RESEARCH BULLETIN 873 NOVEMBER, 1964

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURE EXPERIMENT STATION

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Costs of Hauling Bulk Milk From Farm to Plant

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(Publication Authorized November 18, 1964)

COLUMBIA, MISSOURI

Table of Contents

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O. RICHARD MORRIS AND RUSSELL G. THOMPSON

Highlights of the Study

Labor Costs

Considerably less labor is needed to procure milk from large patrons than from small ones.

Labor costs per hundredweight are significantly less for large trucks than small ones.

The effect of declining patron density upon labor costs in and of itself is relatively small regardless of the size of transport used.

Truck Costs

Large milk hauling units, if well utilized, have smaller truck costs per unit of pay load and distance than small ones.

Hauling Costs

Savings attainable through increased truck utilization are less than three cents per hundredweight.

Relatively large economies of truck size exist when truck and labor costs are aggregated to obtain hauling costs.

The cost effects of patron size and density are quite large and similar in magnitudes for the relatively small truck units.

Lower patron densities have much less effect upon hauling costs of the large trucks than upon hauling costs of the small ones.

The increasing hauling cost effect of decreasing producer density can be minimized and, furthermore, kept quite small through the utilization of relatively large transports and the retention of relatively large patron stops.

STATEMENT OF THE PROBLEM AND OBJECTIVES OF THE STUDY

Prior to 1955, milk was hauled from the farm to the processing plants in the traditional "milk cans" and the van type truck. Since then the development of stainless steel tanks for farm storage and milk hauling in conjunction with the development of other complementary equipment has changed remarkably the methods of transporting milk from dairy farmers to processing plants. These technological changes have affected hauling costs both in terms of truck costs and labor costs and furthermore the structure of the milk industry in southwest Missouri.

[1]The authors are indebted to Floyd Lasley for the data he contributed to this study and to Stephen Whitted for the assistance he freely gave.

Many milk producers have stopped producing milk on their farms and have started producing other commodities such as beef cattle. Yet, at the same time, other farmers have increased their herd sizes to cover the costs of installing bulk milk systems. The net result has been less milk production from a smaller number of producers in this area. Thus, most of the processors have had to increase the sizes of their supply areas to obtain the needed volumes of milk for their plants.

The primary objective of this study was to isolate the significant relationships which largely determine the transportation costs of farm-to-plant bulk milk hauling. Then with this point of departure, our second objective was to develop an accurate set of cost estimates for this type of milk hauling and to test the significance of each of the specified relationships.

RESEARCH PROCEDURE

The analytic framework formulated to explain farm-to-plant bulk milk hauling costs consisted basically of two relationships: labor costs and truck costs. Both relationships were of a form which lent themselves to functional representation.

Classification of Labor and Truck Costs

Labor costs were expressed as a function of miles driven, volume hauled, number of loads, number of loading stops, and sizes of unloading equipment. Truck costs were expressed as a function of truck capacity, miles driven, and number of loads hauled per month.

The labor relation was further partitioned in economically independent plant and route components to facilitate analysis. Time spent by the driver at the plant is distinct from time spent collecting milk.

The plant and route components of labor were further partitioned into variable and fixed classifications.

The components classified as variable generally change with the number of miles driven, volume of milk handled, number of patrons serviced, and sizes of the loading and unloading equipment. At the plant, the time needed for unloading varies with the volume of milk unloaded; while, en route, the time needed for loading and driving varies typically with the volume loaded and miles driven, respectively.

On the other hand, none of the components classified as fixed generally vary significantly with any set of factors. This is true regardless of the distance traveled, the volume of milk handled, or the size of the equipment used.

The truck cost relationship was partitioned into variable and fixed components, too. Costs of fuel, oil, repairs, and tires are classified as variable since each of them typically varies with the distance a truck travels. However, depreciation, insurance, taxes, interest, license, and miscellaneous truck costs generally do not vary much with distance, and thus they are classified as fixed costs.[2]

[2]Depreciation is one of those costs which might be classified as a quasifixed cost. Some managers do attain a high level of utilization; and for their operations, depreciation is a function of time and use. But, with recent rapid rates of obsolescence, they are believed to be the exception rather than the rule. So we classified depreciation strictly as a fixed cost for the purposes of this study.

A summary of this classification of hauling cost is given in Table 1. You may find this summary table helpful in the reading of this manuscript.

Analytical Framework

Using the above classification as a point of departure, we will now formulate a theoretical framework mathematically. It clearly shows the relationships involved in the labor and truck cost analysis and the arguments contained in each relationship.

Much of the work in this section will be done in a mathematical context. We will first define most of the symbols used in the formulation of each model before we begin our model building. In this way, you will have one complete and unified glossary for each discussion.

Labor Cost Models

The total amount of time required to collect the milk on one farm-to-plant bulk milk route is the sum of the time required to complete all of the fixed and variable tasks on each route. The labor cost models will be formulated in a stepwise manner. We will first formulate a model for the fixed labor tasks on each route and then for the variable labor tasks. With models for each of these components, we will then sum the relationships in these two models and obtain a model for the total labor relationship. Of course, it will be in physical terms and we will want it in value terms for our final analysis. Hence, our final step in the formulation of the labor-cost relationship will be to convert the total labor model into value terms.

Symbols for Labor Cost Models

Fixed Labor Components at the Plant in Hours

x_1	Route preparation
x_2	Positioning to unload
x_3	Hookup
x_4	Unhook
x_5	Washing of hauling equipment
x_6	Waiting to unload
x_7	Waiting to move out
x_8	Waiting to wash
x_9	Waiting after washing

Fixed Labor Components on the Route in Hours

x_{10}	Positioning to load
x_{11}	Washing of the farm bulk tank
x_{12}	Driving on the farm
x_{13}	Residual time on farm

Table 1: CLASSIFICATION OF FARM TO PLANT MILK HAULING COSTS FOR BULK TANK TRUCK UNITS

Labor Costs				Truck Costs	
Plant		Route			
Variable	Fixed	Variable	Fixed	Variable	Fixed
Unloading time	Route preparation	Driving time	Positioning to load	Fuel and oil	Depreciation
	Productive time:	Starting point to first patron	Washing farm tank	Repairs and repair labor	Insurance
					Taxes
	Positioning to load		Driving on farm	Tires	
		Route time			Interest
	Hookup	Last patron to unloading point	Residual time on farm		License
	Unhook				
	Washing truck tank	Unloading point to next starting point			
	Unproductive time (Wait):	Unloading time			
	To unload To move out To wash tank After washing tank				

Variable Labor Components at the Plant in Hours

$P_1(k,v)$	Unloading time (pumping) where k is the size of the unloading equipment and v is the hundredweight of milk loaded

Variable Labor Components on the Route in Hours

$P_2(v)$	Loading time (strictly pumping) where v is the hundredweight of milk loaded
$D_1(d_1)$	Driving time from the starting point to the first farm patron where d_1 is the number of miles driven
$D_2(d_2)$	Driving time on the route where d_2 is the number of miles driven
$D_3(d_3)$	Driving time from the last farm patron to the unloading point where d_3 is the number of miles driven
$D_4(d_4)$	Driving time from the unloading point to the next starting point where d_4 is the number of miles driven

Models for Fixed Labor

In the formulation of a fixed labor model, we have to consider the amount of fixed time typically needed at the plant, the amount of fixed time commonly occurring on each farm and the number of farm stops en route.

We can obtain the amount of fixed time needed at the plant by summing the fixed components of time:

$$\sum_{i=1}^{9} X_i = X_1 + X_2 + \cdots + X_9.$$

The fixed time at each farm is derived in the same manner as the fixed time at the plant. The following symbols represent this summation process for fixed farm time:

$$\sum_{i=10}^{13} X_i = X_{10} + X_{11} + X_{12} + X_{13}.$$

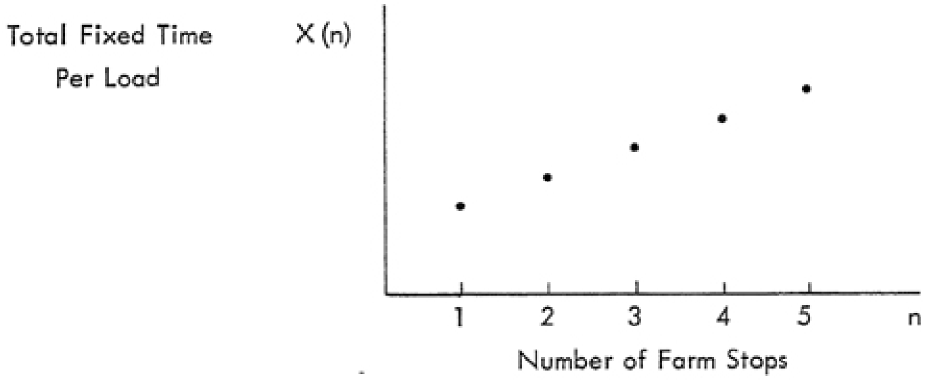
Letting n represent the number of farms on the route, we can express the total amount of fixed time needed for all of the farms on the route as the mathematical product of the number of farms n and the fixed time on each farm:

$$n \sum_{i=10}^{13} X_i.$$

The total amount of fixed time for a load is the sum of the total fixed time at the plant and the total fixed time at all of the farms on the route. Let $X(n)$ represent the total amount of fixed time needed per load where n is the number of patrons on the route. Then we can sum these two totalized components of fixed time mathematically and obtain total fixed time for a load:

$$X(n) = \sum_{i=1}^{9} X_i + n \sum_{i=10}^{13} X_i.$$

You may notice from this symbolic formulation that total fixed time per load X(n) is a function of the number of patrons n. This functional relationship between total fixed time and the number of farm stops is depicted below as a well-known integer function.



The incremental increase in total fixed time per load after the first patron stop represents the amount of fixed time needed for each farm stop.

The function X(n) was estimated in a relatively straight forward manner. We just summed the sample means, X_i, for each of the fixed classifications:

$$X(n) = \sum_{i=1}^{9} X_i + n \sum_{i=10}^{13} X_i.$$

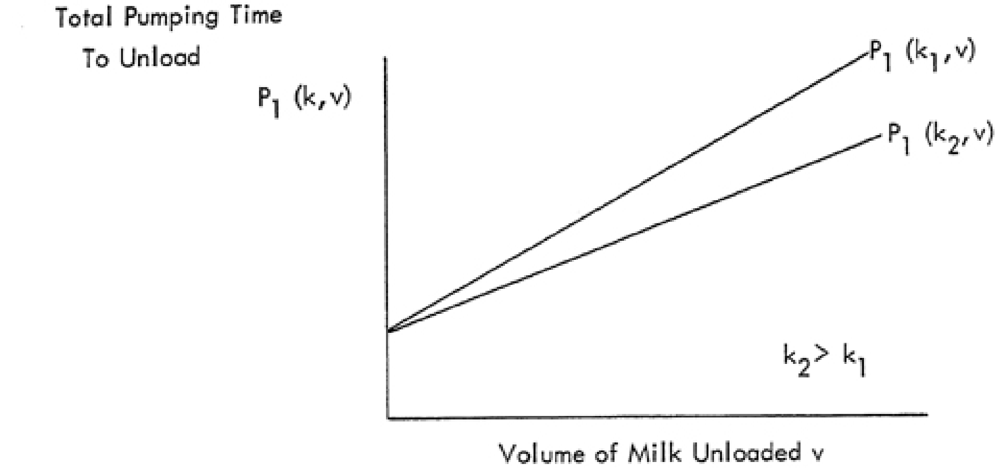
Model for Variable Labor

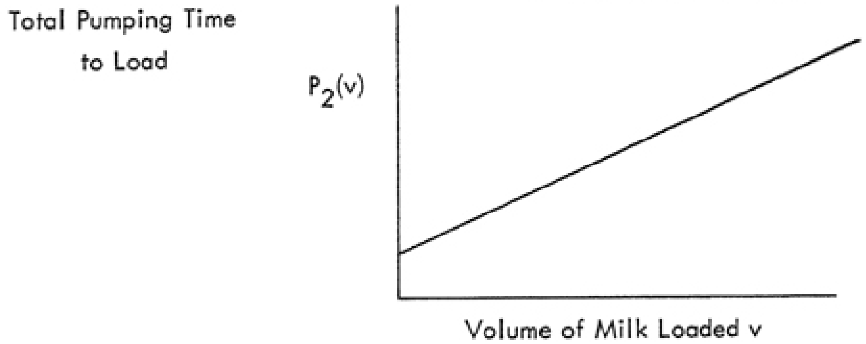
Unloading Labor. Unloading time is a function of the size of the unloading equipment and the volume of milk unloaded. For a given size of unloading equipment k, the amount of time required to unload a load of milk is a linear function of the volume unloaded.

Linear functions such as the ones depicted below provide graphic representations of this relationship. You may observe both relationships originate from the same point and P_1 (k_2,v) rises much slower with volume than P_1 (k_1,v). This characteristic is associated with the assumption that the unloading equipment k_2 is larger than k_1.

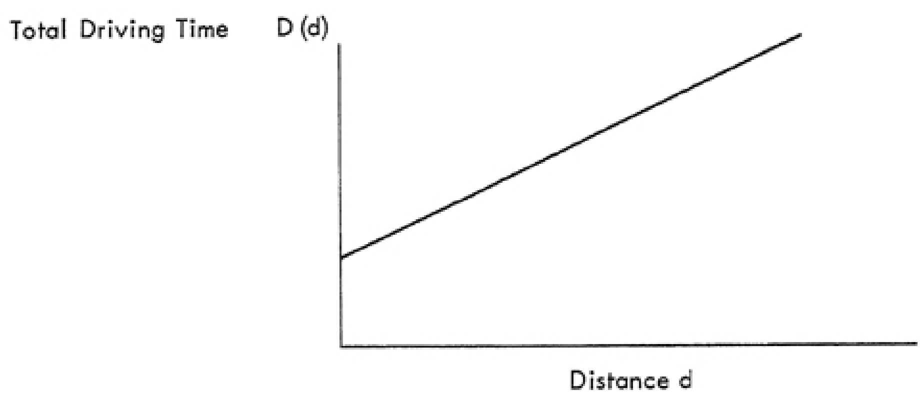
Loading Labor. Loading time is a function of the volume of milk loaded and the size of the loading equipment used. Again, a linear function $P_2(v) = \alpha + \beta v$ provides a good representation of this relationship. Generally, the slope of a loading time relationship will be greater than the slope of an unloading relationship because the pumping equipment is typically smaller in the first case than the second.[3]

[3]Only one unloading function is depicted because just one size of loading equipment was observed in this study .





Driving Labor. You may recall from Table 1 that we separated driving time into four different components: (1) starting point to the first patron, (2) route time, (3) last patron to the unloading point and (4) unloading point to the next starting point. For each of these components, the driving time relationships would be expected to be linear functions of miles driven. This linearity is expected on the basis of the characteristics of the driving process and the results of other studies. In each instance, it generally takes the driver a small amount of time to get the truck unit moving after which his time-wise performance is largely a linear function of the number of miles driven.



Letting D(d) represent driving time we may depict the graphic relationship between driving time and miles driven for each of the components as follows:

Total Variable Labor. Since the variable labor components are relatively independent of each other, we can add these components to obtain total variable labor time per load, $Z(k,d_1,d_2,d_3,d_4,v)$.

The following equation expresses this relationship mathematically: $Z(k,d_1,d_2,d_3,d_4,v) = P_1(k,v) + P_2(v) + D_1(d_1) + D_2(d_2) + D_3(d_3) + D_4(d_4)$

Hours of total variable labor per route is a function of (1) size of the unloading equipment k, (2) the distances that the truck travels over the different route segments d_1, d_2, d_3, d_4, and (3) the volume of milk hauled, v.

To obtain an estimate of this function, we will first estimate each of the variable labor components and then sum all of the estimates. The estimated equation will be expressed in the following form:

$$Z(k,d_1,d_2,d_3,d_4,v) = P_1(k,v) + P_2(v) + D_1(d_1) + D_2(d_2) + D_3(d_3) + D_4(d_4).$$

Model for Total Labor for a Load

The total amount of labor time needed to procure a load of milk is the sum of total amount of time needed for the fixed tasks and the amount of time needed for the variable tasks. Again, this summation is permissible because total fixed time and total variable time are relatively independent.

Letting $L(n,k,d_1,d_2,d_3,d_4,v)$ represent its estimate, the following equations express the total labor relation and its estimate:

$$L(n,k,d_1,d_2,d_3,d_4,v) = X(n) + Z(k,d_1,d_2,d_3,d_4,v),$$
$$L(n,k,d_1,d_2,d_3,d_4,v) = X(n) + Z(k,d_1,d_2,d_3,d_4,v).$$

Model for Total Labor Cost for a Load

For the purposes of this study, we assumed that all of the drivers were paid the same wage rate regardless of the number of hours they worked. Thus, total labor costs are the mathematical product of the total number of hours needed to operate a route and the assumed hourly wage rate of the driver. Letting w represent the wage rate of the driver, total labor costs per load and its estimates are:

$$TLC(n,k,d_1,d_2,d_3,d_4,v,w) = wL(n,k,d_1,d_2,d_3,d_4,v)$$
$$TLC(n,k,d_1,d_2,d_3,d_4,v,w) = wL(n,k,d_1,d_2,d_3,d_4,v)$$

You may now observe that total labor costs of hauling a load of milk are a function of the number of patrons, the size of the transfer equipment, the distances of the different route segments, the volume of milk transported, and the wage rate of the driver. Its estimate is clearly the product of the estimated function (of course, of the same arguments) and the assumed wage rate of the driver.

Truck Cost Models

On the basis of recent work done by Thompson,[4] Groves and Cook,[5] and Miller[6] we expected the total truck costs relationship to break down into independent economic components much like those postulated for labor costs. We naturally expected total variable truck costs for the most part to be a linear function of factors such as miles driven and the utilization of capacity. But, much to our surprise, the sample of data obtained for southwest Missouri made the statistical estimation of such a model virtually impossible. Thus, our mathematical formulation of the analytical framework for truck costs had to be completely revised after we started an analysis of the data base.

The data base consisted of monthly and annual truck records for 23 bulk milk trucks operating in southwest Missouri. The truck records analyzed were organized in terms of total operating expenses less gasoline costs, distance traveled, volume hauled, and gallons of gasoline. We could only obtain data on single truck units for two of the four sizes of trucks typically operated in southwest Missouri.

Included in the monthly data for total operating expenses less gasoline expenses were some expenses which represented operating expenses for several months. Major engine overhauls and new tire purchases were the largest expense items of this type and their lumpiness badly distorted the monthly figures.

Each of the data points in Figures 1 through 4 (and Figures A through D in the Appendix) represent total variable truck costs for the respective distances traveled and volumes hauled for the monthly operation of one truck. Upon examination of these figures, you will notice that the data points tend to concentrate about the means of distance and variable costs.

The data points which lie above these areas of concentration represent months when major expenditures were made upon some truck units. These major expenditures could not be associated with any given truck unit; and furthermore, we lacked specific information on repair costs, tire replacement costs, and the distances traveled between the occurrences of these major expenditures. Hence, we could not justify any specific method of spreading these large deviations over any specific time period, distance, or volume.

Those data points near the origins of the graphs represent largely observations in months when a truck was traded during the early part of a month or a new truck was operated for only part of a month. We had no economic or statistical justification for eliminating these observations from the study; so we included them in our data base for our analysis.

[4]Russell G. Thompson, *An Approach to Estimating Optimum Sizes of Butter-Powder Plants* (Unpublished doctoral dissertation), University of Minnesota, 1962. (See Chapter IV, "Research Procedure Used in Estimating Hauling Costs Between Concentration Points and Processing Plants.") Also Russell G. Thompson, and E. Fred Koller, Interplant Milk Transportation Costs, Univ. of Minn. Ag. Experiment Station Bulletin 465, June '63.

[5]F. W. Groves and H. L. Cook, *Hauling and Transportation Cost Functions for Wisconsin Milk*. University of Wisconsin, Agricultural Economics 31, April, 1961.

[6]Arthur H. Miller, *Bulk Handling Milk—Farm-to-Plant*, Wisconsin Agricultural Experiment Station Bulletin No. 192, 1956.

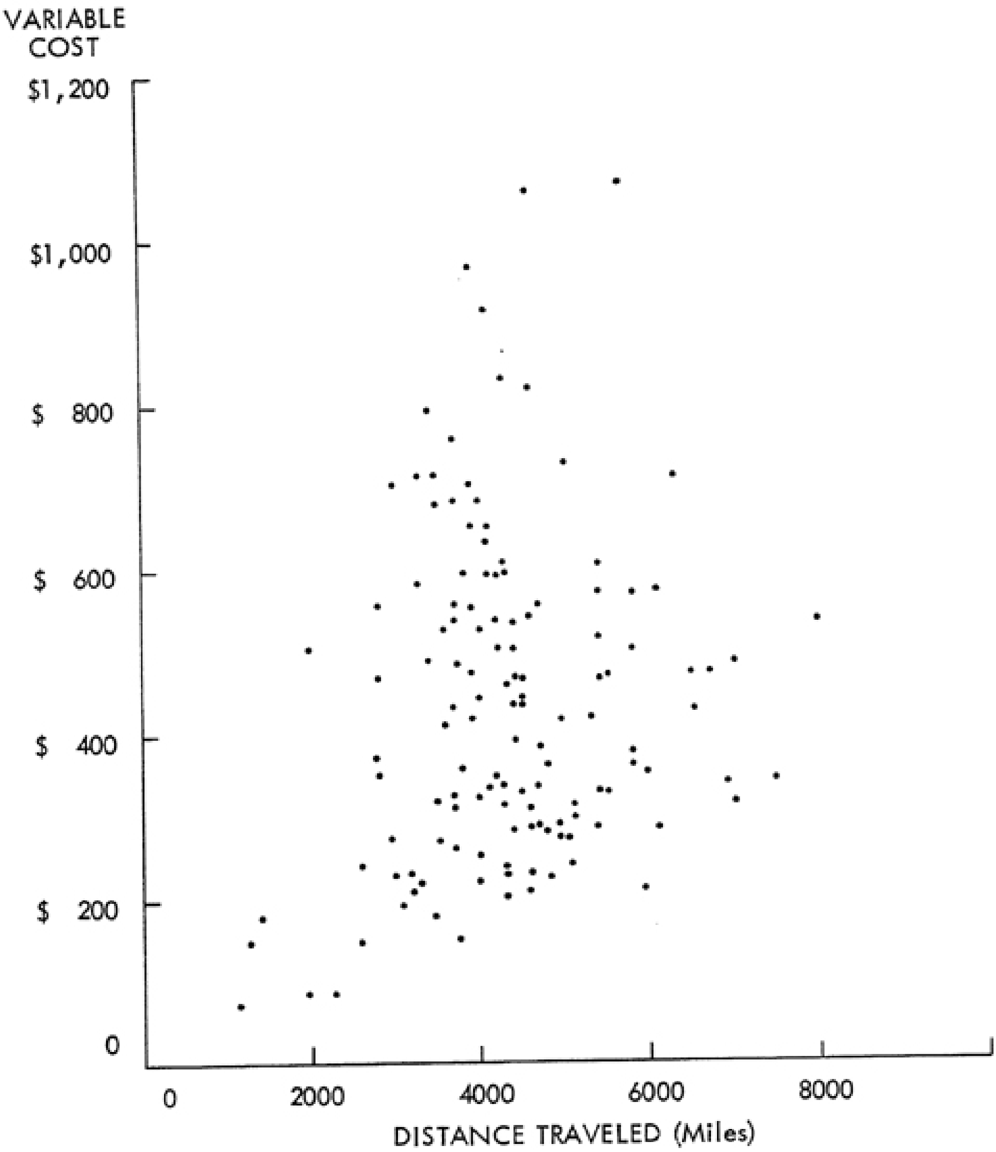


Figure 1: Total Variable Truck Costs Versus Distance Traveled Per Month for 14,800 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri.

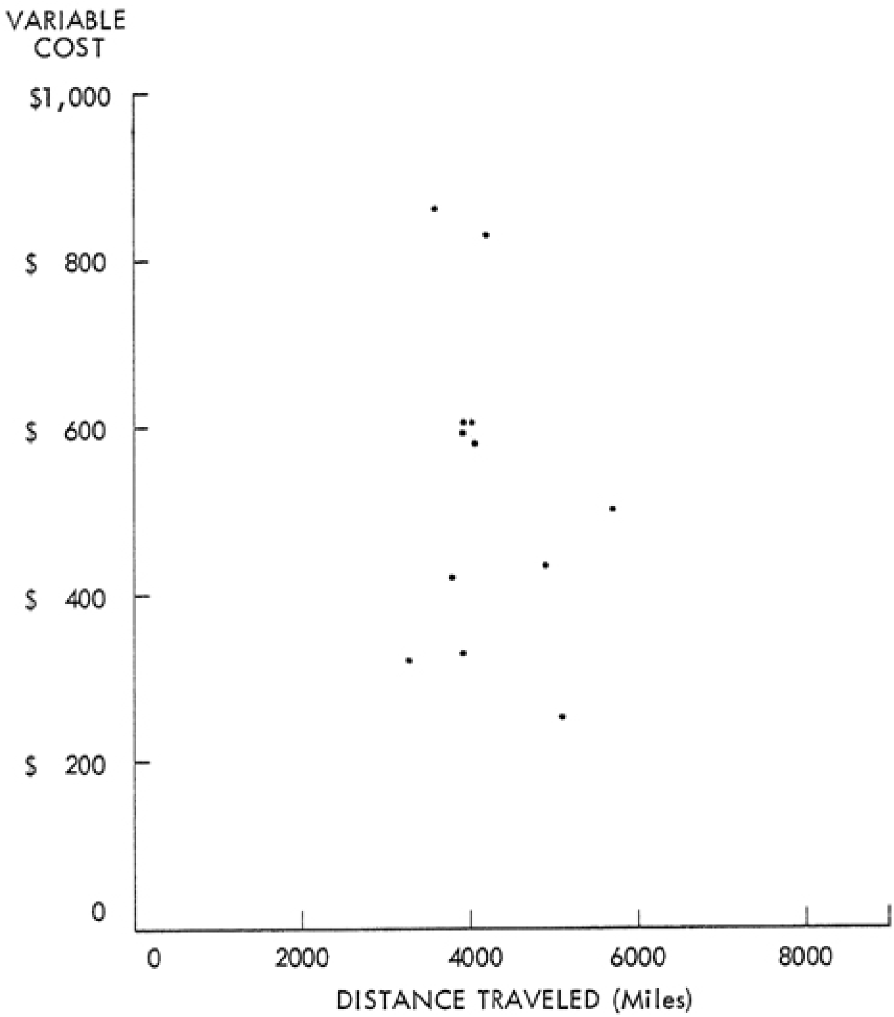


Figure 2: Total Variable Truck Costs Versus Distance Traveled Per Month for 17,500 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri.

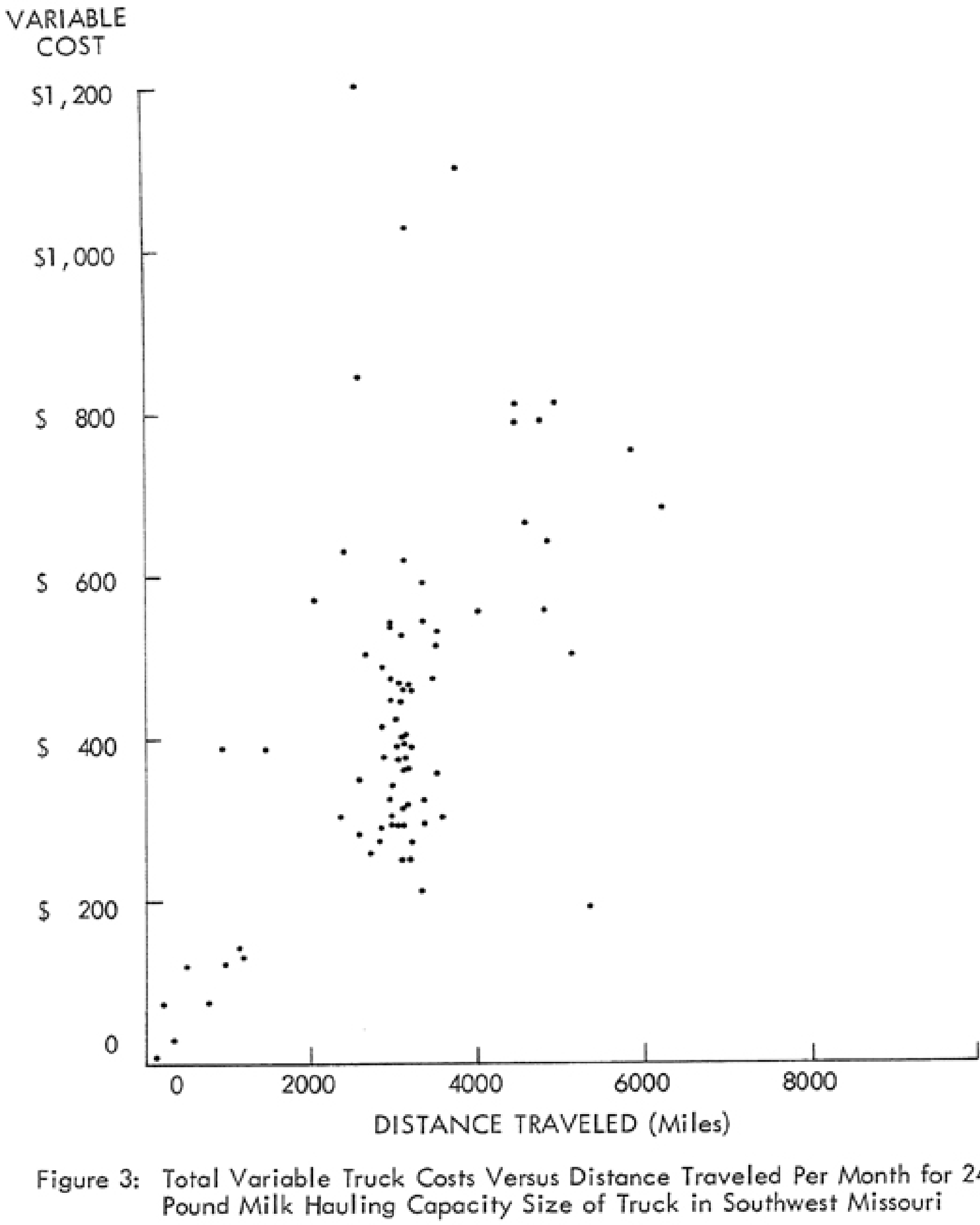


Figure 3: Total Variable Truck Costs Versus Distance Traveled Per Month for 24,600 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri

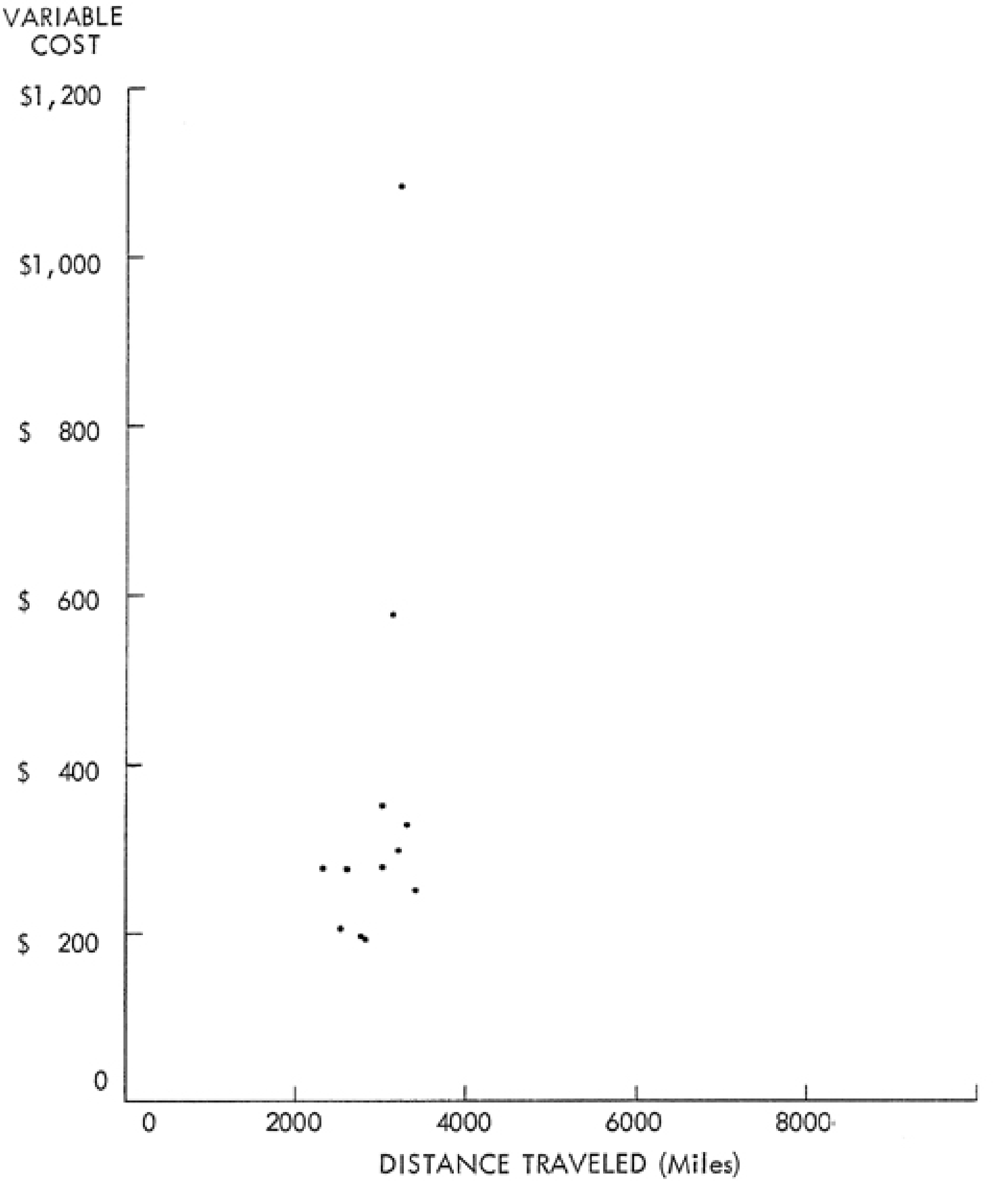


Figure 4: Total Variable Truck Costs Versus Distance Traveled Per Month for 34,400 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri

With these wide variations in total variable truck costs and the relatively small variation in the distance traveled by most of the trucks, the least-squares technique breaks down statistically. Thus, we formulated the analytic framework using largely the results of other studies and statistical theory.

Before proceeding further, we will define a set of symbols for the formulation of the truck cost models. It will give you one complete and unified glossary for the discussion which follows.

Symbols for Truck Costs Models

Fixed Components of Truck Costs in Dollars Per Month

Y_1	Equipment depreciation
Y_2	Interest on equipment investment
Y_3	Property taxes on truck equipment
Y_4	Truck licenses
Y_5	Insurance premiums

Model for Fixed Truck Cost per Load

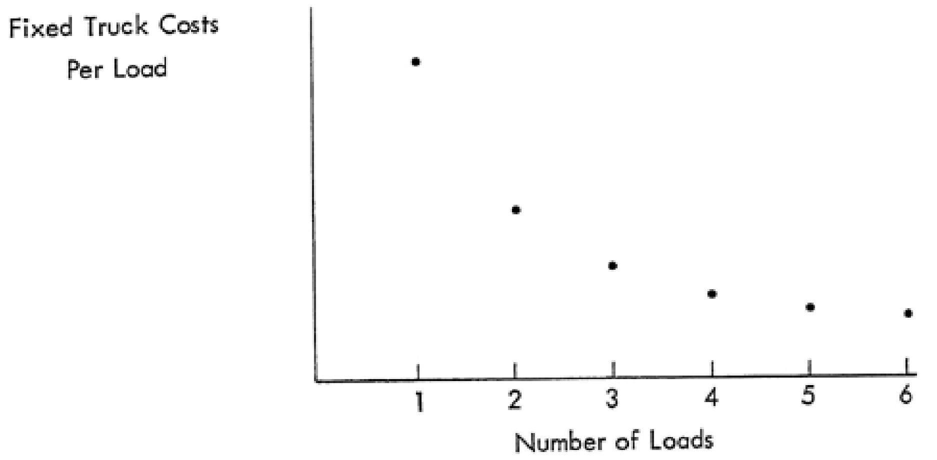
Total fixed truck costs per month are the sum of monthly equipment depreciation, interest on investment, property taxes, truck licenses and insurance on the truck unit:

$$\sum_{i=1}^{5} Y_i = Y_1 + Y_2 + \cdots + Y_5$$

To obtain fixed truck costs per load, we divide the above monthly total by the number of loads hauled per month. Letting Y(m) represent dollars of fixed truck costs per load and m represent the number of loads hauled in a month, we can express fixed truck costs per load in the following way:

$$Y(m) = \frac{\sum_{i=1}^{5} Y_i}{m}$$

We now have a functional relationship between fixed truck costs per load and the number of loads hauled in a month. Since the variable m can only assume non-negative integer values, this relationship is a monotonic-decreasing integer function of the type depicted below.



Model for Variable Truck Costs

In our first model, we expressed total variable truck costs as a function of miles driven and volume. However, upon examination of the data base depicted in Figures 5-8, we observed a high degree of linear association between volume and distance. We measured the degree of this correlation and found it to be greater than .97 in each case. Thus, it was possible to estimate total variable truck costs using only one of the two variables. We chose distance because its influence upon truck costs is more autonomous than that of volume. Volume is influenced by both the sizes of the patrons and their density per unit of land area.

We previously called to your attention the unusual sample of truck costs obtained in this study. Relatively little variation existed in distance and much variation existed in variable truck costs. We couldn't regress variable truck costs against volume and obtain meaningful results. So, given the characteristics of this sample, a variable truck cost relationship was estimated using the results of other studies and statistical theory.

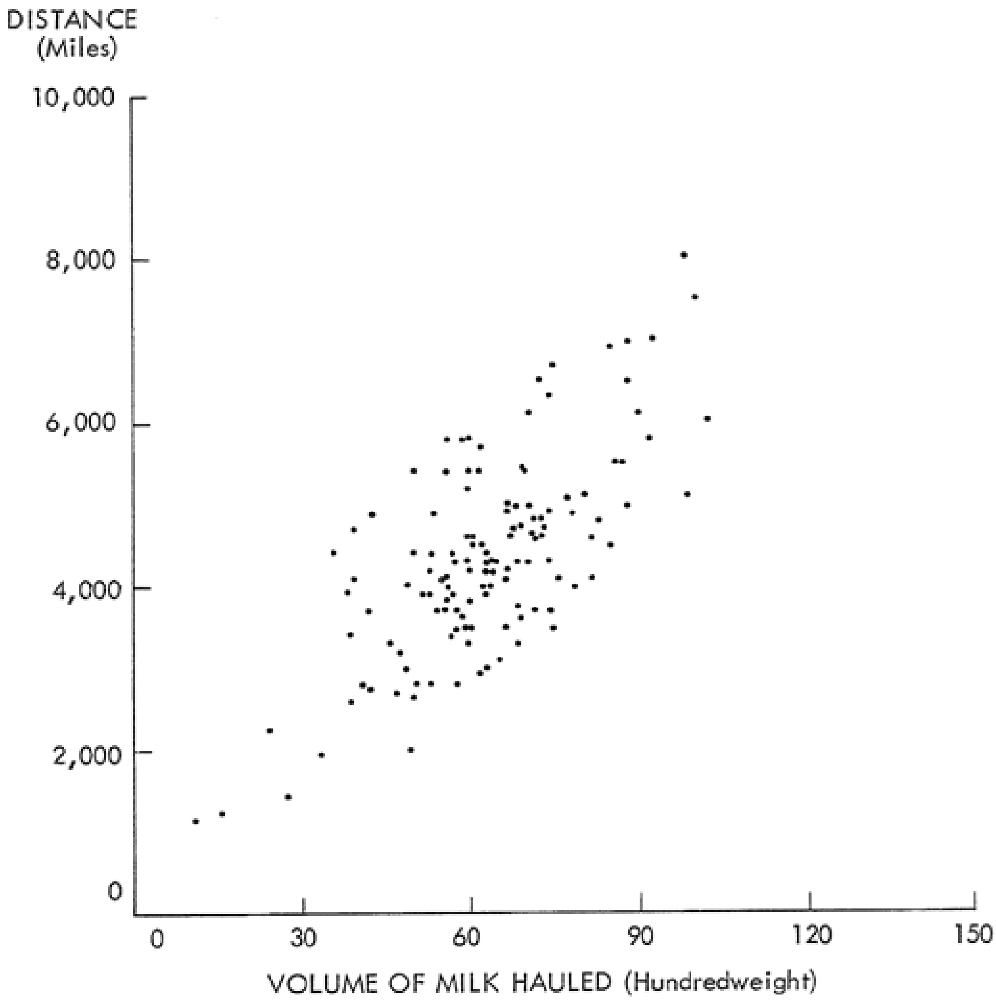


Figure 5: Distance Traveled Versus Volume Hauled Per Month for 14,800 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri

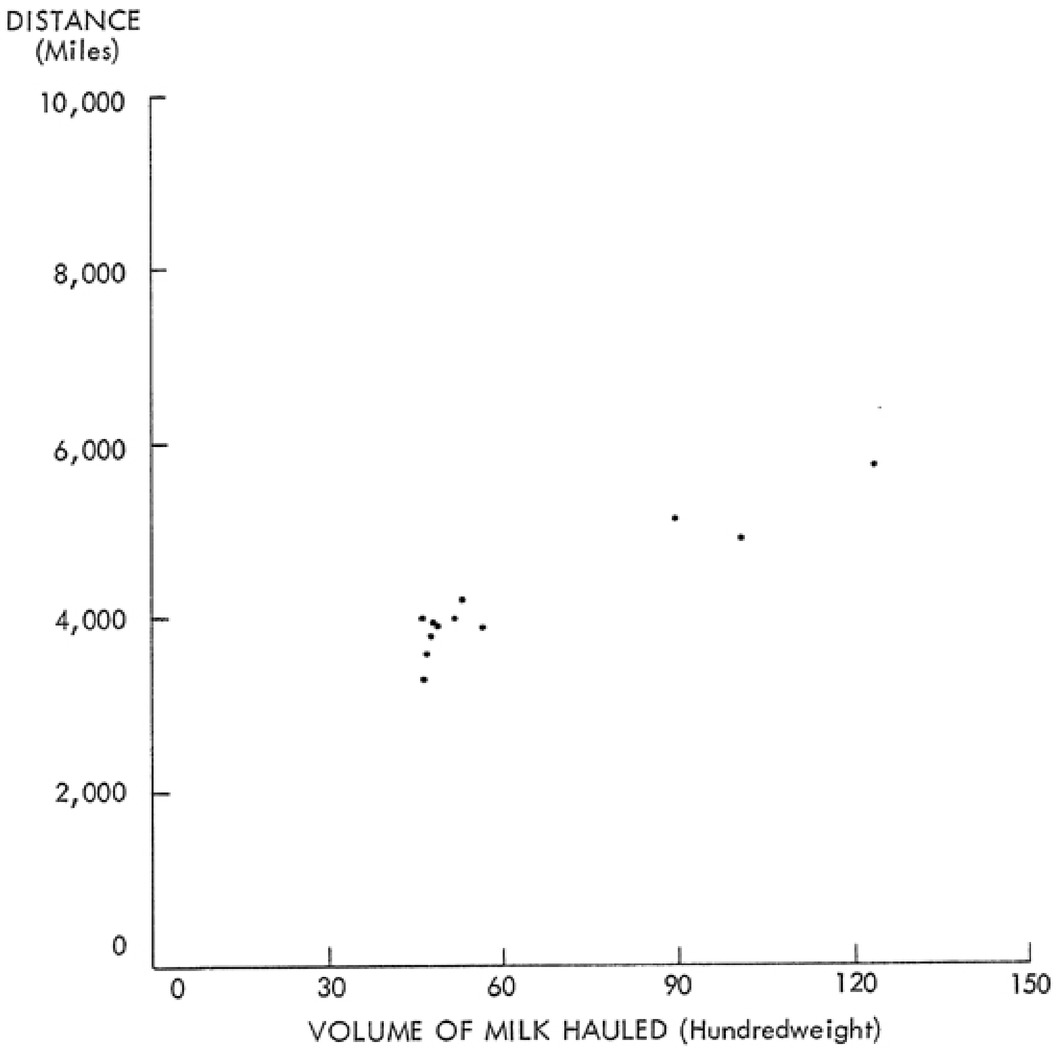


Figure 6: Distance Traveled Versus Volume Hauled Per Month for 17,500 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri

A recent study by Thompson[7] of the costs of hauling milk between plants clearly showed that variable truck costs do vary proportionately with miles driven. Using this relationship, we reasoned that if we could have obtained more information about the lumpy cost items and spread them over periods reflecting their use we would have probably obtained a set of data points which could have been represented well by a linear function. If so, then our cost relationship would have varied proportionately with distance and when fitted statistically gone through the means of variable truck costs and distance.

Using this frame of reference, we formulated total variable truck costs to be a proportionate function of distance and specified the proportionate factor

Russell G. Thompson, *An Approach to Estimating Optimum Sizes of Butter-Powder Plants*. University of Minnesota, 1962.

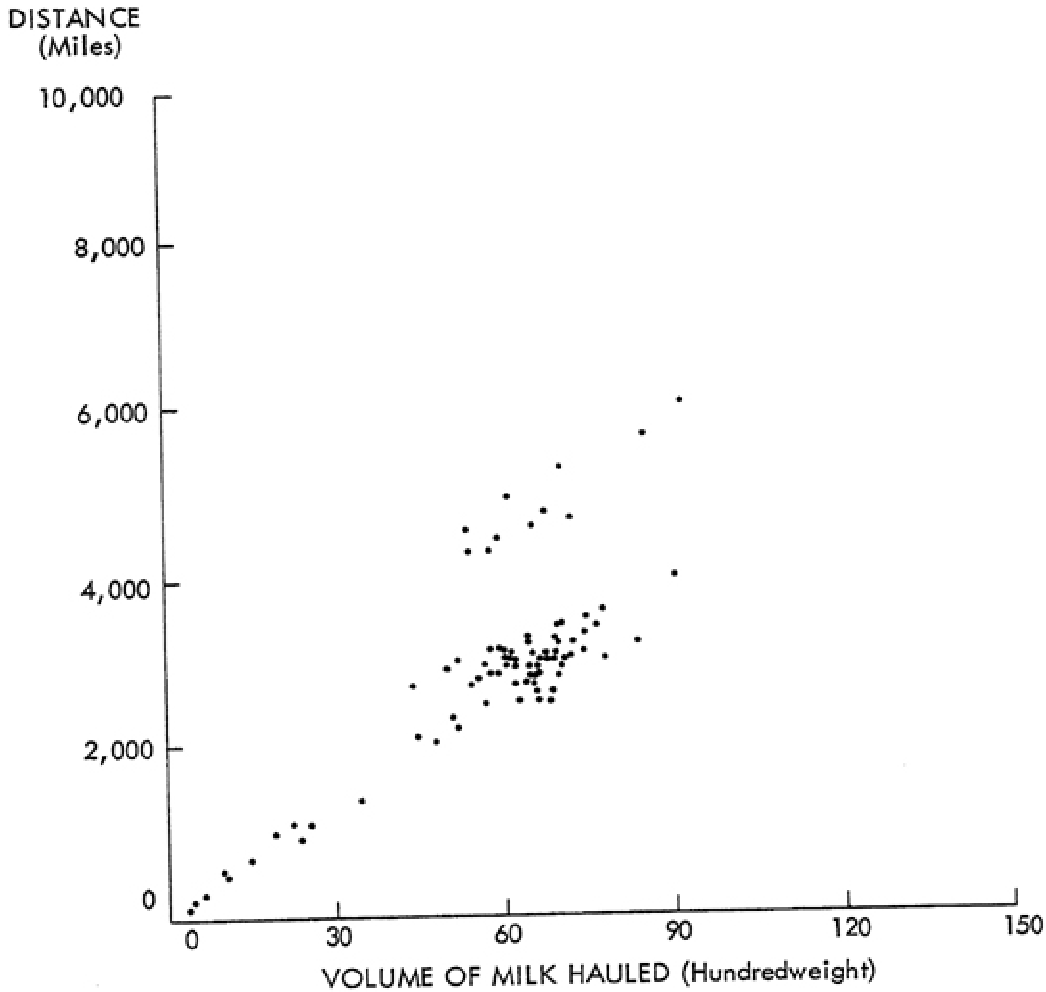


Figure 7: Distance Traveled Versus Volume Hauled Per Month for 24,600 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri

to be the ratio of variable costs to distance. Letting T_r (d) represent variable truck costs and d represent distance we formulated this model as follows:

T_r (d) = βd where β is the ratio of average variable truck costs per month to the average number of miles driven per month.

Model for Total Truck Costs Per Load

Using the previously applied summation technique, total truck costs per load are the sum of fixed truck costs per load and variable truck costs per load. Letting T_r (m,d) represent dollars of total truck costs per load, we can symbolically express this relationship as follows:

T_r (m,d) = Y (m) + Tr (d).

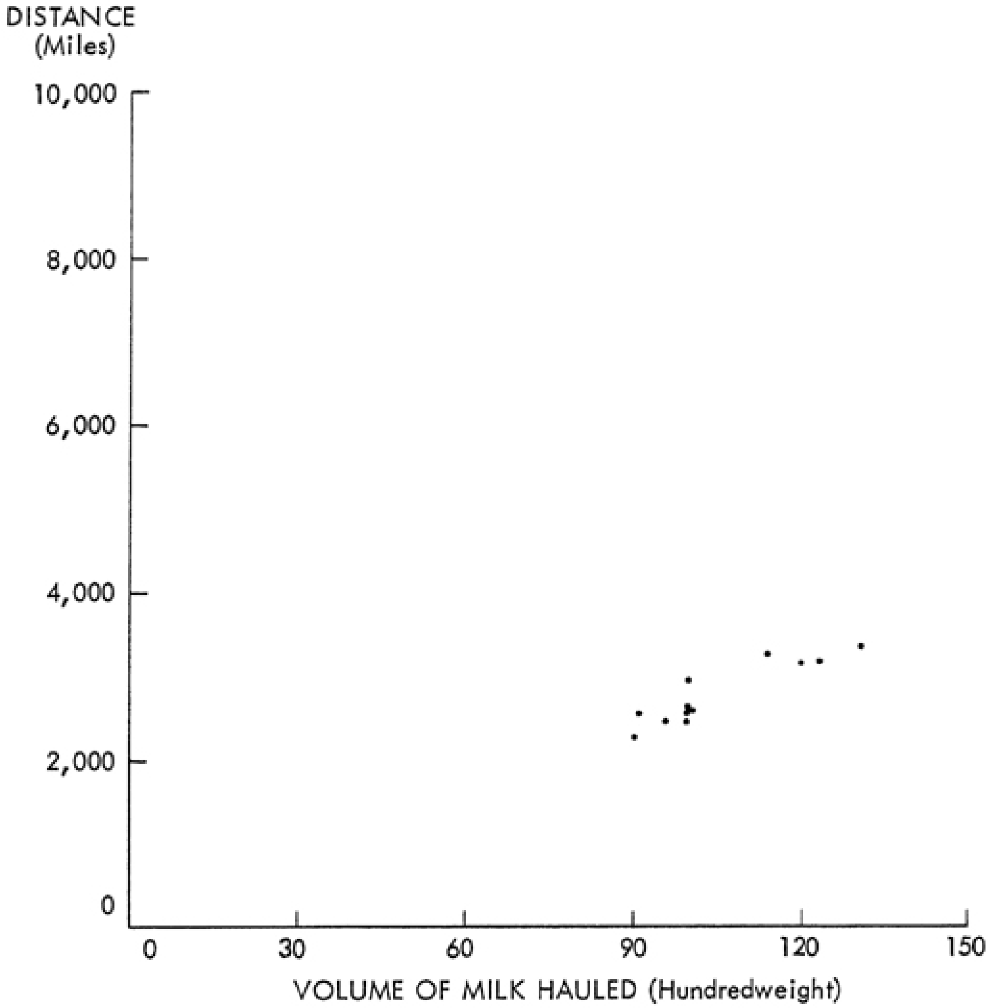


Figure 8: Distance Traveled Versus Volume Hauled Per Month for 34,400 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri

Total truck costs per load are a function of the number of loads hauled in a month m and the distance traveled per load d.

Model for Total Hauling Cost Per Load

Since labor costs and truck costs are relatively independent, we can estimate total hauling costs by summing labor costs and truck costs.

Letting TC $(n,k,d_1,d_2,d_3,d_4,v,w,m)$ represent total hauling costs per load, this relation can be symbolically represented as follows:

$$TC\ (n,k,d_1,d_2,d_3,d_4,v,w,m) = TLC\ (n,k,d_1,d_2,d_3,d_4,v,w) + T_r\ (m,d).$$

Our mathematical formulation of the model clearly highlights several important factors. First, the partitioning of hauling costs into labor and truck costs is evident; second, it specifically isolates the arguments in each function.

SOURCES AND CHARACTERISTICS OF DATA

For this study, data were obtained from six milk processing plants located in southwest Missouri. The supply areas of these plants are largely contained in St. Clair, Hickory, Camden, LaClede, Polk, Cedar, Dade Lawrence, Greene, Webster, Wright, Texas, Douglas, Christian, Dallas, and Barry counties (Figure 9).

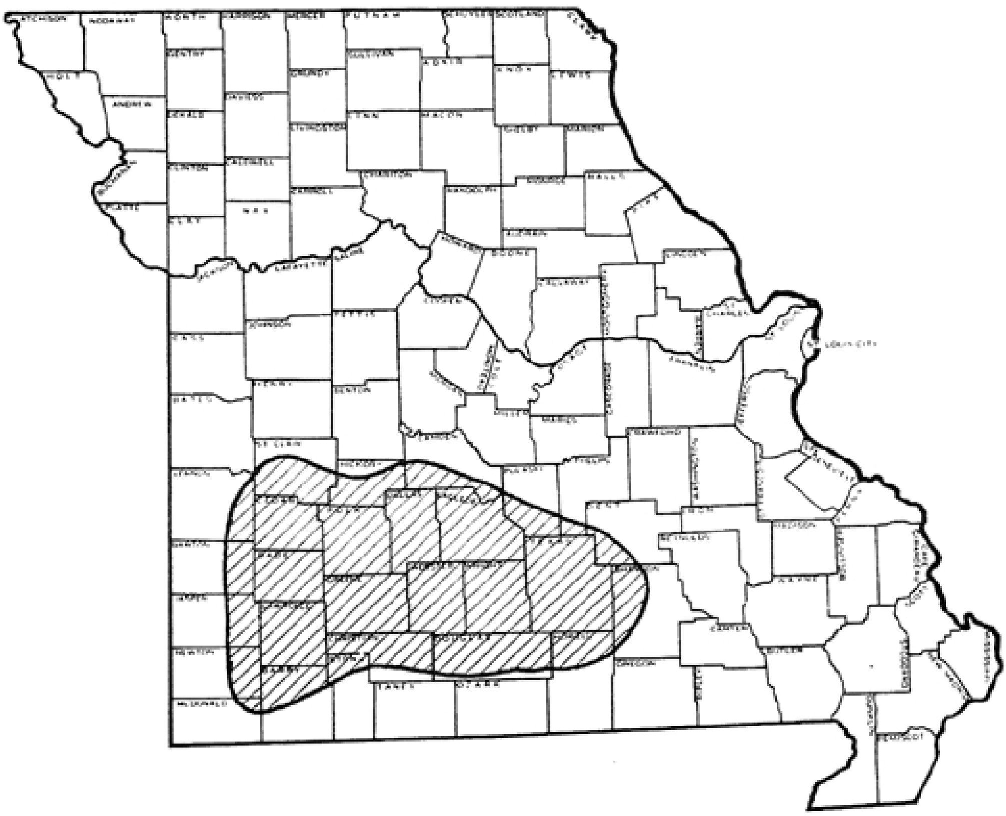


Figure 9: General Supply Area of the Six Milk Processing Plants Operating in Southwest Missouri and Cooperating in This Study

The basic data for estimating labor costs were collected using time-and-motion studies both en route and at the plants. Three hundred fifty-two individual farm stops, 41 truck unloadings and 36 truck washings were observed and recorded. Using these physical data, estimates were made of the amount of labor needed for each hauling task under normal hauling conditions.

Bulk milk in southwest Missouri is typically hauled in truck units having hauling capacities which tend to cluster around four sizes: 14,800, 17,500 24,600, and 34,400 pounds of milk. This clustering is the result of engineering factors. The tank trucks having 14,800 and 17,500 pound milk hauling capacities were straight trucks with single driving axles. The trucks having 24,600 and 34,400 pound milk hauling capacities were tractor-trailer combinations having tractors with a single driving axle and trailers with single and tandem axles, respectively.

All of the trucks observed had gasoline engines for which monthly records had been kept in value and physical terms: fuel costs, gallons of fuel, repair parts, repair labor, miles driven, and total operating expenses. With these data, all of the price variations in gasoline costs were eliminated.

ESTIMATION PROCEDURES

For each of the variable components of labor time, we first plotted the observed amounts of time against those factors thought to have the greatest influence upon them. Then we inspected the graphs and used economic and statistical knowledge to select the most appropriate functional relationships.

Linear functions were used in each instance because of their simplicity and economic realism. You may observe from the graphs in Figures 10-15 that most of the data can be described well by linear relationships.

Each of these linear functions was estimated by using a statistical method called least-squares. The least-squares technique gives the best fitting mathematical relationship, given the specification of the mathematical form.

The fixed components of labor time were estimated by calculating the arithmetic mean of each classification of fixed labor. Also, for each fixed component, the ranges over which the data varied were determined. (See Table 3). Each labor relationship was then converted into costs with an hourly wage rate of $2.32.[8]

ESTIMATES OF THE VARIABLE LABOR COMPONENTS PER LOAD

Unloading Time

Estimates of unloading time were related to the volume of milk unloaded and the sizes of the unloading equipment. Upon examination of Figures 10 and 11, it may be seen that a linear relationship explains well the relationship between unloading time and volume.

Two different sizes of unloading pumps are typically used in southwest Missouri. They are: (1) 7.5 h.p. centrifugal, 3400 r.p.m. pumps having a 2.0 inch hose connection, and (2) 5.0 h.p. centrifugal, 3400 r.p.m. pumps having 1.5 inch hose connections.

Unloading time differences were largely associated with the cross-sectional areas of the unloading lines, Figures 10 and 11. The slope of the line in Figure 11 showing the relationship between unloading time and volume is steeper for

[8]The wage rate of $2.32 includes $2.15 per hour wage paid to the driver plus an employer contribution for social security, workman's compensation and unemployment insurance (3⅝, 1½, 3¼ percent respectively).

Table 2: Summary Table of the
ESTIMATES OF THE LINEAR REGRESSION FUNCTIONS FOR
EACH OF THE VARIABLE COMPONENTS OF LABOR

Variable Component	Number of Observations	Estimated Equations*	Fraction of the Variance Explained** r^2	Standard Error of Estimate** S_e	Sample Means	
					Predictand	Predictor
Plant						
Unloading Labor						
1) 2.0 inch hose 7.5 h.p. pump	15	$P_1(k_1, v) = .00160\ v$ (.000015)	.995	.014	.333	209
2) 1.5 inch hose 5.0 h.p. pump	17	$P_1(k_2, v) = .047 + .0025\ v$ (.011) (.00006)	.990	.020	.453	163
Route						
1) Driving Labor						
(a) Starting point to first patron	36	$D_1(d_1) = .1104 + .02439\ d_1$ (.0229) (.001016)	.948	.078	.562	18.5
(b) Route Time	299	$D_2(d_2) = .0578 + .02705\ d_2$ (.0049) (.00643)	.877	.057	.209	5.60
(c) Last patron to unloading point	36	$D_3(d_3) = .0860 + .02780\ d_3$ (.0350) (.00166)	.911	.105	.598	18.4
(d) Unloading point to next starting point	XX	$D_4(d_4) = .1104 + .02439\ d_4$	XX	XX	XX	XX
2) Farm Time Loading Labor	352	$P_2(v) = .0089 + .0033\ v$ (.005) (.00003)	.971	.070	.050	13.6

*The numbers in parenthesis below each of the estimates are their respective standard errors.

**Both r^2 and S_e are corrected for the number of degrees of freedom lost in the analysis.

TABLE 3

ESTIMATE OF THE TIME REQUIRED FOR THE FIXED LABOR COMPONENTS

Fixed Components	Symbolic Notation	Amount of Time in Hours Range Low	High	Mean	Standard Error of the Mean
A. Plant					
1) Pre-Route Prep.	X_1	.000	1.466	.354	.443
2) Productive					
a) Positioning to unload	X_2	.004	.191	.024	.056
b) Hookup	X_3	.001	.860	.046	.138
c) Unhook	X_4	.001	.073	.021	.015
d) Washing of truck	X_5	.191	.880	.391	.192
3) Unproductive					
a) Waiting time:					
To unload	X_6	.026	5.223	.646	1.021
To move out	X_7	.000	.297	.003	.069
To wash	X_8	.000	.186	.003	.043
After washing	X_9	.000	1.039	.098	.208
4) Estimated Total Fixed Plant Time	xxx	xxxx	xxxx	1.586	xxxx
B. Route					
1) Positioning to Load	X_{10}	.000	.061	.011	.007
2) Washing farm tank	X_{11}	.000	.173	.041	.033
3) Driving on farm	X_{12}	.000	.173	.021	.032
4) Residual time on farm	X_{13}	.033	.842	.182	.089
5) Estimated Total Fixed Farm Time	xxx	xxxx	xxxx	.255	xxxx

pumps with 1.5 inch hoses than the slope of the line in Figure 10 showing the same relationship for pumps with 2.0 inch hoses. Unloading time is inversely related to the cross-sectional area of the unloading line.

The mathematical function estimated for the small unloading equipment labeled type (2) above was:

$$P_1(k_2,v) = \underset{(.011)}{.047} + \underset{(.000061)}{.0025v}$$

where k_2 is the pump size labeled type (2) above.

$r^2 = .99 \qquad S_e = .0203$

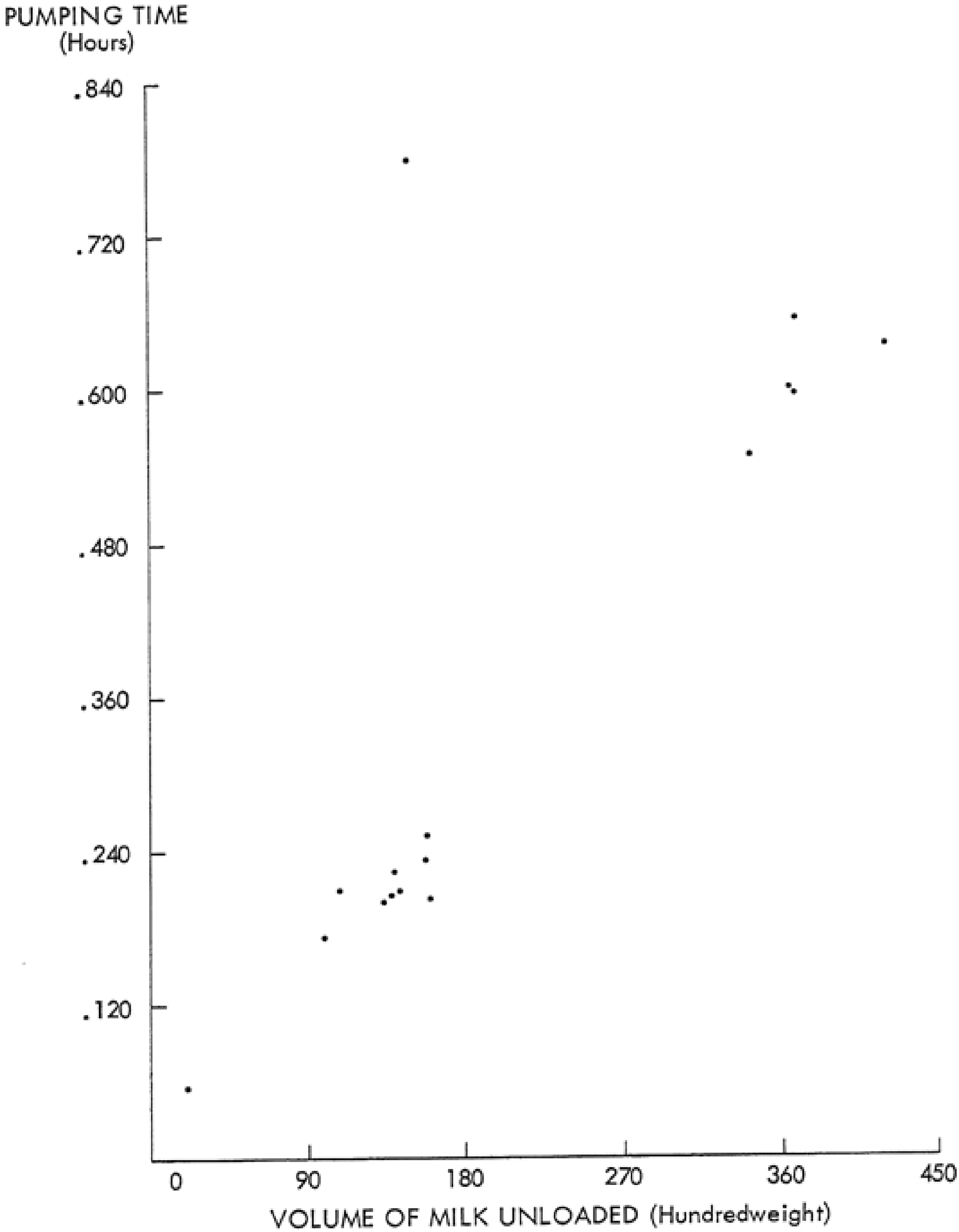


Figure 10: Pumping Time Versus Volume of Milk Unloaded Using a 75 h.p. Pump with a 2.0 Inch Hose

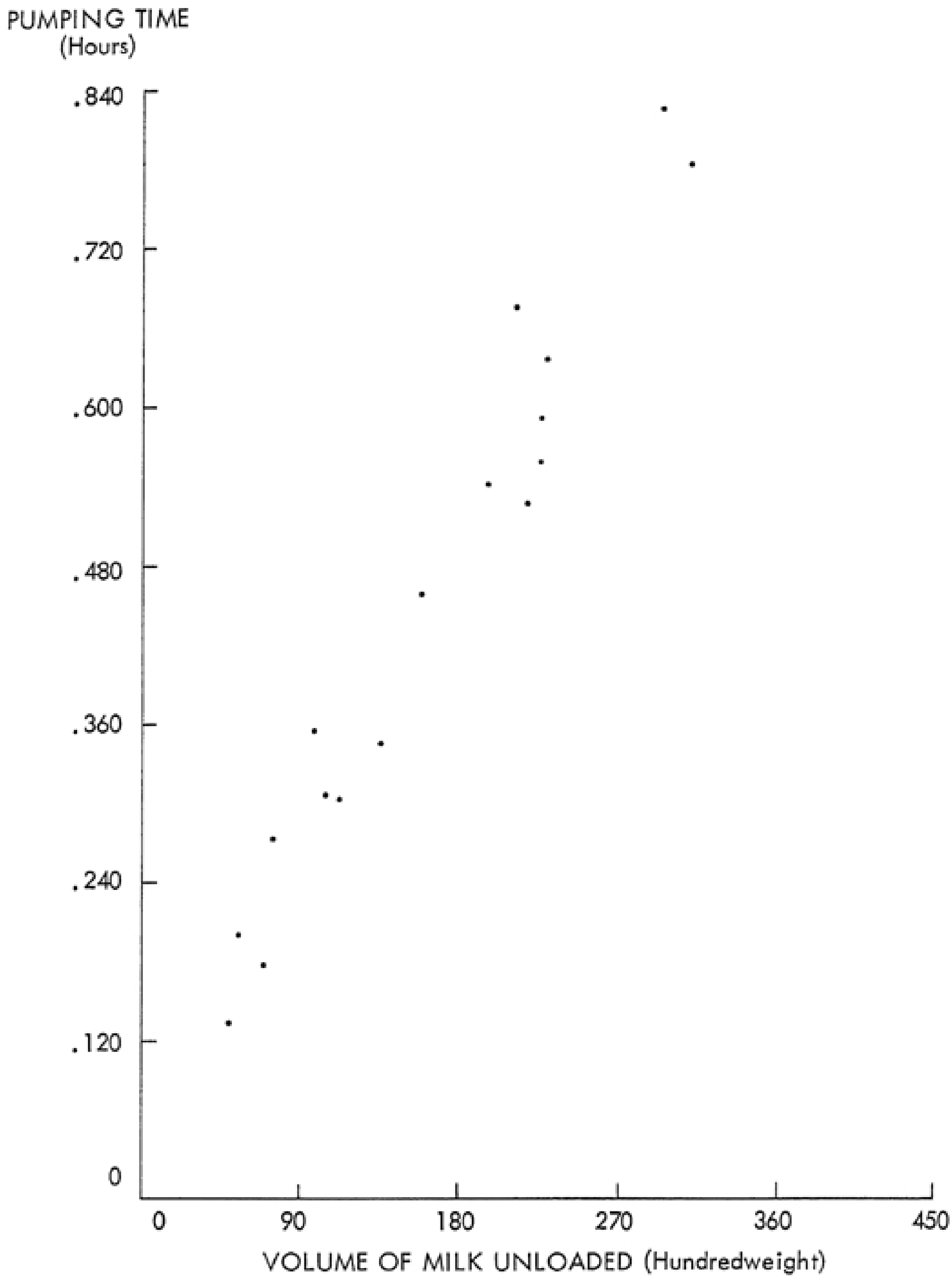


Figure 11: Pumping Time Versus Volume of Milk Unloaded Using a 5.0 h.p. Pump with a 1.5 Inch Hose

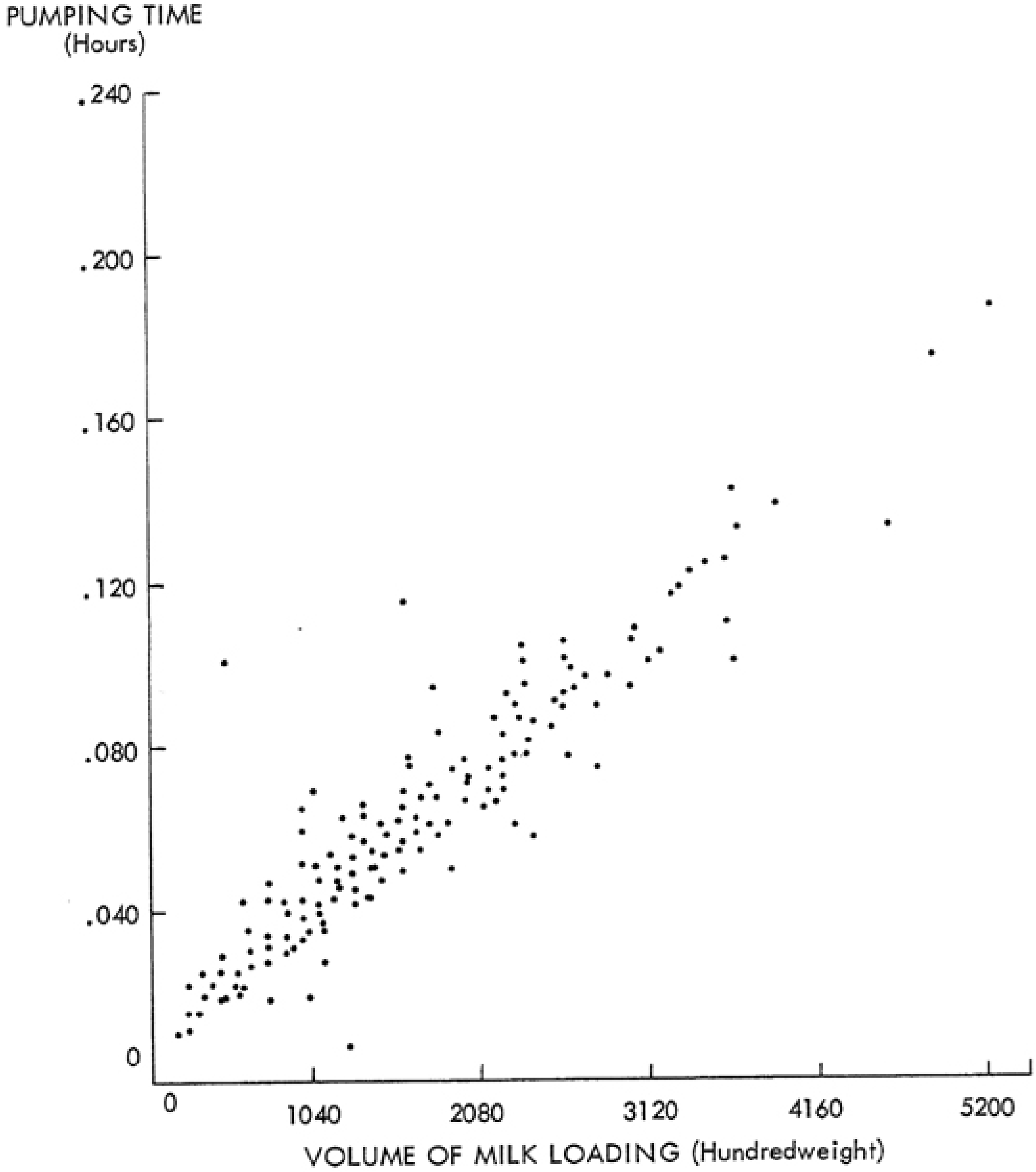


Figure 12: Pumping Time Versus Volume of Milk Loaded in Southwest Missouri

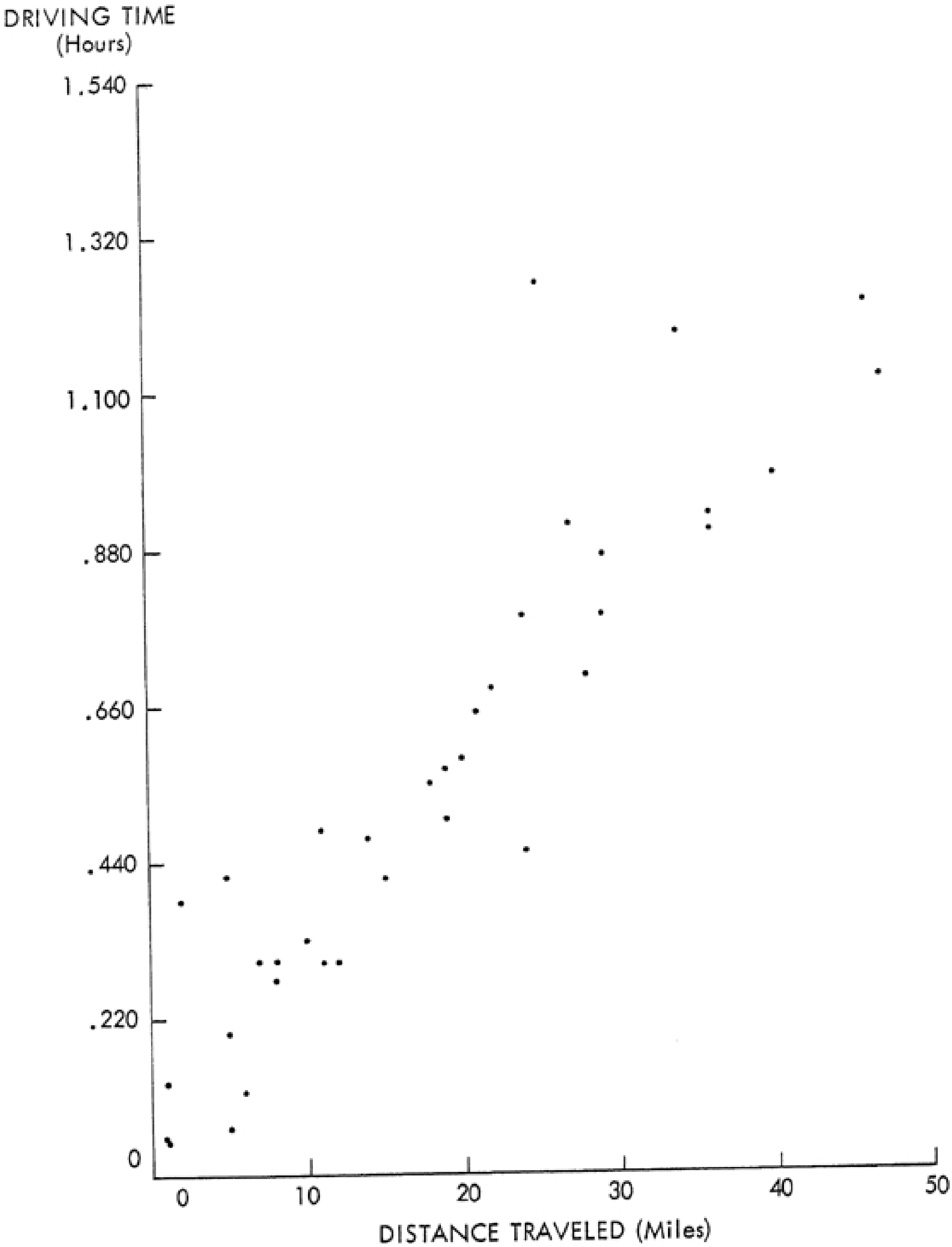


Figure 13: Driving Time Versus Distance Traveled From Starting Point to First Patron Stop in Southwest Missouri

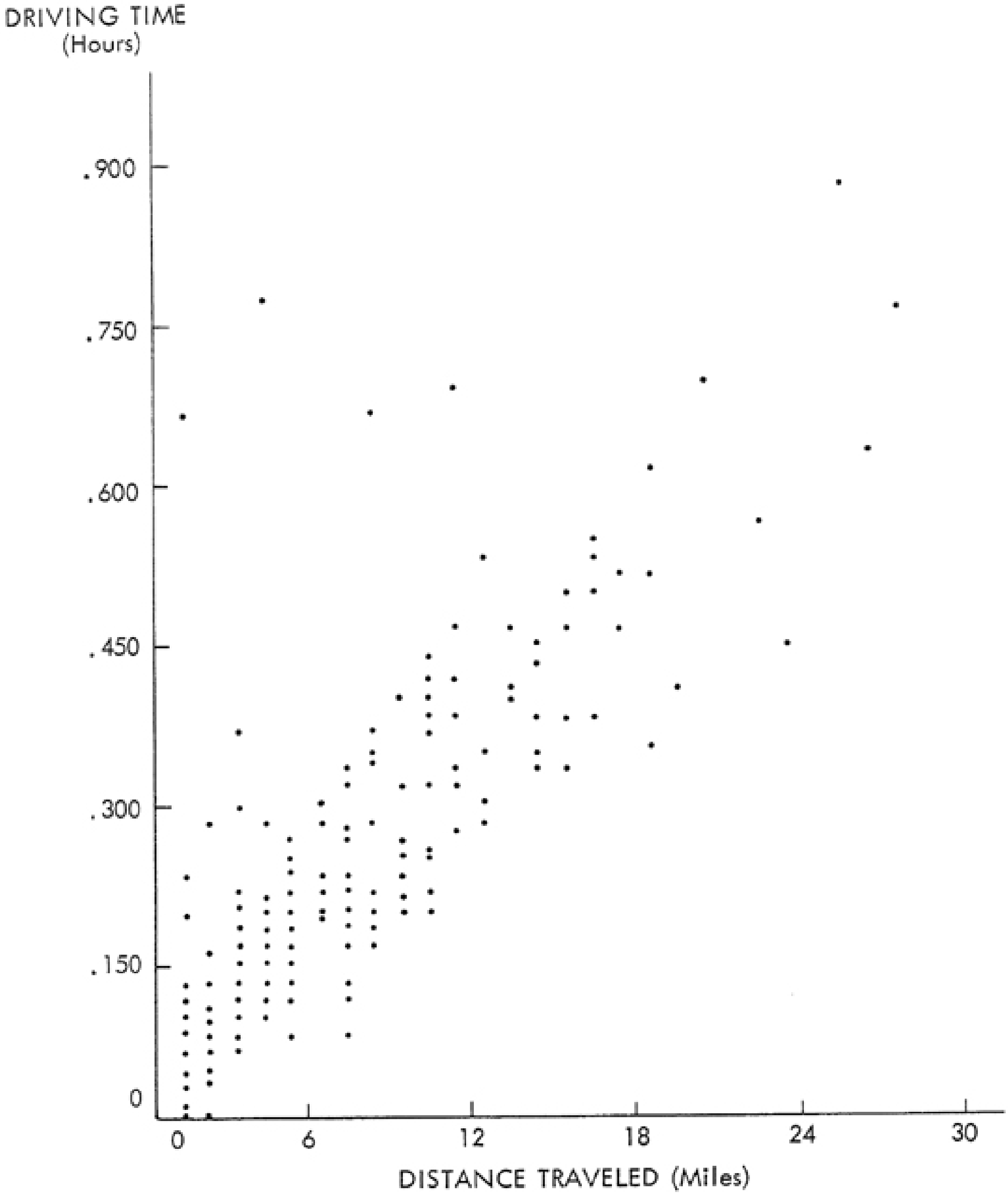


Figure 14: Driving Time Versus Distance Traveled on Route in Southwest Missouri

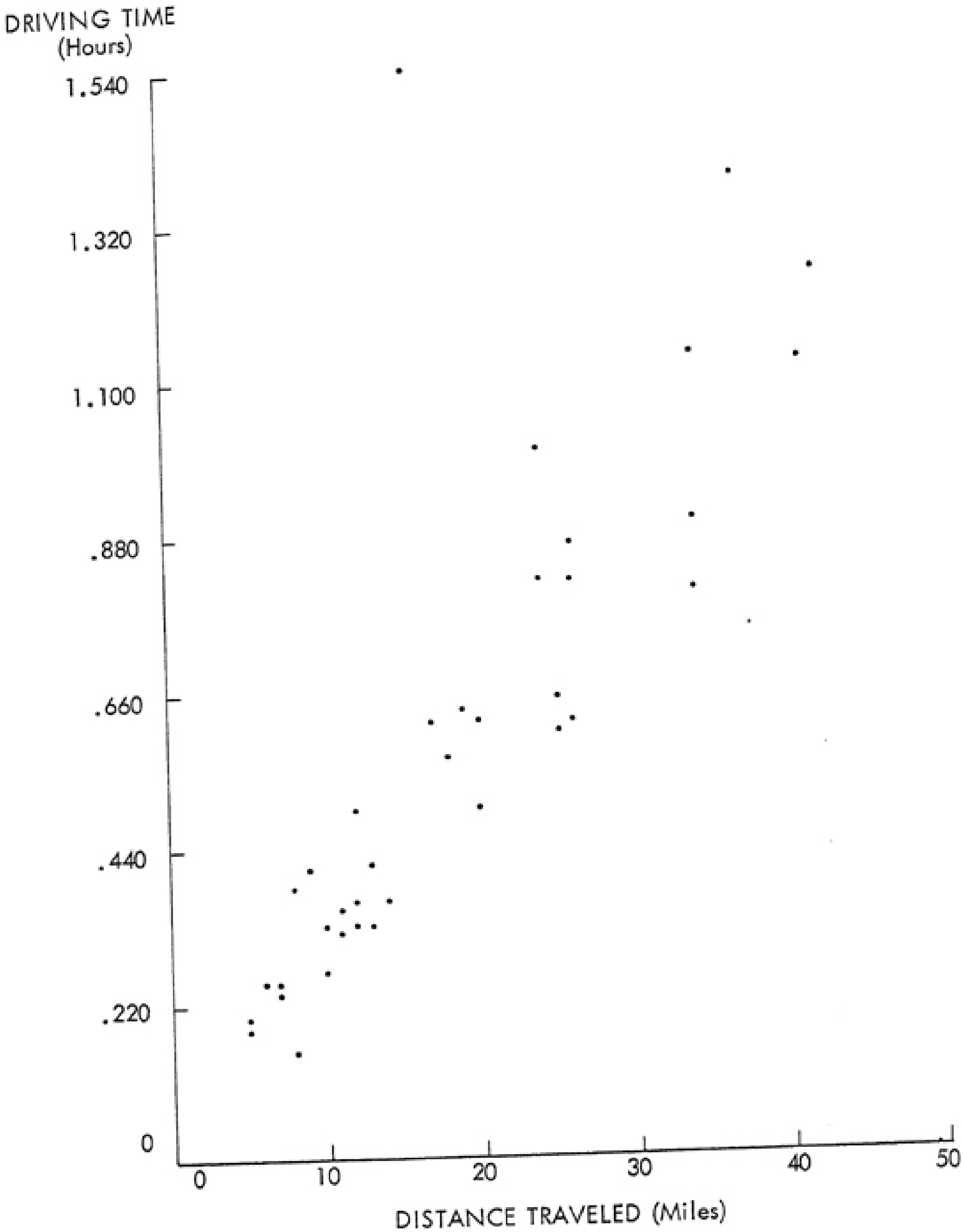


Figure 15: Driving Time Versus Distance Traveled From Last Patron Stop to Unloading Point in Southwest Missouri

You may notice that this equation has two estimates, .047 and .0025. The number .047 is an estimate of the amount of time needed to drain the truck tank of the last bit of milk. The number .0025 represents an estimate of time needed to pump each additional hundredweight of milk once the unloading operation is under way.

The estimated value of r^2 can be interpreted as the fraction of the variation in unloading time which can be explained by variations in volume. Using this interpretation you may observe that 99 percent of the variance in pumping time of the small unloading equipment was explained by volume.

The mathematical relationship estimated for the large unloading equipment was:

$$P_1(k_1,v) = \underset{(.000015)}{.0016}\, v$$

$$r^2 = .995 \quad S_e = .014$$

where k_1 is the (large size) unloading equipment labeled type (1) above and v is the hundredweight of milk unloaded.

This mathematical function has only one estimated coefficient .0016 hours and it is an estimate of the time needed to pump each additional hundredweight of milk, once the pumping operation is started. The estimate of the fixed time needed to drain the tank and unloading lines of the last bit of milk was not significant; and so it was specified to be zero.

You may observe that this regression estimate explained 99.5 percent of the variance in unloading time. Volume again explains virtually all of the variation in pumping time.

One observation appearing at the top of the graph in Figure 10 probably caught your attention. This extreme deviate resulted from a mistake by the person operating the unloading equipment. The unloading lines had been connected to the truck and the pump had been started. However, the valve which controls the flow of milk out of the tank was closed, and this was not discovered for several minutes. Thus, the total amount of unloading time was much larger than expected.

Occasionally, such disruptions are to be expected; but when they become a part of the regular operating routine, look for their cause.

Remark: For illustrative purposes, a regression estimate for unloading time was estimated with this observation included. The estimate is:

$$P_1(k_2,v)^* = \underset{(.035)}{.0548} + \underset{(.00015)}{.00149}v$$

$$r^2 = .89 \quad S_e = .075$$

Again there are two estimated coefficients in the equation, .0548 and .00149 hours. The number .0548 is the fixed time needed to drain the truck tank and unloading lines of the last bit of milk, and the number .00149 is the time required to pump each additional hundredweight of milk.

The value of the r^2 was 89 percent; it is 10 percent less than the fraction of the variance explained with the large deviate deleted.

This example clearly demonstrates the need for close observation and accurate measurement when undertaking a study of this nature.

Loading Time

The information in Figure 12 depicts the loading time relationship. A high degree of linear association exists between time and volume. This is mainly caused by engineering factors. For all 352 loading observations, the trucks used the same kind of pump to transfer the milk from the patron's bulk tank to the truck tank. (Also, the relationship between the heights of the two tanks was about the same for all of these observations.)

The loading equipment consisted of an electric pump and a plastic hose. The pump was a gear-type pump which was belt driven by a 1.5 h.p., 1750 r.p.m., 220 volt electric motor. The loading line was 16 feet long and had an inside diameter of 1.5 inches.

For loading time versus volume loaded, the following mathematical relationship was estimated using the least-squares technique:

$$P_2(v) = \underset{(.005)}{.0089} + \underset{(.00003)}{.0033v}$$

$r^2 = .971 \quad S_e = .070$

In this estimated relationship there are two estimated coefficients: .0089 and .0033. The estimate .0089 hours (32.0 seconds) represents the amount of fixed time needed to drain the residual milk from the farm tank. The estimate .0033 hours (11.9 seconds) represents the time required to pump each additional hundredweight of milk, once the pumping operation is started.

Driving Time

Driving time was divided into four components: (1) starting point to the first farm patron, (2) route time, (3) last farm patron to the unloading point, and (4) unloading point to the next starting point. Driving conditions are slightly different for each of these classifications; thus, this breakdown improves and facilitates the estimation of driving time.

Driving time is closely related to distance as indicated in Figures 13, 14, and 15. The data points cluster along straight lines which have positive slopes.

Using the least-squares technique, a mathematical relationship was estimated for each of the four components of driving time.

Starting point to first farm patron. The starting point was specified as the place where the truck was parked the previous day; and, thus, this component represents the time needed to drive from this parking spot to the first farm patron stop on the actual route. We found the average distance of this component to be 18.5 miles, and the average time required to travel this distance to be .56 hours (33.7 minutes).

The regression estimate for this component was:

$$D_1(d_1) = \underset{(.0229)}{.1104} + \underset{(.00102)}{.02439\, d_1}$$

$r^2 = .948 \quad S_e = .078$

The constant term is .1104 hours (6.6 minutes). It can be interpreted as the amount of fixed time needed for stop signs, traffic lights, railroad crossings, etc. After the truck is moving .02439 hours (1.46 minutes) is needed to travel each additional mile.

The fraction of the variance explained is .948, approximately 95%.

Route time. This component of driving time consisted of the time the driver spent driving the truck on the public roadway between the first patron stop and the last patron stop. The average distance between patrons was 5.6 miles which took a traveling time of .203 hours (12.2 minutes).

The mathematical function estimated for the route driving time was:

$$D_2(d_2) = \underset{(.0049)}{.0578} + \underset{(.00643)}{.02705}\ d_2$$

$r^2 = .877 \quad S_e = .0567$

The estimate .0578 hours (3.47 minutes) represents the amount of time spent at stop signs, stopping along the road to chat with farmers, getting the truck moving, coffee breaks along the route, and other such deviations. The estimate .02705 hours (1.62 minutes) is the time needed to travel each additional mile, once the truck is moving.

The estimated value of r^2, .877, is lower for this component than for the other components of driving time. The distance components were relatively short and the truck speedometers did not register tenths of a mile, so measurement errors were much more important and probably accounted for the lower value of r^2.

Last patron to the unloading point. Once the driver had completed loading the truck, he drove to the unloading point or the plant. This distance averaged 18.4 miles and took an average of .598 hours (35.9 minutes) of driving time. The estimated mathematical function was:

$$D_3(d_3) = \underset{(.0350)}{.0806} + \underset{(.00166)}{.0278}\ d_3$$

$r^2 = .911 \quad S_e = .1052$

Various disruptions in driving resulted in a constant term of .0806 hours (4.84 minutes). On the other hand, the amount of time needed to drive each additional mile is .0278 hours (1.67 minutes).

Approximately 91% of the variation in driving time for this component is explained by variations in the distance traveled.

Unloading point to next starting point. This component was included to allow for circumstances where the truck is not parked where it is unloaded. On most routes, the truck is parked at the plant and the value of this component is zero. However, the amount of time needed for this component is approximately the same as the amount of driving time from the starting point to first patron stop. The truck is again empty and is being driven over the same type of road surfaces. Thus, we specified the estimate $D_1(d_1)$ as representative of this component of driving time:

$D_4(d_4) = .1104 + .02439\ d_4$

Summary of Estimates of Variable Time Components per Load

Using least-squares, a linear regression equation was estimated for each variable labor component. This means that all estimates were of the form $Y = a + bX$ where Y is the dependent variable (predictand) and X is the independent variable (predictor).

The value of *a* represents the amount of fixed time required for the predictand Y regardless of the value of the predictor X. The value of *b* is the rate at which the predictand Y changes for each unit change in the predictor X. The graph of a function $Y = a + bX$ is a straight line which intercepts the Y-axis at the value *a* and has the slope *b*.

Estimates of each of the variable labor components are summarized in Table 2. Under each of the estimates of *a* and *b* are estimates of the standard errors of *a* and *b*, respectively.

ESTIMATES OF FIXED LABOR COMPONENTS PER LOAD

All of those tasks for which the time utilized on each route was relatively constant were classified as fixed labor. We partitioned these fixed tasks, as mentioned before, into time at the plant and time on the farm. The fixed time at the plant included route preparation, wait to unload, positioning to unload, hookup of unloading pumps, unhook of unloading pumps, waiting to move out, waiting to wash, washing truck tanks, and waiting after washing. The fixed time at the farm stop included positioning to load, washing of the farm tank, driving time on the farm and a residual element of fixed time on the farm.

Estimates of these components are summarized in Table 3. It must be noted that some of these components are relatively small. However, they were included in the analysis to show the relative relationships between the components and to facilitate the collection of the data. Some of these smaller tasks provide convenient signals to isolate elements of productive and non-productive time.

For purposes of analysis, the components of total fixed time were classified into the following categories: (1) route preparation, (2) productive plant time, (3) unproductive plant time, and (4) fixed time on the route. A brief description of each of these categories is given below while estimates of these components are found in Table 3.

Fixed Labor at Plant

Route Preparations: Every day a truck was operated, the driver or a plant employee first sanitized the truck, filled the ice chest, collected sample containers, made out patron receipt slips, and placed the patron supply orders in the truck. Much variation existed in the procedure used to perform these tasks and in the data because of variations in the people performing them. Most of the trucks were sanitized only once a day, that usually being in the morning; thus preparation time for the second route was zero.

Productive Fixed Time at Plant: The components included in this category were those which contributed to completion of the unloading operation. They are discussed briefly below:

Positioning to Unload. At all of the plants studied, the unloading facilities were such that the truck had to be backed into the unloading position. Moreover, at some plants, the front wheels of the truck had to be driven onto ramps so the milk would flow into the tank outlet at the rear of the truck. This task was performed relatively free of any disruptions at all of the plants studied.

Hookup. Once the truck was positioned, the unloading lines were connected to the truck tank outlet; and the hatch on top of the truck was opened to prevent a vacuum from being created in the truck tank during unloading. This connecting task was defined as "hookup".

Unhook. This task involved disconnecting the unloading lines after the milk had been pumped out of the truck tank. This task was very simple and was performed with very little variation at all the plants studied.

Washing the hauling unit. Once the milk was unloaded, the truck tank and the loading equipment were thoroughly washed to maintain quality of the milk being transported. Both hand washing and machine washing operations are used in southwest Missouri; but no significant time differences were observed between either of the two types of washing operations regardless of the sizes of the trucks washed. This was due largely to engineering factors. All of the large semi-trailer combinations were washed by mechanical washers and only a few of the smaller straight trucks were washed by hand. The equipment was designed such that it required 20 to 25 minutes to wash a truck. During this time the loading equipment was disassembled and washed; thus no extra time was needed to perform this task.

Unproductive Fixed Time at Plant: The components of this category represent elements of time when the driver had to wait to begin the next task. Each of these waiting periods are discussed briefly below.

Waiting to unload. When the truck arrived at the unloading point, the unloading facilities were sometimes being used to unload another truck; thus, some waiting time commonly occurred. Again you may wonder why the wide range in the sample data occurred. It resulted largely from the fact that one plant did not unload some of its trucks in the order in which they arrived.

At this plant the hauling units were owned by the processing firm. Their drivers were paid an hourly wage. When the drivers had completed their day, they left the truck on the firm's parking lot and went home. The trucks were unloaded by a separate crew of men having one extra man. (This extra person received a wage rate very close to that of the drivers', thus no adjustment was made.) Part of this extra man's job was to position the trucks in the unloading and washing areas.

Wait to move out. When the unloading operation was completed, some time elapsed before the truck was moved to the washing facilities. It represents basically the lapsed time between completion of the unhook task and the time the truck was parked in the washing area. We included this component to cover the cases where the plants did not wash the trucks where they were unloaded.

Wait to wash. This waiting time was defined to be the time interval between the completion of the unhook task (or the time the truck arrived at the washing area) and the time the actual washing operation began.

Wait after washing. This waiting period occurred between the time the washing operation was completed and the time the truck was either parked or left at the next starting point.

Fixed Labor on Route

The total amount of fixed time on the farms was divided into four components: (1) positioning to load, (2) washing the farm bulk tank, (3) driving on the farm, and (4) a residual element of fixed time on the farm. Each of these components is discussed below and estimates for each component can be found in Table 3.

Positioning the truck to load. Since the loading lines were only 16 feet in length, the rear of the truck had to be parked close enough to the farm bulk tank to make a connection. The time needed to position the truck to connect the loading line to the farm bulk tank was defined as "positioning to load". On some farmsteads, the truck could be driven up to the milk house and little positioning time was necessary. However, on the other farmsteads, much time was required for truck positioning.

Washing the farm tank. When the milk had been transferred from the farm tank to the truck tank, the driver usually rinsed the farm tank to remove the residual milk from the tank. This time component was defined as "washing farm tank". It varied somewhat with company policy and the driver. Some drivers would use a long-handled brush to clean the tank during the rinsing, while other drivers would only spray the tank with a hose. There were cases where the farmer would be present when the driver finished loading the milk. Sometimes the farmer would tell the driver to go ahead and he would wash the tank.

Driving on farm. Some time was spent driving on each farm; and for this category, relatively large variations existed in the amounts of time observed. Much variation existed in the farm roads and other factors such as farm gates. Thus, we just calculated the average amount of time needed for this component.

Residual time on the farm. This component of fixed time represents the difference between the total amount of time spent on the farm and the sum of positioning time, washing time, driving time on farm, and loading time. Many tasks were not completed systematically on each farm: agitation of milk in the bulk tank, determination of the volume of milk, and recording of the volume on the patron's slip. It was necessary, for the purposes of the time and motion study, to add the time requirements of the identifiable tasks and subtract them from the total amount of time spent on each farm.

On some occasions, the driver had to wait for the farmer to finish milking and then for the milk to cool. This component was very large in these cases.

Summary of the Estimates of Fixed Labor Components Per Load

Summing the estimates of fixed time for each of the tasks at the plant and on the farm, we obtained estimates of fixed time for each of our major classification and also an overall total, Table 3. It may be seen from the information in Table 3 that it takes an average of 1.586 hours (95.16) minutes for all of the fixed tasks at the plant and .255 hours (15.3 minutes) on each farm.

The route preparation component of fixed plant time per load was .354 hours (21.24 minutes) or about 22 percent of the total fixed time at the plant. Since this task is performed only once a day and typified by unpredicatble disruptions, it seems unlikely that this component might be reduced much.

The fixed time at the plant which we classified as productive amounted to .482 hours (28.92 minutes) per load or 30 percent of the total fixed time at the plant. However, in this classification of time, we included the washing time component; it took .391 hours (23.45 minutes) per load or 25 percent of the fixed time spent at the plant. Thus, the other productive tasks required .091 hours (5.46 minutes) per load or about 6 percent of the total fixed time observed at the plant.

The unproductive fixed time (waiting time) at the plant totaled .750 hours (45 minutes) per load or about 47 percent of total fixed plant time. This is a relatively large percentage of the total time spent at the plant. Most of it resulted from drivers waiting to unload. On the average, the drivers spent .646 hours (38.76 minutes) per load waiting to unload, about 41 percent of the fixed plant time.

It is readily apparent that the amount of time spent waiting at the plant should be watched closely. Substantial labor savings may be attainable through improved scheduling of the truck units.

The total amount of fixed time on each individual farm stop was .255 hours (15.3 minutes). Our classification called residual time represented the major portion of this total; it amounted to .182 hours (10.92 minutes) per farm stop or about 71 percent of the fixed time spent on the farm. However, it may be difficult to reduce this component much. Certain patrons detain the driver.

TOTAL LABOR TIME REQUIREMENTS PER LOAD AND TOTAL LABOR COSTS PER LOAD

Labor requirements per load were related to route length, volume of milk hauled, and number of patron stops. Estimates of unloading time, loading time, total fixed time and driving time were calculated for selected specifications of the variables involved in the labor functions. You will find these estimates in Tables 4 through 7.

You can now use these estimates to estimate total labor requirements for different numbers of patron stops, volumes of milk and lengths of routes. We will illustrate this for the following specification:

Specification of an Example Route

Number of patrons	12
Volume of milk hauled	20,000 pounds
Distances:	
Starting point to first patron	15 miles
First patron to last patron	40 miles
Last patron to unloading point	10 miles
Unloading point to next starting point	5 miles

Labor Requirements of the Example Route

Total fixed time on route	3.060 hours
Total pumping time to load	.669 hours
Total driving time:	
Starting point to first patron	.476 hours
First patron to last patron	1.140 hours
Last patron to unloading point	.364 hours
Unloading point to next starting point	.232 hours
Total pumping time to unload using 1.5" hose and 5.0 h.p. pump	.547 hours
Total fixed time at plant	1.586 hours
Total time for operation of the route	8.074 hours

Using this approach labor requirements can be calculated for any route. Also, total labor cost per load can be determined by multiplying the above amount of labor times the driver's wage rate. Using a wage rate of $2.32 per hour, total labor costs for this example are $18.73. Hence, labor costs are $0.091 or 9.1 cents per hundredweight of milk hauled.

Utilizing this procedure, we calculated estimates of labor requirements, labor costs per load and labor costs per hundredweight for selected numbers of patrons, lengths of routes and each of the four truck sizes, Tables 8, 9 and 10. The information in these tables is organized so that the effects of transport size, sizes of the milk producers and densities of the farmers upon labor costs can be evaluated.

You will notice that the number of patrons necessary for a load varies from 8 to 20 for each of the truck sizes and the route length is constant in each table. Hence, the sizes of the producers vary inversely with the number of patrons for a given size of load.

Among tables the length of the route (the distance from the first patron to the last one) differs. Thus, the effect of different densities of milk producers can be evaluated for each load size and number of patrons by making inter-table comparisons.

Several economic relationships are immediately evident from the cost information in these tables. It is obvious that considerably less labor is needed to procure milk from large patron stops than from small ones. Moreover, the influence of transport size upon labor costs is readily apparent, too. Labor costs per hundredweight for relatively large patrons having around 1500-1600 pounds per stop are at least 3.5 cents less for the largest truck units than the smallest ones. (Compare the labor costs of a 13,000 pound load and 8 patrons against the costs of a 31,000 pound load and 20 patrons.) Many other examples of these economic relationships can be depicted from the cost information in Tables 8, 9 and 10. Labor costs per hundredweight are significantly less for relatively large patron stops and/or trucks than they are for small ones.

The influence of production density can be readily seen from the cost information in these tables, too. An inter-table comparison shows the effect of patron density upon labor costs. Labor costs per hundredweight increase less than two cents with increases in route length from 20 to 60 miles. Hence, the effect of declining producer density upon labor costs in and of itself is relatively small.

TABLE 4

UNLOADING TIME FOR SELECTED VOLUMES, EXCLUSIVELY PUMPING

Volume	1.5" hose 5.0 h.p. motor		2.0" hose 7.5 h.p. motor	
(pounds)	(hours)	(minutes)	(hours)	(minutes)
7,500	.235	14.10	.120	7.20
10,000	.297	17.82	.160	9.60
13,000	.372	22.32	.208	12.48
16,000	.447	26.82	.256	15.36
18,000	.497	29.82	.288	17.28
20,000	.547	32.82	.320	19.20
22,000	.597	35.82	.352	21.12
30,000	.797	47.82	.480	28.80
31,000	.822	49.32	.496	29.76
35,000	.922	55.32	.560	33.60

TABLE 5

LOADING TIME FOR SELECTED VOLUMES, EXCLUSIVELY PUMPING

Volume	Total Pumping Time	
	(hours)	(minutes)
500	.026	1.56
750	.034	2.04
1,000	.042	2.52
1,250	.050	3.00
1,500	.058	3.48
2,000	.075	4.50
3,000	.108	6.48
4,000	.141	8.46
6,000	.207	12.42

TABLE 6

DRIVING TIME FROM STARTING POINT TO FIRST PATRON, FIRST PATRON TO LAST PATRON, AND LAST PATRON TO UNLOADING POINT

Miles	Time From Starting Point to First Patron D_1		Time From First Patron to Last Patron D_2		Time From Last Patron to Unloading Point D_3	
	(hr.)	(min.)	(hr.)	(min.)	(hr.)	(min.)
5	.232	13.92	.193	11.58	.219	13.14
10	.354	21.24	.328	19.68	.358	21.48
15	.476	28.56	.464	27.84	.497	29.82
20	.598	35.88	.599	35.94	.636	38.16
25	.720	43.20	.734	44.04	.775	46.50
30	.842	50.52	.869	52.14	.914	54.84
40	1.086	65.16	1.140	68.40	1.192	71.52
50	1.320	79.20	1.410	84.60	1.470	88.20
60	1.573	94.38	1.681	100.86	1.748	104.88
70	1.817	109.02	1.951	117.06	2.026	121.56
80	2.061	123.66	2.222	133.32	2.304	138.24

TABLE 7

TOTAL FIXED TIME ON ROUTE FOR SELECTED NUMBERS OF FARM STOPS

Number of Farm Stops	Total Fixed Time on Route	
	(hours)	(minutes)
2	.510	30.6
3	.765	45.9
4	1.020	61.2
5	1.275	76.5
6	1.530	91.8
7	1.785	107.1
8	2.040	122.4
9	2.295	137.7
10	2.550	153.0
11	2.805	168.3
12	3.060	183.6
13	3.315	198.9
14	3.570	214.2
15	3.825	229.5
16	4.080	244.8
17	4.335	260.1
18	4.590	275.4
19	4.845	290.7
20	5.100	306.0
21	5.355	321.3

TABLE 8

TOTAL LABOR TIME PER LOAD, TOTAL LABOR COST PER LOAD AND AVERAGE LABOR COST PER HUNDREDWEIGHT FOR TWENTY MILE ROUTE[1]

Size of Load[2]	Total time except driving time from first to last patron[3]	Driving time from first to last patron	Total time per load	Total labor cost per load	Average cost per cwt.
	(hours)	(hours)	(hours)	(dollars)	(dollars)
13,000 lb. load					
8 patrons	5.746	.599	6.345	14.72	.1132
12 patrons	6.766	.599	7.365	17.08	.1313
16 patrons	7.786	.599	8.385	19.45	.1496
20 patrons	8.814	.599	9.413	21.84	.1680
16,000 lb. load					
8 patrons	5.920	.599	6.519	15.12	.1008
12 patrons	6.940	.599	7.539	17.49	.1093
16 patrons	7.960	.599	8.559	19.86	.1241
20 patrons	8.980	.599	9.579	22.22	.1388
22,000 lb. load					
8 patrons	6.264	.599	6.863	15.92	.0723
12 patrons	7.284	.599	7.879	18.29	.0831
16 patrons	8.304	.599	8.903	20.65	.0938
20 patrons	9.324	.599	9.923	23.02	.1046
31,000 lb. load					
8 patrons	6.790	.599	7.389	17.07	.0550
12 patrons	7.810	.599	8.409	19.05	.0614
16 patrons	8.830	.599	9.429	21.88	.0705
20 patrons	9.850	.599	10.449	24.24	.0781

[1]Distances: (1) First patron to last patron - 20 miles, (2) Starting point to first patron - 20 miles, (3) Last patron to unloading point - 10 miles, and (4) Unloading point to next starting point - 10 miles. Component (1) is designated as the route length.

[2]Each size of load is approximately 90 percent of each specified truck unit's hauling capacity. These load sizes were picked to simplify the calculation of the respective estimates.

[3]Total time except driving time from first to last patron = fixed plant time per load + fixed route time per load + unloading time per load + loading time per load + driving time to first patron + driving time from last patron to unloading point + driving time from unloading point to next starting point.

TABLE 9

TOTAL LABOR TIME PER LOAD, TOTAL LABOR COST PER LOAD AND AVERAGE LABOR COST PER HUNDREDWEIGHT FOR FORTY MILE ROUTE[1]

Size of Load[2]	Total time except driving time from first to last patron[3]	Driving time from first to last patron	Total time per load	Total labor cost per load	Average cost per cwt.
	(hours)	(hours)	(hours)	(dollars)	(dollars)
13,000 lb. load					
8 patrons	5.746	1.14	6.886	15.97	.1228
12 patrons	6.766	1.14	7.906	18.34	.1410
16 patrons	7.786	1.14	8.926	20.70	.1592
20 patrons	8.814	1.14	9.954	23.09	.1776
16,000 lb. load					
8 patrons	5.920	1.14	7.060	16.38	.1023
12 patrons	6.940	1.14	8.080	18.75	.1171
16 patrons	7.960	1.14	9.100	21.11	.1319
20 patrons	8.980	1.14	10.120	23.48	.1467
22,000 lb. load					
8 patrons	6.264	1.14	7.404	17.18	.0780
12 patrons	7.284	1.14	8.424	19.54	.0888
16 patrons	8.304	1.14	9.444	21.91	.0995
20 patrons	9.324	1.14	10.464	24.28	.1103
31,000 lb. load					
8 patrons	6.790	1.14	7.930	18.40	.0593
12 patrons	7.810	1.14	8.950	20.76	.0669
16 patrons	8.830	1.14	9.970	23.13	.0746
20 patrons	9.850	1.14	10.990	25.50	.0822

[1]Distances: (1) First patron to last patron - 40 miles, (2) Starting point to first patron - 20 miles, (3) Last patron to unloading point - 10 miles, and (4) Unloading point to next starting point - 10 miles. Component (1) is designated as the route length.

[2]The size of load was assumed to be around 90 percent of the truck unit's hauling capacity. These load sizes were picked for ease of calculation of the respective estimates.

[3]Total time except driving time from first to last patron = fixed plant time per load + fixed route time per load + unloading time per load + loading time per load + driving time to first patron + driving time last patron to unloading point + driving time from unloading point to next starting point.

TABLE 10

TOTAL LABOR TIME PER LOAD, TOTAL LABOR COST PER LOAD AND AVERAGE LABOR COST PER HUNDREDWEIGHT FOR SIXTY MILES ROUTE[1]

Size of Load[2]	Total time except driving time from first to last patron[3]	Driving time from first to last patron	Total time per load	Total labor cost per load	Average cost per cwt.
	(hours)	(hours)	(hours)	(dollars)	(dollars)
13,000 lb. load					
8 patrons	5.746	1.681	7.427	17.23	.1325
12 patrons	6.766	1.681	8.447	19.60	.1507
16 patrons	7.786	1.681	9.467	21.96	.1689
20 patrons	8.814	1.681	10.495	24.35	.1873
16,000 lb. load					
8 patrons	5.920	1.681	7.601	17.63	.1101
12 patrons	6.940	1.681	8.620	20.00	.1250
16 patrons	7.960	1.681	9.641	22.37	.1398
20 patrons	8.980	1.681	10.661	24.73	.1545
22,000 lb. load					
8 patrons	6.264	1.681	7.945	18.43	.0837
12 patrons	7.284	1.681	8.965	20.80	.0945
16 patrons	8.304	1.681	9.985	23.16	.1052
20 patrons	9.324	1.681	11.005	25.53	.1160
31,000 lb. load					
8 patrons	6.790	1.681	8.471	19.65	.0633
12 patrons	7.810	1.681	9.491	22.02	.0710
16 patrons	8.830	1.681	10.511	24.38	.0786
20 patrons	9.850	1.681	11.531	26.75	.0862

[1]Distances: (1) First patron to last patron - 60 miles, (2) Starting point to first patron - 20 miles, (3) Last patron to unloading point - 10 miles, and (4) Unloading point to next starting point - 10 miles. Component (1) is designated as the route length.

[2]The size of load was assumed to be around 90 percent of the truck unit's hauling capacity. These load sizes were picked for ease of calculation of the respective estimates.

[3]Total time except driving time from first to last patron = fixed plant time per load + fixed route time per load + unloading time per load + loading time per load + driving time to first patron + driving time last patron to unloading point + driving time from unloading point to next starting point.

ESTIMATES OF TOTAL FIXED TRUCK COSTS PER LOAD

Operators of bulk milk routes in southwest Missouri use both straight trucks and tractor-trailer combinations clustering around the four size groups mentioned before: 14,800, 17,500, 24,600, and 34,400 pounds of hauling capacity. Variation of course existed in each of these cited sizes; but it was generally quite small because of engineering factors. So we specified our hauling units to be of these four sizes for the purposes of this study.

Depreciation Costs of the Hauling Equipment

Initial costs of bulk milk hauling units have varied considerably over the years, generally upward. Moreover, different managers commonly have different expectations about the useful "economic life" of hauling equipment. If one looks only at accounting costs, he can thus be led badly astray unless he has information about the ages of the hauling units and the methods of calculating depreciation. We decided early in this study to overcome this problem by obtaining from the manufacturers of the commonly used makes of trucks and tanks their 1963 costs of the above four sizes of hauling units, Table 11. With this point of departure, we then used the straight-line method and one set of depreciation periods to calculate depreciation costs of the milk hauling units.

Using one method of calculating depreciation, estimates of depreciation costs depend upon the periods of economic life specified and the sizes of the salvage values assumed. Accurate specification of these two factors is always difficult because of the lengths of the periods involved and possible technological changes.

Evaluating experience, truck salesmen claim that the "normal" operating life of a bulk milk truck has been about five years; and, after that, it has been worth about 20 percent of its original costs for other uses. Tank salesmen, on the other hand, claim bulk milk tank units have been obsolete after approximately ten years of use; and furthermore, no one has found a worthwhile economic utilization of the old tanks.

On the basis of this trading experience, we calculated depreciation costs for the four specified sizes of hauling units from the information in Table 11. These estimates of depreciation costs were $1,299, $1,487, $1,969 and $2,114 per year for the hauling units with 14,800, 17,500 24,600 and 34,400 pounds of capacity, respectively.

You may notice one economic relationship immediately from these figures. The smallest truck unit can haul, if it is fully utilized, only 43 percent as much as the largest transport; but, it has annual depreciation costs which are 61 percent of the biggest one.

Interest on (Net) Investment

Investors in any asset generally have many alternative opportunities for the use of their money. Thus, an allowance should be made for foregone economic opportunities in any cost analysis.

TABLE 11

ESTIMATED INVESTMENT COSTS OF HAULING EQUIPMENT SELECTED SIZES OF BULK MILK TRUCK UNITS, SOUTHWEST MISSOURI*

Milk Hauling Capacity	Costs of Tank or Tank and Trailer	Cost of Truck or Tractor	Total Costs
(pounds)	(dollars)	(dollars)	(dollars)
14,800	6,400	4,120	10,520
17,500	6,950	4,950	11,900
24,600	8,150	7,210	15,360
34,400	9,600	7,210	16,810

*Truck and tank costs represent 1963 costs in southwest Missouri. Cost information was obtained from the quoted prices of the manufacturers of the truck and tank units. These costs include normal delivery charges and the three percent Missouri sales tax.

We made an allowance of this type in this study. It was calculated using a simple interest rate of five percent on one-half of the net investment (original purchase cost less salvage value) in each transport unit. The estimates for the four transport sizes from the smallest to the largest were $242, $273, $348, and $384. They reflect the annual interest costs of the average amount of money invested during the specified periods.

Taxes

Personal property taxes are levied on all trucks and automobiles in Missouri. Of course, these rates vary considerably throughout an area of the State, as in southwest Missouri. So we specified the tax rate for this study to be 4.5 percent of the assessed value of each truck unit (where assessed value is normally about 30 percent of the purchase price). With this specification, taxes amounted to $158 and $178 for the smallest and largest straight truck and, furthermore, $230 and $252 for the smallest and largest semi-units respectively.

License

Costs of a truck license in Missouri are based upon the size of the truck chassis and other factors such as tire size, number of axles, and loaded gross weight. However, costs of trailer licenses are based upon a flat fee of $7.00 per unit regardless of its length, weight, or hauling capacity.

On the basis of the truck records analyzed, license costs of the straight trucks averaged $130 per year. They were considerably more for the tractor-trailer combinations. Annual license costs were $407 for the smallest semi-units and $607 for the largest ones.

Insurance

All owners of motor vehicles in Missouri are required to have an approved form of liability insurance. Most owners carry additional insurance, too. The typical policy generally includes property damage, bodily injury, collision, and comprehensive insurance. We assumed that all of the truck units would have the following insurance package: $25,000 property damage, $50,000 bodily injury, $250 deductible collision and (full coverage) comprehensive. Then we obtained from the insurance companies their standard insurance premiums for this type of policy in southwest Missouri.

TOTAL FIXED TRUCK COSTS PER LOAD

Summing the above estimates of depreciation, interest, license, taxes, and insurance, we obtained estimates of total fixed truck costs per year. This information is summarized in Table 12; and from it, you may observe that total fixed truck costs per year average about 14 cents per pound of hauling capacity for the smallest transports and only 11 cents per pound for the largest ones. Hence, fixed truck costs decrease on a hauling capacity basis as the size of the transport increases.

From these annual estimates, we can obtain quite easily monthly estimates of fixed truck costs. We just divide each of the annual estimates in Table 12 by 12. We have summarized this information in Table 13 and, from it, calculated estimates of fixed truck costs per load for various specified numbers of loads, Table 14.

Evaluating this cost information, you may observe quickly the importance of utilization. If a transport is utilized only for 15 loads a month, fixed truck costs per load are close to $12 for the smallest truck unit and about $10 higher for the largest one. However, fixed costs per load decrease rapidly for all transport sizes with increases in daily utilization. If a utilization of two loads a day can be gotten from each truck unit then fixed costs per load will be around $3.00 for the smallest transport and about $5.50 for the largest one. Fixed costs of this magnitude are considerably less than those when a truck unit hauls only a load every other day.

ESTIMATES OF TOTAL VARIABLE TRUCK COSTS

Using the frame of reference discussed in the development of the truck cost model, we estimated variable truck costs per month in a relatively straight-forward manner. We summed all of the variable truck costs less gasoline costs, calculated gasoline costs with a constant price of $.254 per gallon and summed these two classifications to obtain total variable costs.[9]

The information in Table 15 summarizes the costs of operating 23 trucks in southwest Missouri in 1962 and the distances traveled to procure the recorded volumes. We related these variable truck costs to miles driven and also to volume hauled and calculated the cost information in Table 16.

It is readily apparent from this information that large transports can haul

[9]The price of $.254 per gallon represents an average figure calculated from the truck cost data.

TABLE 12

ANNUAL DEPRECIATION, INTEREST, TAXES, LICENSE, INSURANCE AND TOTAL FIXED COSTS, SELECTED SIZES OF BULK MILK HAULING UNITS IN SOUTHWEST MISSOURI

Milk Hauling Capacity	Depreciation	Interest	Taxes	License	Insurance	Total Fixed Costs
(pounds)			(dollars per year)			
14,800	1,299.20	242.40	157.80	130.00	312.00	2,141.50
17,500	1,487.00	272.75	178.50	130.00	322.00	2,390.25
24,600	1,968.60	347.95	230.40	407.00	566.00	3,519.95
34,400	2,113.60	384.20	252.15	607.00	584.00	3,940.95

TABLE 13

MONTHLY DEPRECIATION, INTEREST, TAXES, LICENSE, AND INSURANCE, SELECTED SIZES OF BULK MILK HAULING UNITS IN SOUTHWEST MISSOURI

Milk Hauling Capacity	Depreciation	Interest	Taxes	License	Insurance	Total Fixed Costs
(pounds)			(dollars per month)			
14,800	108.27	20.20	13.15	10.83	26.00	178.45
17,500	123.92	22.73	14.87	10.83	26.83	199.19
14,600	164.05	29.00	19.20	33.92	47.17	293.33
34,400	176.13	32.02	21.01	50.58	48.67	328.41

TABLE 14

FIXED TRUCK COSTS PER LOAD FOR SELECTED NUMBERS OF LOADS HAULED PER MONTH AND SIZES OF HAULING UNITS, SOUTHWEST MISSOURI

Number of Loads	Pounds of Hauling Capacity			
	14,800	17,500	24,600	34,400
		(dollars per load)		
15	11.90	13.28	19.56	21.89
30	5.95	6.64	9.78	11.95
60	2.97	3.32	4.89	5.47
90	1.98	2.21	3.26	3.65

TABLE 15

VARIABLE TRUCK COSTS, VARIABLE TRUCK COSTS LESS GASOLINE COSTS, GASOLINE COSTS, DISTANCE TRAVELED, AND VOLUME OF MILK HAULED, SELECTED SIZES OF TRUCKS, SOUTHWEST MISSOURI*

Milk Hauling Capacity	Number of Trucks Studied	Variable Truck Costs Less Gasoline Costs	Gasoline Costs**	Total Variable Truck Costs	Distance Traveled	Volume of Milk Hauled
(pounds)		(dollars)	(dollars)	(dollars)	(miles)	(cwt.)
14,800	14	34,216	24,091	58,307	591,147	857,776
17,500	1	4,313	1,987	6,300	50,896	76,130
24,600	7	22,734	14,743	37,477	247,510	482,163
34,400	1	3,279	2,048	5,327	34,311	128,412

*The data in this table are total figures for all of the trucks studied.

**Gasoline costs were calculated as the product of gallons of gasoline and a gasoline price of $.254 per gallon.

Source: Confidential company records.

TABLE 16

ESTIMATES OF VARIABLE TRUCK COSTS PER HUNDREDWEIGHT-MILE AND PER MILE, SELECTED SIZE OF BULK MILK HAULING UNITS, SOUTHWEST MISSOURI

Milk Hauling Capacity (1)	Size of Load* (2)	Variable Truck Costs Per Mile (3)	Variable Truck Costs per Hundredweight-Mile (3) ÷ (2) = (4)
(pounds)	(pounds)	(dollars)	(cents)
14,800	13,000	.09863	.0758
17,500	16,000	.12378	.0773
24,600	22,000	.15142	.0688
34,400	31,000	.15525**	.0500**

* The size of load is approximately 90 percent of the milk hauling capacity.

** Since these data were collected between major overhauls we adjusted these estimates. It was assumed that a major overhaul costing $1,000 occurred every 35,000 miles.

a unit of volume a given distance cheaper than small ones. Truck costs per cwt.-mile are close to .08 cents for the straight trucks, .069 cents for the smallest semi trucks and .050 cents for the largest semi units.

Remark: Some discretion must be exercised in evaluating these estimates. Only one truck was observed for two of the four sizes. However, our estimates agree quite closely with those obtained by Thompson and Miller.[10]

Patron size and patron density must be kept in mind in an evaluation of these estimates, too. On the one hand, the largest straight truck hauled almost exclusively from farmers located farther apart and producing less milk than the typical farmers in the area. On the other hand, the truck unit having the largest capacity was used primarily to service an area having a relatively high patron and size density. Both of these factors probably had some influence upon these estimates of truck costs.

TOTAL TRUCK COSTS PER LOAD

Summing the above estimates of variable and fixed truck costs, we can obtain estimates of total truck costs per month and per load. It seemed to us that truck costs expressed on the latter basis would be more helpful to decision makers than the former. So we summed the estimates of fixed costs in Table 14 and variable truck costs in Table 17 and calculated the estimates of total truck costs in Table 18.

Both of the truck cost relationships cited before may be observed from these estimates. The importance of use can be seen from a comparison of the cost figures under each hauling capacity for different numbers of loads (and the same route length). This relationship is especially evident when we make a comparison of truck costs for one and two loads a day. When the milk is procured over a 20 mile route, truck costs per load decrease as much as 43 percent for the largest hauling units and as little as 32 percent for the smallest ones.

[10]See footnote 4.

TABLE 17

ESTIMATES OF TOTAL VARIABLE TRUCK COSTS, SELECTED DISTANCES AND SIZES OF TRUCK UNITS, SOUTHWEST MISSOURI*

Distance Traveled	Pounds of Hauling Capacity			
	14,800	17,500	24,600	34,400
(miles)	(dollars)			
20	1.97	2.48	3.03	3.11
30	2.96	3.71	4.54	4.66
40	3.95	4.95	6.06	6.21
60	5.92	7.43	9.09	9.32
80	7.89	9.90	12.11	12.42
100	9.86	12.38	15.14	15.53

*The cost information in this table was calculated for the convenience of the user of the results of this study. It represents an intermediate set of estimates needed for the calculation of total truck costs in Table 18.

TABLE 18

ESTIMATES OF TOTAL TRUCK COSTS PER LOAD, SELECTED NUMBERS OF LOADS HAULED AND SELECTED DISTANCES TRAVELED PER MONTH, FOUR SIZES OF MILK HAULING UNITS, SOUTHWEST MISSOURI*

Number of Loads Hauled Per Month and Distance Traveled Per Load	Pounds of Hauling Capacity			
	14,800	17,500	24,600	34,600
	(dollars per load)			
30 loads				
20 miles	7.92	9.12	12.81	15.06
40 miles	9.90	11.59	15.84	18.16
60 miles	11.87	14.07	18.87	21.27
80 miles	13.84	16.54	21.89	24.37
100 miles	15.81	19.02	24.92	27.48
60 loads				
20 miles	4.94	5.80	7.92	8.58
40 miles	6.92	8.27	10.95	11.68
60 miles	8.89	10.75	13.98	14.79
80 miles	10.86	13.22	17.00	17.89
100 miles	12.83	15.70	20.03	21.00
90 loads				
20 miles	3.95	4.69	6.29	6.76
40 miles	5.93	7.16	9.32	9.86
60 miles	7.90	9.64	12.35	12.97
80 miles	9.87	12.11	15.37	16.07
100 miles	11.84	14.59	18.40	18.17

*The cost information in this Table was obtained by summing the respective estimates in Tables 14 and 17.

Further investigation shows a similar pattern of cost savings of somewhat smaller magnitudes for all of the longer routes.

Making an inter-column comparison of the truck cost information in Table 18, it is again evident that large trucks can haul milk much cheaper than small ones. When two loads a day are hauled, truck costs of the largest units are around 70 percent larger than those of the smallest units; however the payload possibilities of the big trucks are as much as 130 percent greater than those of the small trucks. Similar cost and payload relationships of slightly different magnitudes exist for the 30 and 90 load classifications. Large milk hauling units have considerably lower truck costs per unit of payload and distance than small ones.

Total Hauling Costs

Summing the estimates of labor costs and truck costs, we obtained estimates of hauling costs under various route conditions, Tables 19-22. We have in these cost estimates much useful decision making information which gives a perspective for total hauling costs and the magnitudes of the cost effects of the combined labor and truck cost relationships.

Several economic relationships can be evaluated from a study of the cost information in each table. We can determine the cost effect of truck utilization, patron size and furthermore patron density.

An inter-table comparison, furthermore, highlights the economic relationship between hauling costs and truck size. It clearly shows the mitigating effect of truck size upon the utilization, patron size, and patron density relationships.

It is clearly evident from this cost information that the savings attainable through increased utilization of the truck units are relatively small. They run less than three cents per cwt. for all sizes of transports.

One may notice from an inter-table comparison that the influence of truck size upon hauling costs is somewhat greater than that of utilization. When around 1000 pounds of milk are procured at each farm stop, hauling costs of the smallest semi units are three to four cents less per cwt. than those of the smallest straight trucks. (Compare the hauling costs of the following patron number and load size combinations: 12 and 13,000, 16 and 16,000, 20 and 22,000.) We have here an aggregation of what might be called the labor effect and the truck effect upon hauling costs per cwt. It takes less labor to procure milk with large trucks than small ones; and, furthermore, as pointed out above, truck costs per cwt.-mile of the large semi units are less than those of the small straight trucks. The aggregation of these two economic effects clearly results in significant economies of truck size.

The effects of the density factors upon hauling costs and the mitigating influence of truck size upon the magnitudes of the patron size and density relationships are evident, too. Both patron size and density have pronounced effects upon hauling costs, especially when small trucks are used. For them, hauling costs are five to six cents less per cwt. when a load is procured from eight patrons rather than 20 and five cents more when the farmers are spread out

TABLE 19: TOTAL HAULING COSTS AND HAULING COSTS PER HUNDREDWEIGHT, 13,000 POUND LOAD OF MILK HAULED IN A TRANSPORT HAVING 14,800 POUNDS OF CAPACITY, LENGTHS OF ROUTES, NUMBERS OF LOADS PER MONTH, AND NUMBERS OF PATRONS SERVICED SPECIFIED TO REPRESENT TYPICAL OPERATIONS IN SOUTHWEST MISSOURI*

Number of Loads and Number of Patrons Serviced	Components of Hauling Costs for a 13,000 Pound Load of Milk Hauled in a Transport Having 14,800 Pounds of Hauling Capacity											
	20 Mile Route**				40 Mile Route**				60 Mile Route**			
	Labor	Truck	Hauling	Hauling Costs per Cwt.	Labor	Truck	Hauling	Hauling Costs per Cwt.	Labor	Truck	Hauling	Hauling Costs per Cwt.
30 loads per month												
8 patrons	$14.72	$11.87	$26.59	$.20	$15.97	$13.84	$29.81	$.23	$17.23	$15.81	$33.04	$.25
12 patrons	17.08	11.87	28.95	.22	18.34	13.84	32.28	.25	19.60	15.81	35.41	.27
16 patrons	19.45	11.87	31.32	.24	20.70	13.84	34.54	.27	21.96	15.81	37.77	.29
20 patrons	21.84	11.87	33.71	.26	23.09	13.84	36.93	.28	24.35	15.81	40.16	.31
60 loads per month												
8 patrons	14.72	8.89	23.61	.18	15.97	10.86	26.83	.21	17.23	12.83	30.06	.23
12 patrons	17.08	8.89	25.97	.20	18.34	10.86	29.20	.22	19.60	12.83	32.41	.25
16 patrons	19.45	8.89	28.34	.22	20.70	10.86	31.56	.24	21.96	12.83	34.79	.27
20 patrons	21.84	8.89	30.71	.24	23.09	10.86	33.95	.26	24.35	12.83	37.18	.29
90 loads per month												
8 patrons	14.72	7.90	22.62	.17	15.97	9.87	25.84	.20	17.23	11.84	29.09	.22
12 patrons	17.08	7.90	24.98	.19	18.34	9.87	28.21	.22	19.60	11.84	31.44	.24

*Estimates of labor costs are based upon the information in Tables 8, 9 and 10; and estimates of truck costs are based upon the information in Table 18.

**See footnote 1 to Tables 8, 9 and 10 for explanation of route length.

TABLE 20: TOTAL HAULING COSTS AND HAULING COSTS PER HUNDREDWEIGHT, 16,000 POUND LOAD OF MILK HAULED IN A TRANSPORT HAVING 17,500 POUNDS OF CAPACITY, LENGTHS OF ROUTES, NUMBERS OF LOADS PER MONTH, AND NUMBERS OF PATRONS SERVICED SPECIFIED TO REPRESENT TYPICAL OPERATIONS IN SOUTHWEST MISSOURI*

Number of Loads and Number of Patrons on Route	Components of Hauling Costs for a 16,000 Pound Load of Milk Hauled in a Transport Having 17,500 Pounds of Hauling Capacity											
	20 Mile Route**				40 Mile Route**				60 Mile Route**			
	Labor	Truck	Hauling	Hauling Cost per Cwt.	Labor	Truck	Hauling	Hauling Cost per Cwt.	Labor	Truck	Hauling	Hauling Cost per Cwt.
30 loads per month												
8 patrons	$15.12	$14.07	$29.19	$.18	$16.38	$16.54	$32.92	$.21	$17.63	$19.02	$36.65	$.23
12 patrons	17.49	14.07	31.56	.20	18.75	16.54	35.29	.22	20.00	19.02	39.02	.24
16 patrons	19.86	14.07	33.93	.21	21.11	16.54	37.65	.24	22.37	19.02	41.39	.26
20 patrons	22.22	14.07	36.29	.23	23.48	16.54	40.02	.25	24.73	19.02	43.75	.27
60 loads per month												
8 patrons	15.12	10.75	25.88	.16	16.38	13.22	29.60	.19	17.63	15.70	33.33	.21
12 patrons	17.49	10.75	28.23	.18	18.75	13.22	31.82	.20	20.00	15.70	35.70	.22
16 patrons	19.86	10.75	30.61	.19	21.11	13.22	34.33	.21	22.37	15.70	38.07	.24
20 patrons	22.22	10.75	32.97	.21	23.48	13.22	36.70	.23	24.73	15.70	40.43	.25

*Estimates of labor costs are based upon the information in Tables 8, 9 and 10; and estimates of truck costs are based upon the information in Table 18.

**See footnote 1 to Tables 8, 9 and 10 for explanation of route length.

TABLE 21: TOTAL HAULING COSTS AND HAULING COSTS PER HUNDREDWEIGHT, 22,000 POUND LOAD OF MILK HAULED IN A TRANSPORT HAVING 24,600 POUNDS OF CAPACITY, LENGTHS OF ROUTES, NUMBERS OF LOADS PER MONTH, AND NUMBERS OF PATRONS SERVICED SPECIFIED TO REPRESENT TYPICAL OPERATIONS IN SOUTHWEST MISSOURI*

Number of Loads and Number of Patrons on Route	Components of Hauling Costs for a 22,000 Pound Load of Milk Hauled in a Transport Having 24,600 Pounds of Hauling Capacity											
	20 Mile Route**				40 Mile Route**				60 Mile Route**			
	Labor	Truck	Hauling	Hauling Cost per Cwt.	Labor	Truck	Hauling	Hauling Cost per Cwt.	Labor	Truck	Hauling	Hauling Cost per Cwt.
30 loads per month												
8 patrons	$15.92	$18.87	$34.79	$.16	$17.18	$21.98	$39.07	$.18	$18.43	$24.92	$43.35	$.20
12 patrons	18.29	18.87	37.16	.17	19.54	21.98	41.43	.19	20.80	24.92	45.72	.21
16 patrons	20.65	18.87	39.52	.18	21.91	21.98	43.80	.20	23.16	24.92	48.08	.22
20 patrons	23.02	18.87	41.89	.19	24.28	21.98	46.17	.21	25.53	24.92	50.45	.23
60 loads per month												
8 patrons	15.92	13.98	29.90	.14	17.18	17.00	34.18	.16	18.43	20.03	38.46	.17
12 patrons	18.29	13.98	32.27	.15	19.54	17.00	36.54	.17	20.80	20.03	40.83	.18
16 patrons	20.65	13.98	34.63	.16	21.91	17.00	38.91	.18	23.16	20.03	43.19	.20
20 patrons	23.02	13.98	37.00	.17	24.28	17.00	41.28	.19	25.53	20.03	45.56	.21

*Estimates of labor costs are based upon the information in Tables 8, 9 and 10; and estimates of truck costs are based upon the information in Table 18.

**See footnote 1 to Tables 8, 9 and 10 for explanation of route length.

TABLE 22: TOTAL HAULING COSTS AND HAULING COSTS PER HUNDREDWEIGHT, 31,000 POUND LOAD OF MILK HAULED IN A TRANSPORT HAVING 34,400 POUNDS OF CAPACITY, LENGTHS OF ROUTES, NUMBERS OF LOADS PER MONTH, AND NUMBERS OF PATRONS SERVICED SPECIFIED TO REPRESENT TYPICAL OPERATIONS IN SOUTHWEST MISSOURI*

Number of Loads and Number of Patrons on Route	Components of Hauling Costs for a 31,000 Pound Load of Milk Hauled in a Transport Having 34,400 Pounds of Hauling Capacity											
	20 Mile Route**				40 Mile Route**				60 Mile Route**			
	Labor	Truck	Hauling	Hauling Cost per Cwt.	Labor	Truck	Hauling	Hauling Cost per Cwt.	Labor	Truck	Hauling	Hauling Cost per Cwt.
30 loads per month												
8 patrons	$17.07	$21.27	$38.34	$.12	$18.40	$24.37	$42.77	$.14	$19.65	$27.48	$47.13	$.15
12 patrons	19.05	21.27	40.32	.13	20.76	24.37	45.13	.15	22.02	27.48	49.50	.16
16 patrons	21.88	21.27	43.15	.14	23.13	24.37	47.50	.15	24.38	27.48	51.86	.17
20 patrons	24.24	21.27	45.51	.15	25.50	24.37	49.87	.16	26.75	27.48	54.23	.17
60 loads per month												
8 patrons	17.07	14.79	31.86	.10	18.40	17.89	36.29	.12	19.65	21.00	40.65	.13
12 patrons	19.05	14.79	33.84	.11	20.76	17.89	38.65	.12	22.02	21.00	43.02	.14
16 patrons	21.88	14.79	36.67	.12	23.13	17.89	41.02	.13	24.38	21.00	45.38	.15
20 patrons	24.24	14.79	39.03	.13	25.50	17.89	43.39	.14	26.75	21.00	48.75	.16

*Estimates of labor costs are based upon the information in Tables 8, 9 and 10; and estimates of truck costs are based upon the information in Table 18.

**See footnote 1 to Tables 8, 9 and 10 for explanation of route length.

along a 60 mile route rather than a 20 mile route. Considering the larger truck sizes, the offsetting influence of truck size upon hauling costs is readily apparent and quite revealing. Lower patron densities have much less effect upon hauling costs of the large trucks than of the small ones (when the milk is procured from patrons of specific sizes). Hauling costs per cwt. of the largest semi units are only three cents more for 1550 pound patron stops located along a 60 mile route than for the same size patron stops located along a short 20 mile route. *Thus, for an area of declining milk patron density, the increasing hauling cost effect of decreasing producer density can be minimized and furthermore kept quite small through the utilization of relatively large truck units and the retention of relatively large patron stops.*

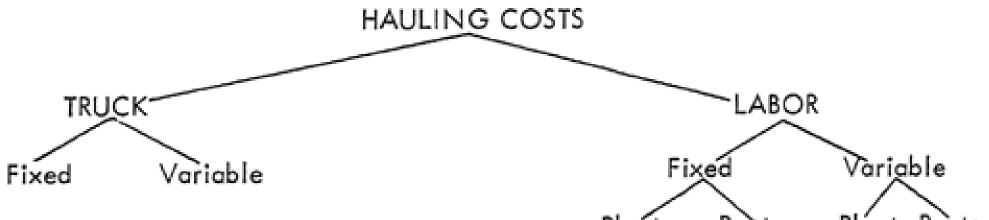
Remark: Certain operating constraints, of course, limit the selection possible in the planning of a farm-to-plant transportation fleet. Farm barnyards may be too small for easy maneuvering of the large transports, or farm lanes may make their operation difficult in inclement weather. Also road restrictions during the spring may force a manager to select hauling units smaller than the largest ones cited.

Other limiting factors are the milk production cycle and equipment failures. Some excess capacity and equipment flexibility must be allowed for these variations. Hence, a truck fleet consisting of a combination of small and large truck units might be more feasible than one consisting of all large units.

SUMMARY AND CONCLUSIONS

The objectives of this study centered initially around the formulation of an analytical framework for the analysis of (bulk) milk hauling costs. Then, with this point of departure, we focused our efforts upon estimating the relationships of this model and analyzing the economic implications of these estimates.

We formulated the analytical framework by partitioning the hauling cost relationship into truck and labor costs. Then we partitioned each of these cost components into fixed and variable costs consisting of plant and route factors. The following diagram illustrates this partitioning:



Models were formulated for each component of fixed and variable truck costs and also each component of fixed and variable labor costs. For each size of truck, truck costs per load were considered as related to miles driven and the number of loads hauled. Labor costs, on the other hand, were considered as related to the wage rate, the volume of milk hauled, patron density and size, and the sizes of the loading and unloading equipment.

Statistical analyses were made of 23 truck records and a time-and-motion study of 41 farm-to-plant milk routes. Estimates were made of each individual component of the overall model. All of these estimates were converted to a comparable cost basis and summed to obtain estimates of milk hauling costs.

Estimates of truck costs were made for four different sizes of hauling units, three different levels of utilization and five different patron densities. The hauling capacities of the truck units were specified to be 14,800, 17,500, 24,600, and 34,400 pounds. We similarily specified four different levels of utilization each month: 30 loads, 60 loads and 90 loads.

Estimates of truck costs were expressed on a load basis, and from these expressions several economic relationships were evident. First, truck costs per load decreased with increased utilization; and second relatively large truck units cost less to operate on a capacity basis (over a given number of miles) than small ones.

Using a wage rate of $2.32, labor costs were estimated on a load basis from the estimates of the time required for each variable and fixed hauling task. Again, significant economies were found to be associated with larger hauling capacities for typical sets of hauling conditions: (1) 8, 12, 16 and 20 patrons per route, (2) 30, 60 and 90 loads per month, and (3) 20, 40 and 60 mile routes. Labor costs per cwt. were considerably less for relatively large trucks than small ones; furthermore, the effect of patron size upon labor costs was found to be generally greater than that of patron density.

When labor and truck costs were summed to obtain milk hauling costs, the cost effect of the labor factors magnified the transportation economies of truck size and further increased the procurement economies possible from servicing large patrons located close together. The magnification of these three relationships was especially striking for the smaller trucks representing the larger relative users of labor (per unit of milk hauled). Hauling costs per cwt. of the largest trucks were more than five cents less (and as much as eight cents less) for comparable patron sizes than those of the smallest trucks studied. The increased cost effect of smaller patrons on the other hand ran as much as six cents per cwt. for the smallest transports studied. Patron density had somewhat similar effects upon hauling costs. Hauling costs per cwt. of the smallest trucks were five cents more when the distance from the first to the last patron was 60 miles than when it was 20 miles. These costs decreased to two cents per cwt. for the same route length and patron size comparisons when the large trucks were considered. The influence of truck size mitigated the relative magnitudes of these hauling cost relationships.

Our results clearly show that relatively large truck units can haul milk significantly cheaper than small ones. Also they vividly illustrate the cost effects of procuring milk from different sizes of milk producers located at different distances apart.

The increasing hauling cost effect of decreasing producer density can be minimized and furthermore kept quite small through the the use of relatively large milk transports and the retention of relatively large patrons.

APPENDIX

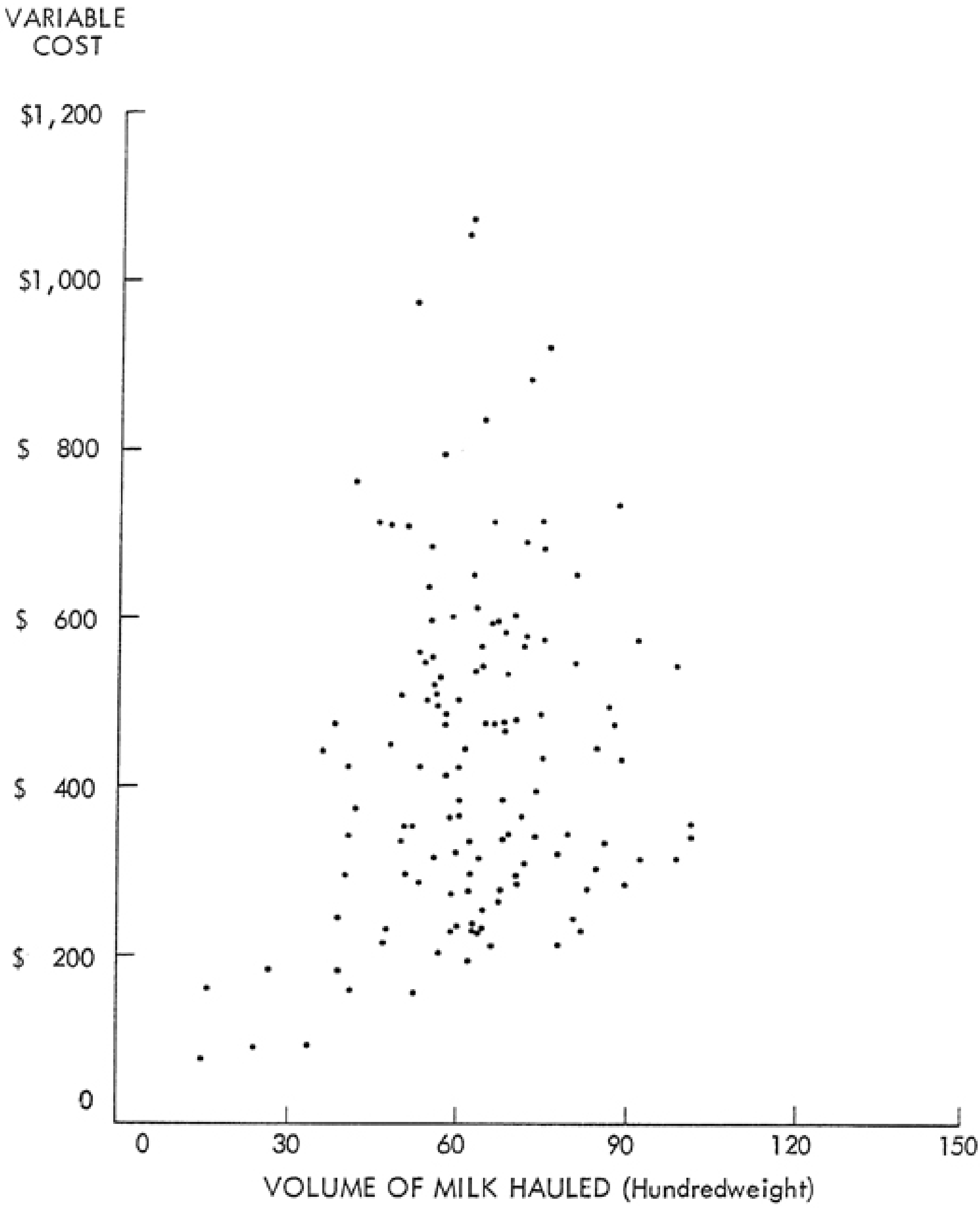


Figure A: Total Variable Truck Costs Versus Volume Handled for 14,800 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri.

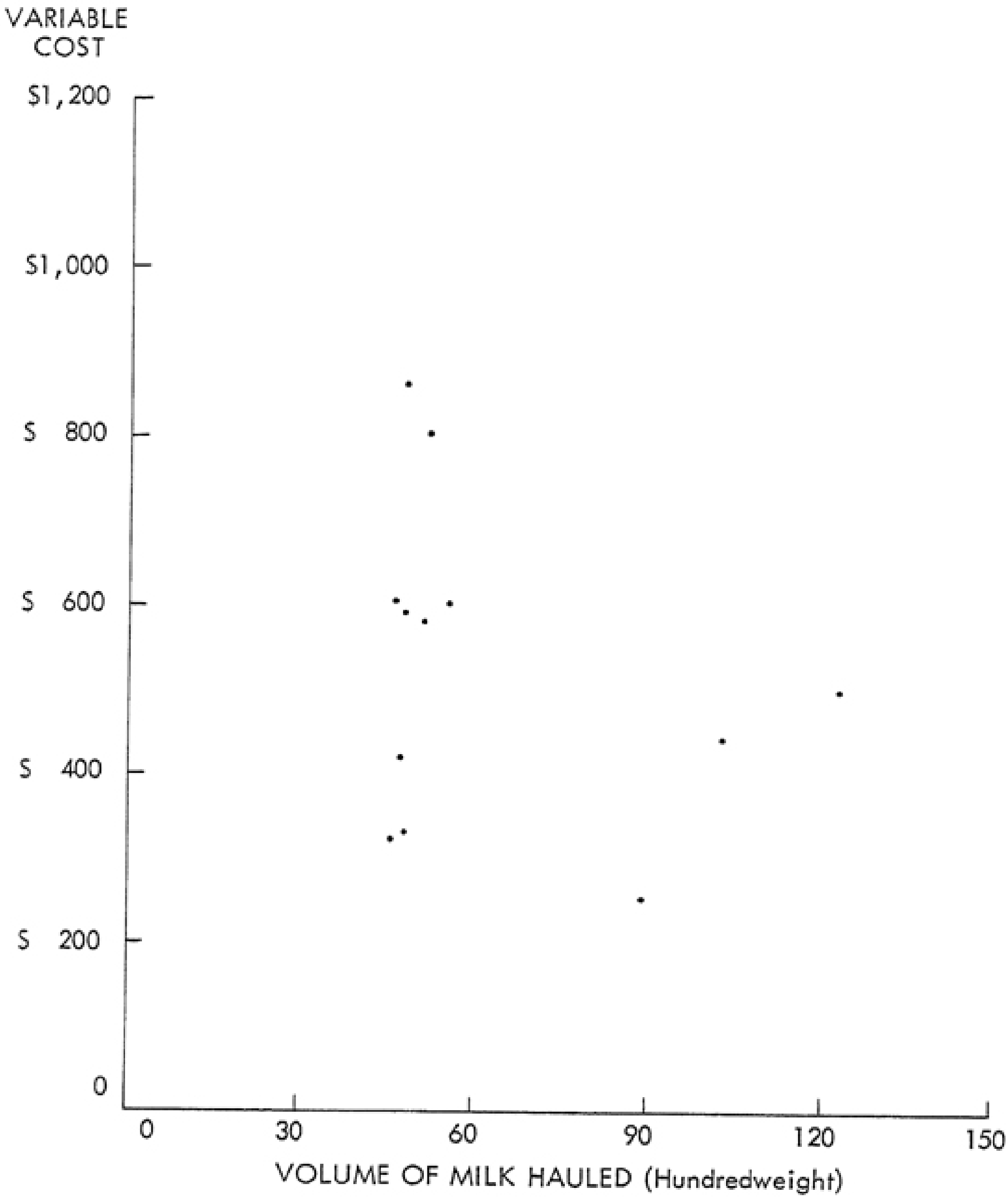


Figure B: Total Variable Truck Costs Versus Volume Handled for 17,500 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri.

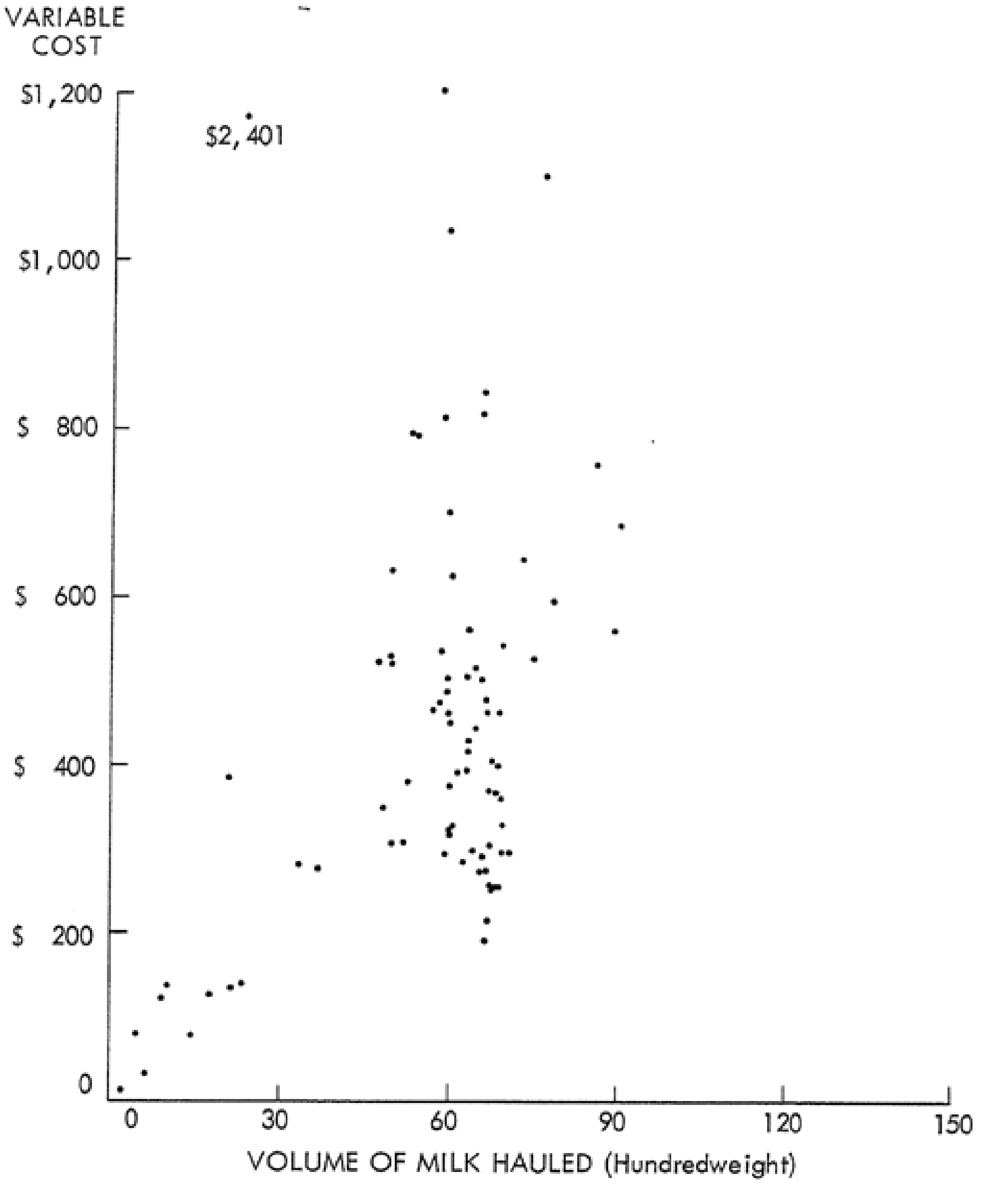


Figure C: Total Variable Truck Costs Versus Volume Handled for 24,600 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri.

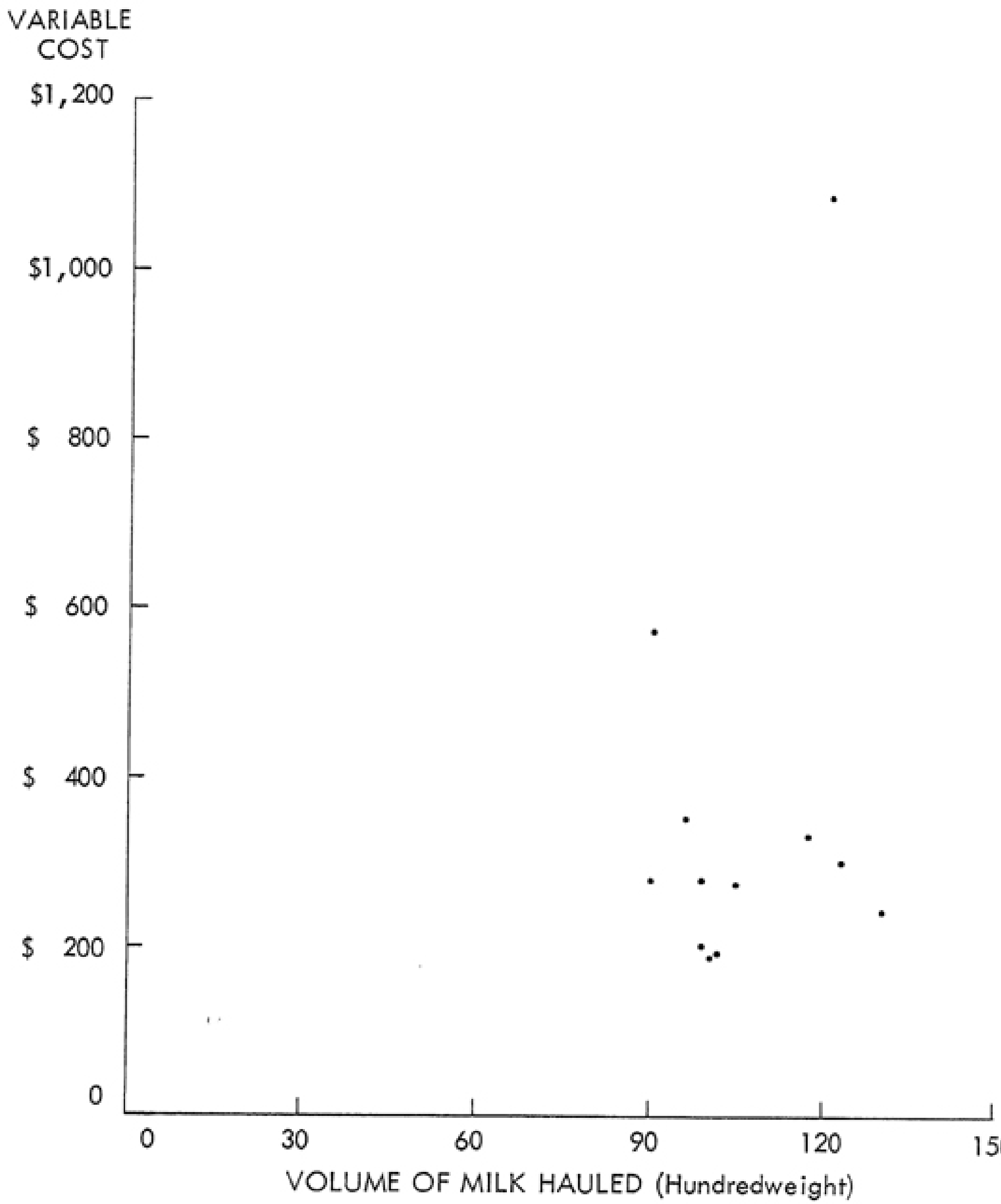


Figure D: Total Variable Truck Costs Versus Volume Handled for 34,400 Pound Milk Hauling Capacity Size of Truck in Southwest Missouri.