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Introduction

The United States beef delivery system is composed of three stages: procurement, processing, and distribution. Minimization of costs associated with these stages can be accomplished best by identification of optimal plant sizes and locations.

Research was directed toward an analytical approach that could be used to minimize total costs of the U.S. beef delivery system. This report will discuss the grid system used to divide the United States into study units, describe features of the model used, discuss research results, and offer conclusions.

The Grid System

A grid based on cattle production density was used to divide the contiguous United States to illustrate how products flow from production to consumption areas. A four-level stratification system was used. Strata I had fewer than five animals marketed per square mile per year and was made up of states in Grid 27. Strata II had 6-10 animals marketed per square mile per year and contained Grids 20 and 22-26. Strata III had 11-15 animals marketed per square mile per year and was composed of Grids 16, 18, 19 and 21. Strata IV had 15 or more animals marketed per square mile per year and comprised the major beef producing states, Grids, 1-15 and 17.

In 1976 Grids 1-4 and 8 slaughtered 47.3% of the beef produced in the U.S. Grids 1-3 alone accounted for 31.4% of the total. The grid system was effective in delineating production and population density.

Production centers were geographically centered in each grid. Demand centers were easily identifiable by population statistics. In most grids there was one dominant consumption area. In grids where this was not the case and two areas appeared to exist, each was designated a demand center. These served as reference points for later analysis.

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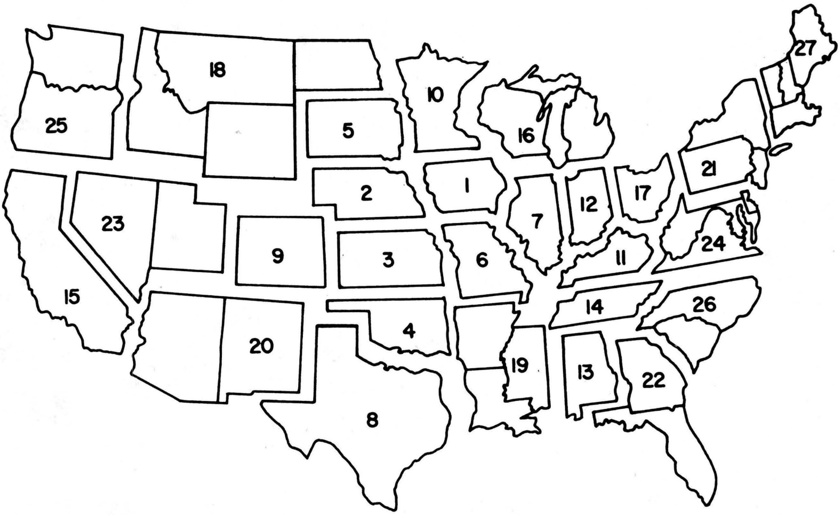

Figure 1. Grid system of the United States.

Table 1. Supply centers and quantity supplied.

Grid No.	Supply point	Quantity supplied (MMcwt)
1	Ames, IA	21.1171
2	Broken Bow, NE	19.7635
3	McPherson, KS	19.4721
4	Oklahoma City, OK	15.8719
5	Pierre, SD	12.0367
6	Jefferson City, MO	9.7572
7	Decatur, IL	7.7973
8	Abilene, TX	31.768
9	Colorado Spring, CO	13.3574
10	Brainard, MN	9.4846
11	Danville, KY	4.5731
12	Indianapolis, IN	4.0514
13	Birmingham, AL	5.1559
14	Nashville, TN	4.0702
15	Fresno, CA	13.7334
16	Sheboygan, WI	7.2474
17	Columbus, OH	3.99030
18	Red Lodge, MT	13.9308
19	Greenville, MS	8.0229
20	Alpine, AZ	11.1296
21	Scranton, PA	3.5344
22	Valdosta, GA	4.9397
23	Garrison, UT	2.303
24	Charlottesville, VA	2.4803
25	The Dalles, OR	4.5026
26	Fayetteville, NC	1.8001
27	Berlin, NH	.7332

Figure 1 illustrates the grid system while Tables 1 and 2 list the specific basing points. Twenty-seven supply points and 32 demand points were used. The quantities of beef (all in carcass beef equivalents) are listed along with their respective points.

The Model

The model used was founded on the work of Stollsteimer (50), King and Henry (33), Snodgrass and French (48), King and Logan (32), and Leath and Martin (37). These works focused on size economies or minimization of transportation costs. Goodwin and Crow (22) adopted Leath and Martin's (37) earlier work for a model of beef production and processing.

The goal of this study was to identify the cost minimizing networks which ultimately deliver processed beef to demand points. This model used a cost minimizing, linear programming search procedure. It

Table 2. Demand centers and net quantity demanded.

Grid No.	Demand center	Quantity (MMcwt)
1	Des Moines, IA	3.452854
2	Omaha, NE	1.868391
3	Wichita, KS	2.779126
4	Oklahoma City, OK	3.327733
5	Pierre, SD	.825316
6	Kansas City, MO	2.874170
	St. Louis, MO	2.874170
7	Chicago, IL	13.5094415
8	Dallas-Ft. Worth, TX	7.511461
	Houston, TX	7.511461
9	Denver, CO	3.107568
10	Minneapolis-St. Paul, MN	4.770232
11	Lexington, KY	4.124175
12	Indianapolis, IN	6.378756
13	Montgomery, AL	4.409306
14	Nashville, TN	5.069800
15	Los Angeles, CA	12.945119
	San Francisco, CA	12.945119
16	Milwaukee, WI	5.545018
	Detroit, MI	10.952885
17	Cleveland, OH	12.860978
18	Pocatello, ID	1.574838
	Fargo, ND	1.574838
19	New Orleans, LA	9.990417
20	Phoenix, AZ	4.136206
21	New York, NY	44.853415
22	Miami, FL	16.110511
23	Salt Lake City, UT	2.211270
24	Washington, D.C.	14.775086
25	Seattle-Tacoma, WA	7.147528
26	Charlotte, NC	10.006058
27	Boston, MS	14.702902

consisted of approximately 140,000 activities with 59 rows—each activity a possible shipping and destination point, unique plant size, and a potential candidate for the solution. Six plant sizes were possible for each processing point.

The objective function was generated by summing four component costs (adapted from the work of Cothern *et al.* (14), Henry and Seagraves (29), and Anderson and Budt (1)). Optimization was achieved on the IBM 370 computer using the MPSX linear programming package.

Four separate costs were considered. First, the assembly cost function estimated the transportation expense of moving live cattle to processing points. Second, the slaughter cost was synthesized. Third, the processing cost was synthesized via economic engineering.[2] The last cost function was the meat shipment cost for truckloads of processed beef.

The following diagram illustrates the model's logic flow.

Assembly of cattle from all possible points

Does i=j

Calculate cost of transferring cattle from origins to slaughter plants

No **Yes**

Calculate slaughter cost

Use average length of haul

Do loop for each of six plant sizes

Calculate processing cost

Shipping distance for beef to all regions

Does i=j

Calculate shipping cost

No **Yes**

Sum all costs for each unique network

Use average length of haul

Compare Cj's of all possible locations

Select network that satisfies supply and demand and min. total cost

The sum of these four costs made up the Cj in the linear programming matrix. Each Cj represented a unique product flow network.

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[2] Processing refers only to the breaking of quartered beef into subprimals (rounds, chucks, short loins, etc.) that are wrapped, boxed, labeled and then temporarily stored and shipped out immediately.

Table 3. Slaughter volumes by plant size.

Plant size	Kill/hr.	Kill/day[a]	Annual kill
1	47	353	88,125
2	60	450	112,500
3	75	563	140,625
4	90	675	168,750
5	110	825	206,250
6	300	2,250	562,500

[a]7.5 hr/day, 250 days/year.
Source: Cothern *et al.*

Assembly Cost

A navigational program was used to determine the distance between points for interregional product flows. When intragrid activities were considered, the program used an "average length of haul" value based upon the procedures developed by Henry and Seagraves (29). Appendix A lists the average length of haul for each state.

Use of the navigational program resulted in distances in terms of statute miles. Regression analysis was done with actual road miles and "calculated" miles. The following equation resulted:

Road miles = −23.2 + 1.12244 (Statute Miles)
t = (15.90) (R^2 = .968)

The assembly cost calculation (Appendix B) used $1.20 per mile (.745 per km), multiplied by the product of the distance generating subroutine and the conversion formula. The resultant figure was then converted to a cost per hundredweight of beef. The linear cost function showed that it cost slightly over $.0092 per mile ($.0062 per km) to transport 100 pounds of beef in live form.[3]

Slaughter Cost

Slaughtering cost was divided into four segments. The largest segment was labor and fringe benefits. The others were utilities, land cost, and a component called "other" fixed and variable costs. These costs were based upon the 1976 economic engineering data of Cothern *et al.* (14).

Slaughter costs were developed for six plant sizes ranging from 47 to 300 head per hour (Table 3).

[3]Shrinkage does exist in transporting cattle. However, no reliable research could be found that specified a functional relationship. A shrinkage function would be very suspect due to the wide range of affecting variables, i.e. climate, distance, age of cattle at time of shipment, and handling procedures. Research tended to focus on specific regions of the country and yielded nothing that could be universally applied. Also, this type of research usually concluded with a variety of disclaimers citing the previous variables as factors that were influential but unpredictable.

Fixed costs were those relating to buildings, land and equipment—primarily depreciation, interest, taxes and insurance. Total variable costs included repair and maintenance, labor and fringe benefits, electricity, leases, licenses, miscellaneous selling expenses, fuel, supplies, miscellaneous expenses, sanitation sewage, and boilers. Rendering was not considered, but the cost of a freezer was.

All costs were based upon 1976 figures. California was used as a basis upon which to index all other states. The cost of labor was calculated assuming a 7.5 hour workday and 250 days per year. The wage range was from $3.50 to $8.75 per hour, depending upon skill. It was assumed that the labor hours per head were independent of plant location. All locations were assumed to be working at the same level of capacity.

To arrive at a labor plus fringe benefits cost for each processing grid, the California figures were taken as a base and adjusted for each state using the 1976 Annual Survey of Manufacturers' figures for S.I.C. 20111, or S.I.C. 2011. Appendix C lists the adjustments for each grid.

Another part of slaughter cost was the cost to manage pollutants discharged into the community sewage plant. The cost of pollution control is about 1% of the total slaughtering cost per head if a lagoon system is used.

Slaughtering cost included cost of buildings and equipment. It was assumed that buildings and equipment of the same general design would serve all locations. Building construction costs were $60 per square foot. The annual fixed cost of buildings and equipment amounts to 10-13% of the total annual slaughter cost.[4]

"Other" variable costs were assumed to be constant regardless of location. It was assumed that spatial distribution of firms did not influence costs such as repairs, maintenance, leases, licenses, selling expenses, fuel, supplies, etc. The sum of these "other" variable costs comprised approximately one-fourth of the total slaughter cost.

Land costs were adjusted by taking the state-by-state values of farm land per acre[5] and dividing each by the value of California land for 1976.

Electric utility rates were adjusted in a two-step process. First, state-by-state electrical power revenues were divided by the sales (in Mkwh) to yield an average rate.[6] This average rate was divided by California's rate to produce an index.

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[4]Hafer (24). Total building and equipment fixed cost is the sum of depreciation, interest, insurance, taxes and installation charges. For the six plant sizes considered, the totals ranged from 10-12% of the total slaughter cost.

[5]Source: Farm Real Estate Market Developments, March 1978, Economics, Statistics, and Cooperatives Service, USDA.

[6]Source: Statistical Yearbook of the Electrical Utility Industry, Edison Electric Institute, N.Y., Copyright 1977, No. 44. See Tables 22S and 36S.

Table 4. Total slaughter cost per head (California 1976).

Labor and fringes	=		$ 14.7300
Utilities	=		.3185
Land ($1332.18/yr + 88125 hd/yr)	=		.0152
Fixed cost + other variable costs			
Building and equipment	=	2.8772	
Leases, Lic., Sell.	=	3.5857	
Fuel, Supplies, Misc.	=	1.6245	
Sanitation, Sewage	=	.4527	
Repair + maintenance	=	1.2974	
Total fixed cost + other VC			9.8375
Total slaughter cost	=		$ 24.9012

Source: Cothern *et al.*

Table 5. Four major cost categories by plant sizes, cost/head (California 1976).

Capacity	Total F.C.+V.C.	Land cost	Utilities	Labor & fringes	Total
47	9.8419	.0152	.3185	14.73	24.90
60	11.12	.0294	.3455	14.17	25.66
75	9.891	.0244	.3406	13.63	23.89
90	9.8983	.0277	.3277	12.47	22.72
110	9.5466	.0297	.3315	11.71	21.62
300	7.7989	.0150	.7486	10.02	18.58

Source: Cothern *et al.*

Labor was adjusted by taking state-by-state data for S.I.C. 20111 for production man-hours and total wages paid. The former was divided by the latter, resulting in an average wage rate. Again, California's average was divided into the rest for a labor index. For any grid comprising more than one state, a simple average was taken. This was done for all cost adjustments. A simple calculation for a 47-head-per-hour plant is listed in Table 4. Table 5 shows the four major slaughter cost categories for all plant sizes.

These results indicated that economics exist with larger facilities. The rise at the 60-head-per-hour rate is due to the use of a different slaughtering technique than that used in smaller plants. Following the summation of adjusted component costs, the resultant cost in terms of dollars per head was converted to dollars per hundredweight using a 59% dressing percentage.

Processing Cost

The processing stage breaks the beef carcass down to primal cuts, which are then wrapped or bagged and boxed for storage or shipment. Carcasses are usually halved or quartered in a holding room, then mechanically conveyed to a cutting and trimming area.

With the rapid acceptance of boxed beef by the packing industry and retail meat trade, it was assumed that plants doing processing would have to do the primal cutting and boxing. The other processing operations, i.e. ground beef, etc., may or may not be done. The processing volumes for this model were:

	Slaughter volume head per hour[7]	Processing volume head per hour[7]
Small	47	30
Plant	60	30
Medium	75	50
Plant	90	50
Large	110	75
Plant	300	300

Components of processing cost were the same as for slaughter costs except for land cost. Thus, processing cost was calculated using labor plus fringe benefits, electricity, and other fixed and variable costs (Table 6).

Table 6. Summary of processing cost, by size of operation, cost/head (California 1976).

Capacity	Labor & fringes	Electricity	F.C.	"Other" V.C.	Summary
30	$ 9.97	.016565	.46224	1.4871	11.93589
50	9.4993	.01033	.427328	1.50016	11.4371
75	8.93075	.0069	.43889	1.48267	10.859
300	6.74158	.0097	.16397	2.6659	9.5812

Source: Cothern *et al.*

Meat Shipping Cost

Cost of shipping meat from a processing point to a demand center is a function of distance and weight. Truck transport is the dominant mode due to its dependability and flexibility.

The function used to calculate the meat transportation cost was adapted from Budt's (8) work. His original function was inflated at 6% per year to arrive at the function for this research. The result was the following function:

$$\$/\text{cwt.} = 2.1024 + .0027\ (\text{miles}) - .0000503\ (\text{pounds})$$
$$.001685\ (\text{km}) - 9.0176938\ (\text{grams})$$

Cost Summary

Analysis of the cost functions and derivations used to calculate the total cost indicated several things. First, distance, not weight, was found to be the key element in transportation costs. Thus, total cost would be minimized if total distance was minimized. Secondly, size

[7]Cothern *et al.* (14).

Table 7. Summation of slaughter plus processing cost (California 1976).

Slaughter capacity	Processing capacity	Slaughter cost	Processing cost	Total cost
47	30	24.91	11.94	36.85
60	30	25.37	11.94	37.60
75	50	23.89	11.44	35.33
90	50	22.72	11.44	34.16
110	75	21.62	10.86	32.48
300	300	18.58	9.58	28.16

Source: Cothern *et al.*

economies in slaughter, processing and meat transportation indicated that total costs would be minimized by operating the largest plants.[8] Throughout the range examined, the total cost per head (the sum of slaughter and processing costs per head) fell as plant size increased (Table 7).

Results

The optimal solution of the linear programming run was the combination of activities that provided a least cost system of moving cattle to processing points, slaughtering and fabricating those cattle, then transporting the beef to demand destinations.

For analytical ease, the U.S. was divided into eight regions, each containing several grids. The regions: 1) Northwest, 2) Southwest, 3) North Central, 4) South Central, 5) Lake States, 6) South, 7) Southeast and 8) Northeast. Table 8 denotes the grids and states in each region.

Live Animal Movements

The majority of animals processed came from within the grid where the processing was done. The supply of animals in each grid where processing took place was sufficient except in four grids. Grids 7 and 12 (Illinois and Indiana) showed that cattle could be moving between them. Grid 13 (Alabama) imported cattle from Grid 19 (Louisiana – Arkansas – Mississippi). A similar situation existed in Grid 24. Grid 24 (Virginia – West Virginia – Maryland – Delaware) processed cattle imported from Grid 26 (North and South Carolina), which processed nothing and imported its beef from Tennessee and Alabama.

Size, Number and Location of Plants

In all but two locations, the largest plant was indicated to be optimal. This was not unexpected, given the shape of the average cost curve.

[8]Assuming that enough cattle were available to sustain the operation of these large plants.

Table 8. Regions (grids and states) of the U.S.

Region	Grids	States
Northwest	18	Montana-Idaho-Wyoming-North Dakota
	25	Washington-Oregon
Southwest	9	Colorado
	15	California
	20	Arizona-New Mexico
	23	Nevada-Utah
North Central	1	Iowa
	2	Nebraska
	3	Kansas
	5	South Dakota
	6	Missouri
South Central	4	Oklahoma
	8	Texas
	19	Arkansas-Louisiana-Mississippi
Lake States	7	Illinois
	10	Minnesota
	12	Indiana
	16	Wisconsin-Michigan
	17	Ohio
Southeast	13	Alabama
	22	Georgia-Florida
	26	North Carolina-South Carolina
South	11	Kentucky
	14	Tennessee
	24	Virginia-West Virginia-Maryland-Delaware
Northeast	21	New York-New Jersey-Pennsylvania
	27	Vermont-New Hampshire-Rhode Island-Connecticut-Massachusetts-Maine

In Grid 23 (Utah – Arizona), a "size 5" plant (110 head per hour) was indicated to be optimal and in Grid 27 (Maine – Vermont – New Hampshire – Rhode Island – Connecticut – Massachusetts), a "size 2" plant (60 head per hour) was optimal. These areas are low cattle producing areas.

The optimal solution indicated that 72 plants could have slaughtered the nation's total kill of beef cattle for 1976, assuming maximum operating capacity for all plants. This represents a substantial reduction from the 1,502 federally inspected slaughterhouses in operation in 1976. Ninety-one percent, or 1,374 plants had production between 1 and 47 head per hour. Most of these plants had an annual production of less than 5,000 head per year. The category of 110-300 head per hour (206,000-562-000 annual production) contained only 27 plants, or 1.8%.

If the beef packing industry is to remain competitive with meats that substitute for beef, centralization and concentration are indicated by this research. The optimal solution indicated that plants should be located in all but two grids, one comprising Arkansas – Lousiana – Mississippi, the other made up of North and South Carolina. The North Central, South Central, Southwest and Northwest regions were the net exporters, while the Southeast, South, Northeast and Lake States regions were the net importers. The Plains states, North Dakota to Texas, showed the greatest stability for "exporting states."[9] Stability was defined as the ability to remain in the solution throughout a wide range of costs and volumes.

Optimal Beef Flows

The model does not consider the location of existing plants, nor the existing physical distribution of cattle or beef.

The North Central region exported 82% of its production to destination points in the Lake States and Northeast regions. The Lake States region found it essential to import 40% of its needs, and the Northeast 93%. The Southern region exported a small percentage to the Northeast, which needed to have 53% of its demand met with outside sources. The South Central region exported 52% of its production. Its customers spanned the full length of the Atlantic and Gulf Coasts. The Southeast region consumed its own production and imported 61% of its needs. The Southwest and Northwest regions were small exporters, 20% and 22% respectively. Their major destinations were the heavily populated Pacific Coast areas. Figures 2 through 7 illustrate beef exports by region. Table 9 presents the destination, cost, and demand data for the optimal beef flows that minimize the system's total cost.

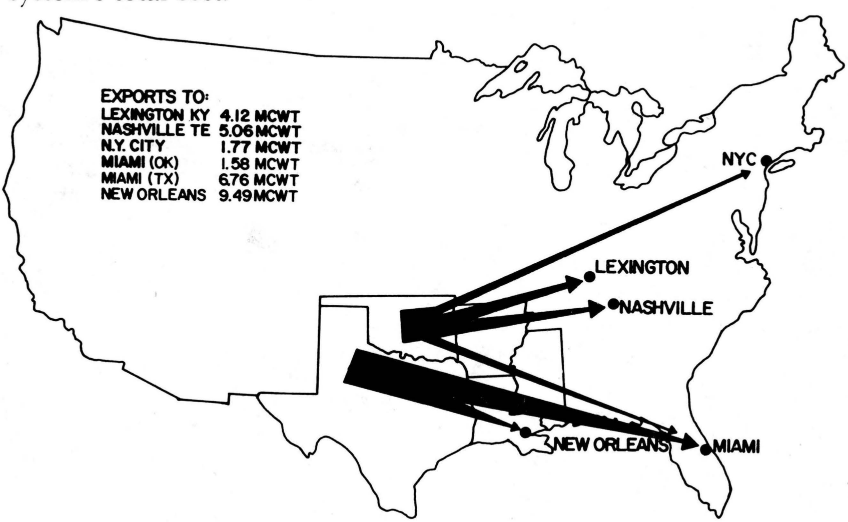

Figure 2. Exports from South Central region.

[9]Exporting means interregional shipments.

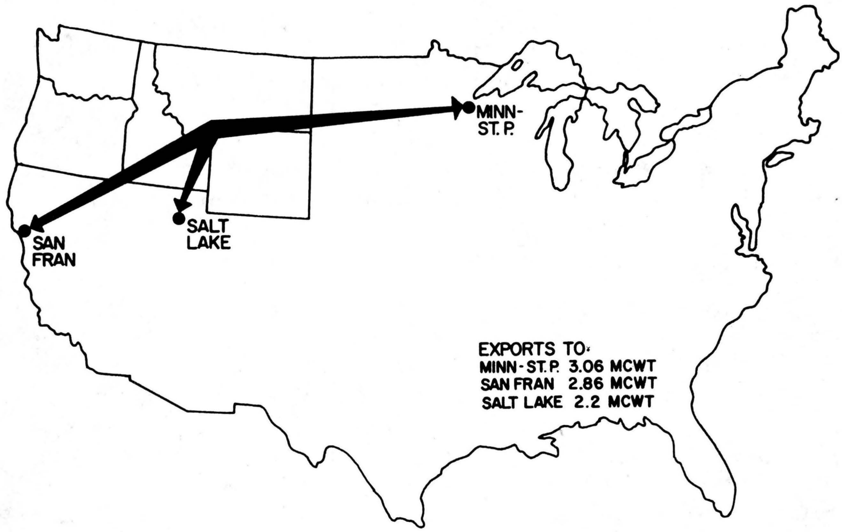

Figure 3. Exports from the Northwest region.

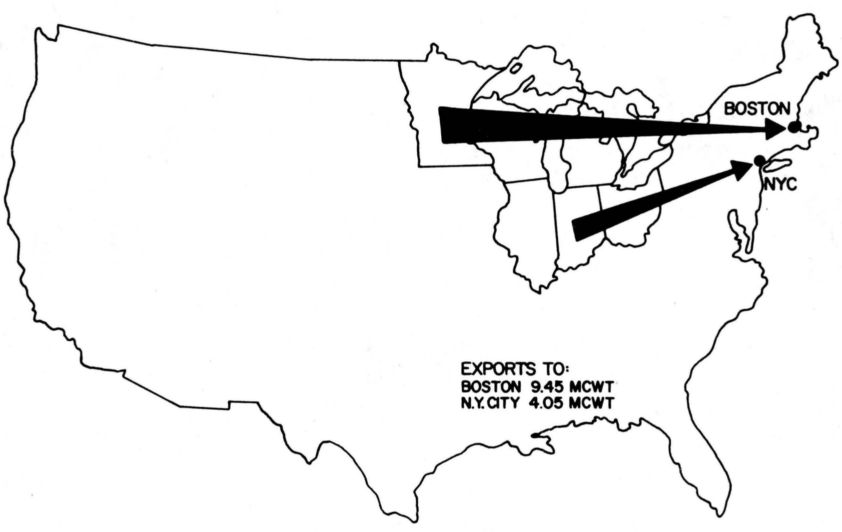

Figure 4. Exports from Lake states.

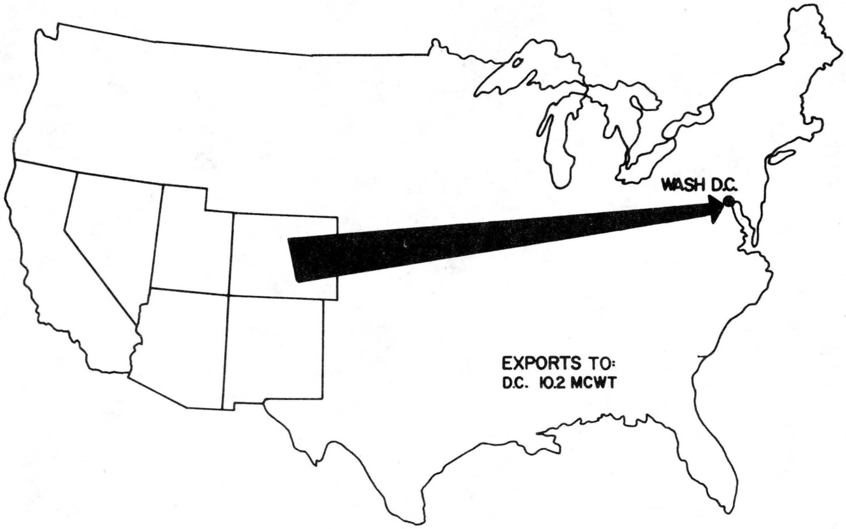

Figure 5. Export from Southwest region.

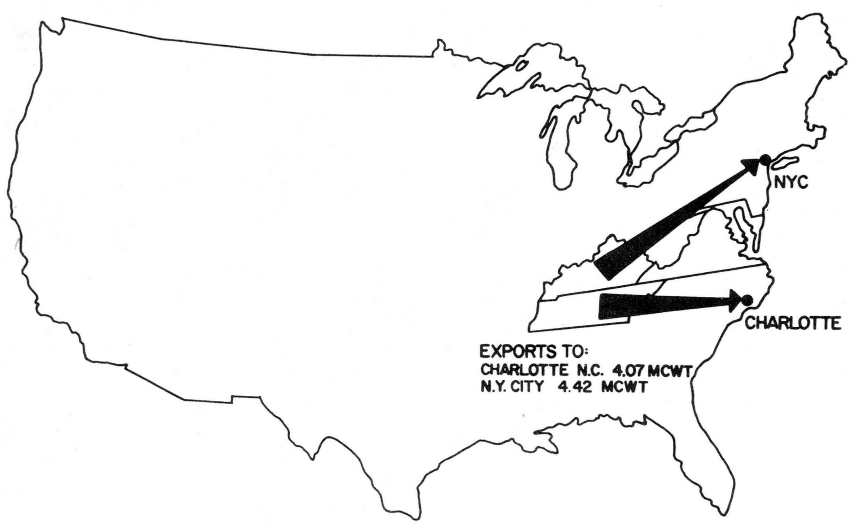

Figure 6. Export from Southern region.

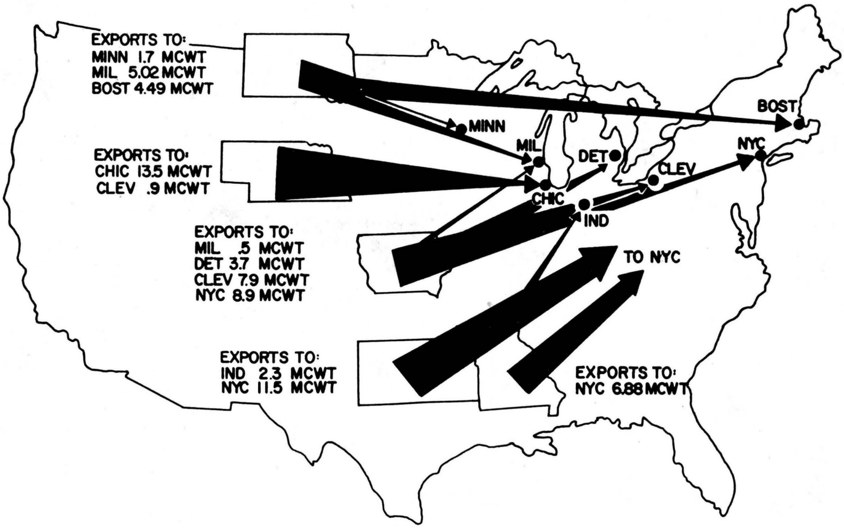

Figure 7. Exports from North Central region.

Table 9. Optimal beef flows and costs.

Grid		Origin	Destination	Cost	% of demand satisfied	Total cost
1	=	Iowa	Milwaukee	@ 6.4891	9.5%	$ 3,403,449
			Detroit	@ 7.24495	33.8%	26,846,053
			Cleveland	@ 7.51242	61.7%	59,632,643
			New York City	@ 8.70301	19.9%	77,885,264
2	=	Nebraska	Iowa	@ 6.33372	100.0%	21,869,391
			Nebraska	@ 5.57723	100.0%	10,420,440
			Illinois	@ 7.26105	100.0%	98,092,690
			Cleveland	@ 8.20328	7.0%	7,652,028
3	=	Kansas	Kansas	@ 5.32638	100.0%	14,802,675
			KCMO	@ 5.60047	100.0%	16,096,702
			Indiana	@ 6.95744	36.5%	16,192,432
			New York City	@ 8.91456	25.6%	102,441,140
4	=	Oklahoma	Oklahoma	@ 4.69259	100.0%	15,615,677
			Kentucky	@ 6.72606	100.0%	27,739,435
			Nashville	@ 6.3398	100.0%	32,141,511
			New York City	@ 8.48098	4.0%	15,009,239
			Miami	@ 8.11044	9.8%	12,818,023
5	=	South Dakota	South Dakota	@ 5.72892	100.0%	21,728,164
			Minnesota	@ 6.59659	35.8%	11,252,126
			Milwaukee	@ 7.37674	90.5%	37,035,129
			Massachusetts	@ 9.97911	30.5%	44,757,286
6	=	Missouri	St. Louis	@ 5.28833	100.0%	15,199,548
			New York City	@ 8.04542	15.4%	55,276,835
7	=	Illinois	Indiana	@ 4.50342	63.5%	18,245,142

Table 9. Optimal beef flows and costs (continued).

Grid		Origin	Destination	Cost	% of demand satisfied	Total cost
8	=	Texas	Texas	@ 5.94441	100.0%	$89,302,407
			New Orleans	@ 7.25406	100.0%	72,471,077
			Miami	@ 9.23220	41.9%	62,379,565
9	=	Colorado	Colorado	@ 5.69596	100.0%	17,700,571
			Washington	@ 8.77464	69.4%	89,938,524
10	=	Minnesota	Massachusetts	@ 9.70201	64.5%	92,019,606
11	=	Kentucky	New York City	@ 6.53611	9.9%	28,943,470
			Wash., D.C.	@ 5.97267	1.0%	86,177,000
12	=	Indiana	New York City	@ 6.47654	17.4%	50,499,499
13	=	Alabama	Alabama	@ 4.04782	100.0%	17,848,072
			Miami	@ 6.07077	17.6%	17,202,340
			N. Carolina[a]	@ 4.90477	7.5%	3,661,867
			N. Carolina[b]	@ 5.19639	51.9%	26,965,429
14	=	Tennessee	N. Carolina	@ 5.52297	40.7%	22,479,570
15	=	California	California	@ 6.20071	53.0%	85,116,799
16	=	Wisconsin-Michigan	Detroit	@ 5.35620	66.17%	38,818,497
17	=	Ohio	Ohio	@ 5.11342	31.0%	20,404,064
18	=	Montana-Idaho-Wyoming-N. Dakota	Minnesota	@ 4.95907	64.2%	15,196,969
			San Francisco	@ 6.06310	22.1%	17,343,145
			Pocatello	@ 3.53926	100.0%	5,574,337
			Fargo	@ 3.53926	100.0%	5,574,337
			Salt Lake	@ 4.60447	100.0%	10,181,783
			Seattle	@ 5.51503	37.0%	14,586,851
19	=	Arkansas-Mississippi-Louisiana		Nothing		
20	=	Arizona-New Mexico	Los Angeles	@ 4.9896	54.0%	34,894,503
			Phoenix	@ 3.69560	100.0%	15,285,755
21	=	New York-Pennsylvania-New Jersey	Pennsylvania	@ 4.5289	7.9%	16,006,935
22	=	Georgia-Florida	Miami	@ 4.36121	30.7%	1,132,644
23	=	Utah-Nevada	Los Angeles	@ 5.21767	17.8%	12,016,283
24	=	Virginia-Maryland-Delaware-W. Virginia	Wash., D.C.	@ 4.00644	17.5%	10,337,813
			Wash., D.C.[c]	@ 4.64722	12.2%	8,365,451
25	=	Washington Oregon	Oregon	@ 3.73724	63.0%	16,827,289
26	=	N. Carolina-S. Carolina		Nothing		

Table 9. Optimal beef flows and costs (continued).

Grid		Origin	Destination	Cost	% of demand satisfied	Total cost
9A	=	Vermont-Massachusetts-Rhode Island-New Hampshire-Maine	Massachusetts	@ 4.17472	5.0%	$3,090,903

[a]Cattle from Alabama
[b]Cattle from Louisiana
[c]Cattle from North Carolina

Conclusions

Study results indicated that markets of the Northeast and Lake States should continue to be dominated by the North Central region, and that flows of beef to other regions were suboptimal from a cost minimizing perspective. In essence, it would appear that the Northeastern markets offer potential for greater market development and penetration of beef from the North Central and Lake States. The major population centers in the Lake States region used its own beef, as well as beef from neighboring regions.

The major markets for Southern, Southeast and South Central beef were within their own regions. The South Central region supplied all of its own beef, and was the major exporter. The Southeast region consumed all of its production, as did most of the Southern region.

Population growth in the Sun Belt areas of the Southeast and South Central regions should present an encouraging picture for regional packers, since labor, land, and utility costs were among the lowest in the country.[10]

The Northeast region should always consume all of its own production, and be a major importer of beef from the North Central, Lake States, and some states from the Southern region.

The Northwest region enjoys relatively large animal populations and sparse human concentration, making it a major and stable supply source for beef in the Pacific Coast states and Salt Lake area.

The Southwest region exhibited a comparative advantage into the western Sun Belt. Like states in the eastern Sun Belt, population growth will attract increasing volumes of beef to the area.

Several generalizations can be drawn. First, the Plains states should continue to dominate the beef packing industry. The North

[10]At the time of this study the GA-FLA grid had a labor cost 46% lower than the California base, 10% lower land cost. Texas' labor was 30% lower, land 60% lower, and utilities 25% lower. Alabama's labor was 53% lower and utilities 25% lower. Oklahoma's land was 50% lower, and labor 34% lower.

Central region's comparative advantage into the Northeast and Lake States should continue and possibly expand. The expansion may result from two factors: 1) the decrease in small local plants due to government regulation, competition from box beef packers, and lack of new entrants due to high cost or the gradual shifting of cattle feeding to the Plains states (see Goodwin and Crow (22) and Byrkett *et al.* (9)), and 2) the population growth in the Sun Belt areas may attract beef away from the Mid-Atlantic and New England areas.

The second generalizaton refers to the growth of the Sun Belt area. An ideal area for beef packing is one close to both cattle and demand centers. The South Central region has the cattle, and if the population of that region continues to grow, there will be a natural increased demand for beef. Since this area has no climate or terrain problems, and some of the lowest resource prices in the nation, it would be reasonable to expect this to be a prime growth area. It also represents optimal network flows in accord with the optimal solution's goal of cost minimization for the industry.

Third, to minimize cost in the industry, the trend should be toward centralization and larger but fewer plants. Size economies indicate that plants taking advantage of automation and mechanization, combined with enough volume to permit labor specialization, can have the lowest average total cost and the greatest profit potential.

APPENDIX A

Average Length of Haul per Grid

Grid No.	States	Average length of haul, miles	(km)
1	Iowa	89	(143.2)
2	Nebraska	104	(167.3)
3	Kansas	108	(173.8)
4	Oklahoma	99	(159.3)
5	South Dakota	104	(167.3)
6	Missouri	99	(159.3)
7	Illinois	89	(143.2)
8	Texas	193	(310.5)
9	Colorado	121	(194.7)
10	Minnesota	106	(170.5)
11	Kentucky	75	(120.7)
12	Indiana	72	(115.8)
13	Alabama	85	(136.8)
14	Tennessee	77	(123.9)
15	California	149	(239.7)
16	Wisconsin-Michigan	89	(143.2)
17	Ohio	76	(122.3)
18	Montana-Idaho-Wyoming-North Dakota	17	(27.3)
19	Mississippi-Arkansas-Louisiana	83	(133.5)
20	Arizona-New Mexico	29	(46.7)
21	Pennsylvania-New Jersey-New York	56	(90.1)
22	Georgia-Florida	90	(144.8)
23	Utah-Nevada	17	(27.3)
24	Virginia-Delaware-Maryland-West Virginia	43	(69.2)
25	Washington-Oregon	7	(11.3)
26	North Carolina-South Carolina	74	(119.1)
27	New Hampshire-Vermont-Rhode Island-Maine-Connecticut-Massachusetts	37	(59.5)

APPENDIX B

Cost Formula in the Cj Generator

Assembly Cost

CASS = ((CAPYR (I) ÷ 20) ($1.2 Dist 1) ÷ (CAPYR (I)* CONV (I))

CAPYR	=	Annual capacity of the plant
Dist 1	=	Mileage
CONV(I)	=	Conversion factor

Slaughter Cost

CSL = (SCMISC (I) + (SCLND (I) * LNDADJ (L) + (CUTL (I) − UTLAdj
+ (SCLAB (I) * LABAdj (L))) ÷ CONV (I)

SCMISC (I)	=	"Other" FC + VC
SCLND (I)	=	Land cost
LNDADJ (L)	=	Land cost adjust
CUTL (I)	=	Utility cost
UTLAdj	=	Utility adjust
SCLAB (I)	=	Labor cost
LABADJ (I)	=	Labor adjust

Processing Cost

CPO = ((PLCAB(I) LABADJ(L)) + (PCELEC(I) UTLAdj (L)) + PCMISC (I)
+ PCATF(I)) ÷ CONV(I)

PCLAB	=	Labor cost
PCELEC	=	Electric Cost
PCMISC	=	"Other" variable cost
PCATF	=	Fixed cost

Meat Transportation Cost

CDIST = 2.1024 + ((.0027 Dist2) − (.0000503 40,000))
Dist2 = Mileage

Total Cost

TC = CASS + CPrO ÷ CDIST

APPENDIX C

Cost Adjustments by Grid

Grid No.	Land Adj.	Util. Adj.	Labor Adj.
1	1.34	.96763	1.12637
2	.54	.80544	.97563
3	.49	.86605	.85714
4	.50	.74828	.65830
5	.24	1.05406	1.02348
6	.67	.95833	.87969
7	1.57	.98416	.97714
8	.40	.75344	.70870
9	.33	.85882	.94079
10	.78	.92872	1.26786
11	.75	.54787	.84694
12	1.31	.77514	.86607
13	.60	.71798	.47430
14	.74	.62087	.77210
15	1.00	1.00	1.00
16	.82	1.01395	.94963
17	1.28	.74793	.02725
18	.31	.55970	.59913
19	.69	.80910	.51926
20	.15	.94956	.58674
21	1.68	1.26857	.76922
22	.90	1.07247	.55640
23	.23	.83510	.7379
24	1.28	1.0215	.63825
25	.52	.318	.73293
26	.84	.80578	.57886
27	1.45	1.21450	.72239

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