vice versa. This is accomplished through lower transportation tariffs, volume discounting, etc., or by reducing the distance travelled. In the case of supply this cost reduction may be attempted

by more intensive procurement of cattle closer to the plant. In the case of supply the more distant markets may have to be abandoned or cheaper methods of transportation found. In either case, the marginal markets will be eliminated.

A more dynamic examination would have to include the externality problem that would result if firms eliminate marginal markets. On the procurement side more intensive purchases of livestock in a particular area would create a stronger quantity demanded for the existing stock and drive prices up in the short run and possibly offsetting anticipated savings. From the distribution perspective, reducing the market area increases the competition for the "local" buyer's dollar and could cause lower beef prices in the short run. Efficiency becomes the essence of competitive staying power, from the perspective of the physical input/output of the plant, and the size of plant built. Plants that can take advantage of size economies can operate at lower average costs and be the last firms to withdraw from a market and be able to withstand the competitive pressures.

One could hypothesize that if size economies exist then large plants should prove to be the most stable in their price and cost sensitivity. The underlying tennet is the theory of comparative advantage applied to production costs and location. To permit location selection to be achieved to its fullest, all possible combinations of supply, slaughter, and destination regions should be considered. The optimal solution would then reflect the flows of cattle and beef to minimize the total cost and satisfy supply and demand at same price.

The stability of each "network" in the solution would also be an important consideration, as it shows the resiliency of optimal "networks" to cost changes and the potential for market penetration and development.

Chapter IV

REVIEW OF LITERATURE

Studies of the optimal spatial distributions of processing plants for meats, fruit, milk products, etc. date back into the late 1940's. The difficulty in doing early work was a lack of computers to do justice to the inter-relationships existing in complex problems. As a result, the growth in the number and complexity of research problems has paralelled the growth in computer sophistication.

This literature review examines approximately fifty articles and papers and spans about twenty-eight years. It is by no means a complete review of all the literature on the subject. In light of this, the early literature cited is what this writer judged to be the most seminal in the topic area, and related to agricultural economics. Some works were selected because of their illustration of technique or their application to the subject of this paper. This literature review is chronologically structured and lays the foundation for the justification and objectives of this research.

One of the first articles to appear in the agricultural economics journals was that of Snodgrass and French (Journal of Farm Economics, Feb. '57). They illustrated in a nonmathematical example the essence of the transportation problem that had been theoretically treated by earlier authors. This was a procedural example whose purpose was to illustrate a technique for manual computation. It made the restrictive assumption of costless intraregional transfers. This is questionable in light of their example using the United States as a

subject area and dividing it into four regions.

In 1957, Orr's (43) dissertation research looked at meat packing in the southestern United States. He took as given the regional demand, regional supply, cost functions for processing, and the transportation cost relations faced by carriers. He determined supply, demand, and price patterns, and the movement between regions. He concluded that growth of demand in the Southeast was a primary factor in expansion of meat packing there. Secondly, the changes in transportation rates of meat products into and out of the Southeast relative to the other quadrants of the nation would have to be changed to elevate these "rate relationships that appear unfavorable to Southern packers". This he hypothesized to be highly unlikely. This research was in essence testing the locational stability of the southeastern meat packing industry.

In 1959 Hassler (J.F.E., Dec. 1959) challenged the researcher studying interregional competition to bring spatial, temporal, and product form inter-relationships together for more realistic and applicable models. His descriptions of space models (single homogeneous products), space-time models, and space-time-form models are valuable

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5 T. C. Koopmans, "Optimum Utilization of the Transportation System", Econometrica, Vol. 17, Suppl. (July 1949).

P. A. Samueleson, "Spatial Price Equilibrium and Linear Programming", A.E.R. Vol. 42, No. 3, June 1952.

J. N. Boles, "Linear Programming and Farm Management Analysis", J.F.E., Feb. 1955.

E. O. Heady, "Simplified Presentation and Logical Aspects of Linear Programming Technique", J.F.E., Dec. 1954.

reading. His discussion of needed data and the structure of the above models serves as a valuable "road map" in studying the application of model building to the complexities of the real world. His concluding remarks are worth quoting, "We have too many economic 'artists' who 'know' what is right and wrong about economic structures without analyses or facts." The model in this dissertation research would be considered normative and of the space-form variety. It converts a raw product, cattle, into beef, then considers the cost of live animal transportation, slaughter and processing, beef transportation costs and the spatial imbalances of supply and demand.

In this same journal King and Henry (J.F.E., Dec. 1959) discussed Hassler's points but devoted more effort to an actual calculation of a transportation problem. Whereas Hassler's treatment was conversational, King and Henry went into more depth on not only model types but also the side analysis that can be gleaned from transportation models. Here the concern was with both transportation costs and processing cost. That paper was a result of Henry's work with the North Carolina broiler industry where the space-form model was applied.

Henry published a paper in the J.F.E. of 1957 entitled "Broiler Production Regions of the Future", where his concern was with the growth or decline of the industry in various locations. The article's tables and illustrations of formalized L.P. matrices is a great aid for the model builder. The early work of both King and Henry served as a springboard for future location and transportation research concerning agricultural products.