An Economic Analysis of the Optimum Number, Sizes and Locations of Livestock Auction Markets in Tennessee

University of Tennessee Agricultural Experiment Station

Dan L. McLemore
Emily A. McClain
Emmit L. Rawls

Follow this and additional works at: http://trace.tennessee.edu/utk_agresreport

Part of the Agriculture Commons

Recommended Citation
University of Tennessee Agricultural Experiment Station; McLemore, Dan L.; McClain, Emily A.; and Rawls, Emmit L., "An Economic Analysis of the Optimum Number, Sizes and Locations of Livestock Auction Markets in Tennessee" (1987). Research Reports.
http://trace.tennessee.edu/utk_agresreport/100
An Economic Analysis of the Optimum Number, Sizes and Locations of Livestock Auction Markets in Tennessee

Dan L. McLemore, Emily A. McClain and Emmit L. Rawls

Department of Agricultural Economics and Rural Sociology
AN ECONOMIC ANALYSIS OF THE OPTIMUM NUMBER, SIZES AND LOCATIONS
OF LIVESTOCK AUCTION MARKETS IN TENNESSEE

Dan L. McLemore, Emily A. McClain and Emmitt L. Rawls
# Table of Contents

<table>
<thead>
<tr>
<th>Component</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Method</td>
<td>4</td>
</tr>
<tr>
<td>Components of the Model</td>
<td>4</td>
</tr>
<tr>
<td>Supply Area and Livestock Numbers</td>
<td>4</td>
</tr>
<tr>
<td>Transportation Cost</td>
<td>5</td>
</tr>
<tr>
<td>Market Operation Cost</td>
<td>6</td>
</tr>
<tr>
<td>Buyer Operating Cost</td>
<td>7</td>
</tr>
<tr>
<td>Total Net Marketing Cost</td>
<td>9</td>
</tr>
<tr>
<td>Solution Method</td>
<td>10</td>
</tr>
<tr>
<td>Alternate Model and Sensitivity Analysis</td>
<td>13</td>
</tr>
<tr>
<td>Results</td>
<td>13</td>
</tr>
<tr>
<td>Primary Model</td>
<td>13</td>
</tr>
<tr>
<td>Alternate Model</td>
<td>19</td>
</tr>
<tr>
<td>Conclusions and Implications</td>
<td>21</td>
</tr>
<tr>
<td>References</td>
<td>25</td>
</tr>
<tr>
<td>Appendix: The Separable Programming Model</td>
<td>27</td>
</tr>
</tbody>
</table>
AN ECONOMIC ANALYSIS OF THE OPTIMUM NUMBER, SIZES AND LOCATIONS OF LIVESTOCK AUCTION MARKETS IN TENNESSEE

Dan L. McLemore, Emily A. McClain and Emmitt L. Rawls*

Introduction

The auction market system is an important component of the livestock industry in Tennessee and in other Southern states. In 1986, a total of 1.6 million head of cattle and hogs were sold through auction markets in Tennessee (Tennessee Department of Agriculture, 1986). This sales volume represents almost one-half of the total inventory of cattle and hogs in the state at the beginning of 1986 (Tennessee Department of Agriculture and USDA Statistical Reporting Service, 1986).

Economic efficiency in the organization of the auction market system is important to the economic viability of livestock enterprises.¹ Thus, both producers and users of Tennessee livestock, as well as related industries, are affected by changes in the efficiency of the system. Many different factors affect the efficiency of the system. Three of the more important factors are: 1) cost of operation of auction markets, 2) cost of transportation of animals to auction markets and 3) cost of operation incurred by buyers who purchase livestock at

---

¹Economic efficiency as used here may be measured as the ratio of the value of product or service produced to the value of the inputs used in the production process.

*Professor and former Graduate Research Assistant, Department of Agricultural Economics, and Professor, Extension Agricultural Economics and Resource Development, University of Tennessee, Knoxville, respectively.
auction markets. The most efficient or optimum system would be the one that minimizes the sum of these costs.

Previous research has shown that the per head cost of operation of livestock auction markets is affected by economies of size (Hicks and Badenhop; Spielman et al.). That is, as sales volume in a particular market increases, the cost of market operation per head decreases. This implies that efficiency in the marketing system could be improved by increasing the size and reducing the number of markets in the system.

Also, conventional wisdom holds that the per head costs that buyers incur in carrying on the business of purchasing livestock would be reduced if the auction system were composed of fewer but larger markets. These cost savings would result from the potential for buyers to: 1) purchase the same volume of livestock with less travel and time expenditure, 2) acquire truckload size lots of cattle at a single market, thus reducing hauling expenses and 3) acquire larger groups of cattle with more consistent characteristics, thus eliminating additional sorting. These factors would tend to make auction market systems with a smaller number of larger markets more efficient.

However, reducing the number and increasing the size of markets would make it necessary for most producers to haul livestock longer distances in order to reach the markets. Cost of transporting livestock to market would be greater. This would tend to reduce the efficiency of the system. Factors that affect the cost of transportation to market

---

2 Costs of operation of buyers include all costs involved in purchasing livestock except the price paid for the livestock.
include the transportation rate per mile and the geographic locations of
the markets relative to the geographic locations of livestock produc-
tion. With other things equal, transportation costs to market would be
reduced if markets were located near the heaviest concentrations of
livestock production. System efficiency is influenced by the location
as well as the size and number of markets.

Thus, a change in the livestock auction market system toward
larger but fewer markets would have mixed effects on efficiency. Costs
per head for market operation and for buyer operation would be reduced
while cost of transportation of livestock to market would be increased.
Based upon this logic, it is not clear whether larger but fewer markets
would actually improve efficiency. The most efficient or optimum number
of markets would be the one for which the sum of market operation, buyer
operation and transportation to market costs were minimized. The
optimum system of markets would also need to locate markets so as to
account for the geographic distribution of livestock across the state.
Thus, the optimum market number, sizes and locations must be determined
simultaneously.

The purpose of the research reported here was to determine the
optimum number, sizes and locations of livestock auction markets for
Tennessee considering costs of market operation, buyer operation and
transportation of livestock to market. The analysis assumed that the
geographic location of livestock production across the state was con-
stant. It was also assumed that there were no impediments to the
movement of markets among geographic locations. The following sections
discuss how estimates were obtained for the various pieces of informa-
tion needed to solve the problem. In general, this information was combined with a separable programming computer routine to find the optimum system of markets. For comparison purposes, an alternate model was also solved that ignored the cost of buyer operation. In addition, this research analyzed the effects of specific percentage changes in livestock numbers, transportation costs and market operation costs on the optimum number, sizes and locations of markets.

Method

Components of the Model

Supply area and livestock numbers. The basic geographic unit used in this study was the county. This was necessary because data on livestock numbers were not available for smaller geographic areas. For simplicity all livestock to be marketed in a given county were assumed to be located at the geographic center of the county. The geographic center of each county was also considered to be the potential auction market location for that county. Thus, all transportation routes between counties were from the geographic center of one county to the geographic center of the other county.

The area included in the study encompassed Tennessee and all counties outside the state whose geographic centers were within 50 air-miles of Tennessee's borders. The inclusion of areas surrounding Tennessee recognized that livestock are shipped across state lines. It

3The method of analysis used in this study could accommodate only one market per location. Therefore, this study considered only one market for each county.
also should have reduced the bias against border market locations within Tennessee in the optimum solution. A total of 238 counties were included in the area analyzed.

The potential supply area from which any given auction market could draw livestock was limited to those counties whose geographic centers were within 50 air-miles of the potential auction market location. This limit helped to reduce the number of potential transportation routes to be considered by the model without excluding realistic shipment routes. A total of 3,524 potential shipment routes were included in the analysis.

Livestock numbers to be marketed in each county were developed from livestock inventory data for 1983 from agricultural statistical bulletins for Tennessee and surrounding states (Tennessee Department of Agriculture and USDA Statistical Reporting Service, 1984). Expected annual marketings were estimated by taking a percentage of 1983 inventory numbers for each county. The percentage was the average percentage of total state inventory that was marketed through auctions during the 1972-82 period (McClain, p. 98). This approach averaged out fluctuations in percentage marketed that are associated with the cattle inventory cycle.

**Transportation cost.** Since both cattle and hogs are marketed through auctions, it was necessary to develop a common equivalency unit that could be used to represent livestock of both types. For this study an animal transportation unit (A.T.U.) was defined as one cow or two
calves or three hogs. Use of the A.T.U. allowed aggregation across livestock types for purposes of calculating transportation cost.

Typical farm-to-market transportation cost per mile per A.T.U. was estimated to be $0.226 in 1983 dollars. This estimate was developed from transportation cost budgets for various types of livestock hauling equipment and from typical loads of livestock hauled to auctions in Tennessee. Typical loads and types of equipment were based on a survey and study reported by McLemore et al. Details on the development of transportation costs may be found in McClain (pp. 83-96).

The transportation rate per mile per A.T.U. was multiplied by the air mileage for a given route to determine farm-to-market transportation cost for a shipment over that route. An arbitrary 10-mile distance was assigned for transportation from a county to itself to reflect within-county shipment costs.

**Market operation cost.** Cost of auction market operation was developed from a nonlinear long-run average total cost function developed for Tennessee markets by Spielman et al. This function was inflated to 1983 dollars and multiplied by volume to obtain the following nonlinear total cost function:

\[
TMC = 27,555 + 4.8728V - \frac{33,686,926}{V}
\]

4 The equivalencies used are roughly based on weight and space requirements in hauling.

5 It should be noted that the use of air mileage fails to account for differences in quality of roads and the necessity in some cases to use rather indirect road routes. However, simplicity justified use of this method of estimating distance.
where:

\[ TMC = \text{annual total cost of auction market operation (dollars)} \]

\[ V = \text{annual market volume in animal marketing units (A.M.U.).} \]

Since this function applied to both cattle and hogs marketed through auctions, it was again necessary to use a standard unit of measurement to allow aggregation across animal types. The animal marketing unit (A.M.U.) was defined as one cow or one calf or three hogs.\(^6\)

A graph of the total cost of market operation function is shown in Figure 1. While the function is nonlinear, it is almost linear at volumes larger than 20,000 A.M.U.

**Buyer operating cost.** The costs incurred by buyers in purchasing livestock were estimated by an indirect method. Estimates of cost savings associated with buying through fewer, larger auctions were developed from an estimated relationship between market volume and livestock price. If buyers realize cost savings by buying at auctions with larger volumes, then these cost savings should affect the price buyers are willing to pay for livestock. If competition among buyers is strong, prices should be forced up to the limit of cost savings. Thus, larger markets would exhibit higher average prices. To quantify this relationship, regression analysis was applied to Tennessee Department of Agriculture data on livestock prices and volumes from 16 auction markets in Tennessee during 1982-83.

---

\(^6\)The equivalencies used in the A.M.U. definition are roughly based on handling and space requirements during marketing.
Figure 1. Total Costs of Auction Market Operations
Data were collected for feeder steers, slaughter cows and sows. A separate regression relationship was developed for each type of livestock. The three separate relationships were combined by weighting each equation by the percentage of that type of livestock in the state's annual marketings. The resulting equation was manipulated to represent the total amount of buyer operating cost savings at various volume levels:

\[ TBS = 7.3579V - 0.000254V^2 \]

where:

- \( TBS \) = total annual change in buyer operating cost (dollars)
- \( V \) = annual market volume in animal marketing units (A.M.U.).

Additional details on procedures for developing this relationship are provided by McClain (pp. 104-112).

**Total net marketing cost.** Adding equation 2 to equation 1 results in the total net marketing cost function (TNC) used in the primary separable programming model:

\[ TNC = 27,555 + 12.2307V - \frac{33,686,926}{V} - 0.000254V^2 \]

where:

- \( TNC \) = the sum of annual total cost of market operation and total annual buyer operating cost savings (dollars).

Since this function is a combination of the level of market operation cost and the change in buyer operating cost, its absolute level has meaning only when compared to other levels from the same type of function. That is, the TNC function does not measure the level of total marketing cost.
A graph of equation 3 is presented in Figure 2. The equation is highly nonlinear and becomes negative at volumes larger than 51,000 A.M.U. This negative portion of the function results where the reduction in buyer operating cost exceeds the additional market operation cost associated with selling one additional animal.

**Solution Method**

Because of the nonlinear TNC curve, separable programming was chosen as the method for determining the optimum number, sizes and locations of auction markets (Baritelle and Holland). A general mathematical statement of the primary model is presented in the Appendix. Initially, the models were constrained to the actual locations and volumes of markets that existed in Tennessee in 1983. This actual 1983 pattern of markets in the state is shown in Figure 3. The initial constraints were then removed to allow the computer routine to identify the optimum system using the current system as the beginning point.  

In seeking an optimum market system, an upper limit of 90,000 A.M.U. per year was placed on individual market volume. Larger markets were not allowed in the solution because the data used to estimate market operation cost and buyer operation cost contained no observations on volumes above the 90,000 A.M.U. level. That is, no markets in Tennessee sold more than 90,000 A.M.U. This represents an unavoidable limitation on the results of the study.

---

7For additional information on solution procedures see McClain.
Figure 2. Total Net Cost Function
Figure 3. Map of the Supply Area with Locations and Volume Categories of Livestock Auction Markets in Tennessee, 1983 (Source: Tennessee Department of Agriculture, 1983).

Legend

Volume of Market (A.M.U.'s)

- X 1 to 7000
- • 7001 to 10000
- ○ 10001 to 20000
- □ 20001 to 30000
- ▲ 30001 to 50000
- △ 50001 to 80000
- ★ 80001 to 90000
Alternate Model and Sensitivity Analysis

To determine how the optimum solution would differ if the model did not account for buyers' operating costs, an alternate model was used that included only auction market operation cost and transportation cost to market. This type of model has been used by other studies dealing with the auction market system (Hicks and Badenhop; Grinnell and Shuffett). The marketing cost function used in the alternate model was equation 1 rather than equation 3.

In addition, sensitivity analyses were performed on both the primary and alternate models. These analyses consisted of arbitrarily changing the basic elements of the models to determine the resulting impacts on the optimum solutions. The changes included 10 and 25 percent increases in farm-to-market transportation cost per mile and in market operation cost per A.M.U. and 10 and 25 percent increases and decreases in livestock numbers in the state. Solutions to the models under these altered conditions help to demonstrate the validity of the model. These solutions also show how the optimum market system would change if the altered conditions actually occurred.

Results

Primary Model

The primary model identified an optimum system of 19 auction markets with an average annual volume of 80,562 A.M.U. each for Tennessee. The county locations of these markets and the sales volume

8 The solution to the primary model indicated that a substantial number of livestock would be hauled into Tennessee from bordering counties in other states.
of each for the optimum solution are shown in Table 1. Figure 4 provides a map of the state with optimum market locations and volume categories. This map may be compared with Figure 3, which shows the actual 1983 pattern of markets across the state. In 1983 there were 54 markets actually in operation in Tennessee with an average annual volume of 21,959 A.M.U. Some of the counties in Figure 3 had more than one market operating in 1983 (Tennessee Department of Agriculture, 1983).9

The optimum solution for the primary model suggests that a substantial reduction in the number of markets and a corresponding increase in the average size of markets would lead to a less expensive marketing system. Since the research method used in this study is an accumulation of estimates or approximations (e.g., all livestock were located at the geographic center of the county; air-miles were used instead of road-miles; buyer operation cost was estimated indirectly; etc.), the specific number of markets (19) and the specific locations from the optimum solution are probably not absolutely reliable. However, it is clear that efficiency in the livestock auction market system could be improved by reducing the number and increasing the size of markets.

The effect of changes in livestock numbers, transportation cost and market operation cost on the optimum number of markets are shown in Table 2 for the primary model. Changes in livestock numbers had substantial impact on the number of markets while changes in farm-to-market transportation cost and market operation cost did not have much impact.

9 In counties where more than one market was in operation in 1983, the volumes of the markets were summed to obtain the volume shown in Figure 3.
Table 1. Optimal Solutions to the Primary and Alternate Models for Tennessee

<table>
<thead>
<tr>
<th>Location (County)</th>
<th>Annual Volume (A.M.U.'s)</th>
<th>Primary Model</th>
<th>Alternate Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson</td>
<td>--</td>
<td>18,221</td>
<td></td>
</tr>
<tr>
<td>Carroll</td>
<td>--</td>
<td>15,937</td>
<td></td>
</tr>
<tr>
<td>Claiborne</td>
<td>90,000</td>
<td></td>
<td>21,000</td>
</tr>
<tr>
<td>Cocke</td>
<td>--</td>
<td>16,773</td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>--</td>
<td>42,552</td>
<td></td>
</tr>
<tr>
<td>Crockett</td>
<td>--</td>
<td>37,092</td>
<td></td>
</tr>
<tr>
<td>Cumberland</td>
<td>--</td>
<td>29,802</td>
<td></td>
</tr>
<tr>
<td>Dickson</td>
<td>90,000</td>
<td></td>
<td>51,810</td>
</tr>
<tr>
<td>Dyer</td>
<td>23,584</td>
<td></td>
<td>11,921</td>
</tr>
<tr>
<td>Fentress</td>
<td>90,000</td>
<td></td>
<td>36,412</td>
</tr>
<tr>
<td>Gibson</td>
<td>--</td>
<td>20,513</td>
<td></td>
</tr>
<tr>
<td>Giles</td>
<td>--</td>
<td>31,719</td>
<td></td>
</tr>
<tr>
<td>Greene</td>
<td>29,055</td>
<td></td>
<td>40,436</td>
</tr>
<tr>
<td>Hamblen</td>
<td>--</td>
<td>44,090</td>
<td></td>
</tr>
<tr>
<td>Hamilton</td>
<td>38,034</td>
<td></td>
<td>29,029</td>
</tr>
<tr>
<td>Hardeman</td>
<td>--</td>
<td>36,950</td>
<td></td>
</tr>
<tr>
<td>Hardin</td>
<td>90,000</td>
<td></td>
<td>8,977</td>
</tr>
<tr>
<td>Hawkins</td>
<td>--</td>
<td>35,900</td>
<td></td>
</tr>
<tr>
<td>Henderson</td>
<td>--</td>
<td>25,730</td>
<td></td>
</tr>
<tr>
<td>Henry</td>
<td>90,000</td>
<td></td>
<td>22,751</td>
</tr>
<tr>
<td>Jackson</td>
<td>90,000</td>
<td></td>
<td>13,482</td>
</tr>
<tr>
<td>Johnson</td>
<td>--</td>
<td>6,069</td>
<td></td>
</tr>
<tr>
<td>Knox</td>
<td>90,000</td>
<td></td>
<td>29,351</td>
</tr>
<tr>
<td>Lawrence</td>
<td>--</td>
<td>32,077</td>
<td></td>
</tr>
<tr>
<td>Lincoln</td>
<td>90,000</td>
<td></td>
<td>25,010</td>
</tr>
<tr>
<td>Macon</td>
<td>90,000</td>
<td></td>
<td>11,757</td>
</tr>
<tr>
<td>Marion</td>
<td>--</td>
<td>7,085</td>
<td></td>
</tr>
<tr>
<td>Location (County)</td>
<td>Annual Volume (A.M.U.'s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primary Model</td>
<td>Alternate Model</td>
<td></td>
</tr>
<tr>
<td>Marshall</td>
<td>49,093</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maury</td>
<td>90,000 50,027</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monroe</td>
<td>90,000 68,010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obion</td>
<td>21,606</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perry</td>
<td>4,781</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Putnam</td>
<td>15,618</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhea</td>
<td>5,630</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robertson</td>
<td>90,000 26,074</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rutherford</td>
<td>32,421</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shelby</td>
<td>90,000 14,619</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smith</td>
<td>16,013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stewart</td>
<td>90,000 22,310</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sullivan</td>
<td>90,000 21,014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trousdale</td>
<td>90,000 35,126</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warren</td>
<td>46,662</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td>26,378</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weakley</td>
<td>19,952</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>26,249</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williamson</td>
<td>40,757</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilson</td>
<td>27,566</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 4. Optimum Livestock Auction Market Locations and Size Categories for the Primary Model

Legend

Volume of Market (A.M.U.'s)

\[ \begin{align*}
\times & \quad 1 \text{ to } 7000 \\
\bigcirc & \quad 7001 \text{ to } 10000 \\
\square & \quad 10001 \text{ to } 20000 \\
\bullet & \quad 20001 \text{ to } 30000 \\
\blacksquare & \quad 30001 \text{ to } 50000 \\
\blacktriangle & \quad 50001 \text{ to } 80000 \\
\star & \quad 80001 \text{ to } 90000
\end{align*} \]
Table 2. Changes in the Primary and Alternate Models' Solutions in Response to Variations in Model Components

<table>
<thead>
<tr>
<th>Variation in the Model</th>
<th>Changes in the Number of Tennessee Markets</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Primary Model</td>
<td>Alternate Model</td>
</tr>
<tr>
<td>Livestock numbers decreased 10%</td>
<td>-4</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>Livestock numbers decreased 25%</td>
<td>-5</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td>Livestock numbers increased 10%</td>
<td>0(^a)</td>
<td>0(^a)</td>
<td></td>
</tr>
<tr>
<td>Livestock numbers increased 25%</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Transportation cost increased 10%</td>
<td>0(^a)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Transportation cost increased 25%</td>
<td>0(^a)</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Marketing cost increased 10%</td>
<td>-1</td>
<td>0(^a)</td>
<td></td>
</tr>
<tr>
<td>Marketing cost increased 25%</td>
<td>0(^a)</td>
<td>-4</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Changes in market number for the total supply area were consistent with prior expectations, though changes for the state alone might not have exhibited this same consistency.
Reductions in livestock numbers of 10 and 25 percent caused comparable reductions in the number of markets (to 15 and 14 markets, respectively). A 10 percent increase in livestock numbers was accommodated with no increase in market number, while a 25 percent increase in livestock led to an increase in markets from 19 to 23. This suggests that a substantially larger livestock industry than currently exists in Tennessee could be handled efficiently by a relatively small number of auction markets. The lack of change in market number as a result of increases in transportation cost implies that rather large increases in fuel cost would probably have little impact on the most efficient number of markets.

**Alternate Model**

The optimum solution for the alternate model (ignoring buyer operating cost) consisted of a system of 47 markets with average annual volume of 26,859 A.M.U. per market for Tennessee. The counties in which these markets would be located and the market volumes are shown in Table 1. The corresponding map is given in Figure 5. This map may be compared with the actual pattern of markets in Figure 3. The alternate model suggests that a reduction of seven markets statewide would lead to improved efficiency. This reduction was suggested even though buyer operating cost was excluded from the model. As noted earlier, the exact number and locations of markets in the optimal solution are probably not important. The direction of change in the number of markets needed to improve efficiency is clear.

Sensitivity of the optimum solution from the alternate model is indicated in Table 2. The changes in the optimum system in response to
Figure 5. Optimum Livestock Auction Market Locations and Size Categories for the Alternate Model

Legend

Volume of Market (A.M.U.'s)

- \( \times \) 1 to 7000
- \( \circ \) 7001 to 10000
- \( \square \) 10001 to 20000
- \( \bullet \) 20001 to 30000
- \( \blacksquare \) 30001 to 50000
- \( \blacktriangle \) 50001 to 80000
- \( \blackstar \) 80001 to 90000
changes in livestock numbers, transportation cost and marketing cost seemed to be relatively small except for the case in which transportation cost was increased by 25 percent wherein an increase of nine markets was indicated (an increase from 47 to 56 markets).

Comparison of the optimum number of markets in the alternate model solution with the optimum number of markets in the primary model solution provides an indication of the effect of ignoring one of the costs inherent in the total marketing system. The failure to consider estimated economies of size in buyer operation cost resulted in more than doubling the number of markets that appeared to be most efficient in Tennessee.

**Conclusions and Implications**

The results of this study provide evidence that the economic efficiency of the livestock auction market system in Tennessee would be improved if the number of markets was reduced, and the average sales volume of the remaining markets was increased. The increased size of markets would allow the system to take advantage of economies of size in auction market operation and in the operation of buyers who purchase livestock through auction markets. The increased distance from farm to market that is implied by fewer but larger markets would not increase the transportation cost per head by enough to offset the economies of size. Improvements in overall efficiency would continue as market
number is reduced to the point where fewer than half the current number of markets remain in operation.\textsuperscript{10}

This conclusion is consistent with results obtained by Hicks and Badenhop in the late 1960s. They found that a total of 18 markets in the state would be optimum whereas the current study suggested 19 markets.

These results are also consistent with the recent trend in auction market number in Tennessee. At the time of the Hicks and Badenhop study, a total of 74 markets were in operation. By 1983, 54 markets were left and at the end of 1986 only 52 markets remained. This trend provides evidence that economic pressure may be pushing the industry slowly in the direction indicated by this study.

In addition, the most efficient number of markets indicated by the primary model was not changed substantially by increases in either farm-to-market transportation cost or market operation cost. Increases in livestock numbers in the state would increase the most efficient number of markets somewhat.

Implications of this study for individual auction markets and their operators are that there will probably be continued economic pressure to increase the number of livestock handled or to cease operation. This suggests that some markets should grow while others shrink and finally close. Consolidation of smaller markets might be

\textsuperscript{10}This study did not consider the benefits to be derived from competition among auction markets. These benefits might include such things as lower fees for auction market services and improved quality of service for those patronizing the markets. Degree of competition is difficult to quantify and was, therefore, omitted from the analysis.
practical. The establishment of new markets should probably be dis-
couraged unless each new market can expect to replace two or more
existing smaller markets, leading to a net reduction in the total number
of markets over time. Duplication of marketing services would prove
detrimental to overall system efficiency.
References


Appendix

The Separable Programming Model

In order to use the separable programming optimization method, the nonlinear TNC function (Figure 2) was approximated by seven linear segments. This procedure allowed a reasonably accurate representation of the function without employing an excessive number of linear segments.

The general mathematical optimization model may be stated as follows for the primary model:

Minimize: \[ TCC = \sum_{i=1}^{m} \sum_{j=1}^{m} t_{ij}a_{ij} + \sum_{i=1}^{m} \sum_{j=1}^{m} c_{nj}a_{ij} \]

Subject to:

1. \[ \sum_{j=1}^{m} a_{ij} \leq a_i, \quad i = 1, 2, \ldots, m \]
2. \[ \sum_{i=1}^{m} \sum_{j=1}^{m} a_{ij} \geq A \]
3. \[ \sum_{i=1}^{m} a_{ij} = A \]

where:

- \( TCC \) = total annual combined costs of transportation and marketing of livestock sold through auction markets in the supply area
- \( t_{ij} \) = cost of transporting one A.T.U. from county \( i \) to market \( j \)
- \( a_{ij} \) = number of A.T.U. transported from county \( i \) to market \( j \) or number of A.M.U. marketed at market \( j \)
- \( c_{nj} \) = marketing cost (consisting of market operation cost and buyer operation cost savings) per A.M.U. along segment \( n \) of the linearized cost function for market \( j \)
- \( A \) = the total quantity of livestock (A.T.U.) to be marketed through auctions in the supply area
\[ a_i = \text{number of A.T.U. to be marketed from county } i \]

\[ m = \text{the number of counties, which equals the potential number of markets (} m = 238) \]

\[ n = \text{the number of linear segments into which TNC was separated (} n = 7) \]

The first term of the objective function is the summation of transportation costs for all livestock. The second term is the summation of the net costs of marketing all livestock. The three constraining equations combine to insure that all livestock are shipped and marketed and also to eliminate the possibility of negative shipments.

For the alternate model, \( c_{nj} \) consisted of market operation cost only, rather than including both market operation cost and buyer operating cost savings as shown above for the primary model.