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BULK MILK Assembly Costs in Oklahoma

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CONTENTS

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The first commercial assembly of milk from farm bulk milk tanks in Oklahoma was initiated in 1954 in Chickasha. Since then, bulk milk pickup systems in the state have expanded rapidly, particularly in the milksheds serving the Oklahoma Metropolitan Marketing area. Early in 1959 about 50 percent of all milk delivered in this major marketing area was assembled under the bulk milk system.

The equipment used in bulk milk assembly generally is larger, more expensive to purchase, and more expensive to operate than the equipment used in the conventional can system. Larger and more expensive equipment will result in higher transportation costs per mile and per 100 pounds of milk unless these costs can be reduced by efficient organization of bulk milk assembly operations. Consequently, the Oklahoma Agricultural Experiment Station undertook a study to determine the costs of performing each function in bulk milk assembly in order to provide a framework of data and analytical techniques for: (1) attainment of maximum efficiency in present operations, (2) establishment of criteria which management may use in expanding bulk milk assembly operations, and (3) evaluation of alternative procedures for pricing the hauling service to producers.

Procedure

The two major milksheds in Oklahoma, Oklahoma City and Tulsa, were the area of study. At Oklahoma City, the Central Oklahoma Milk Producers Association was the only firm involved in commercial bulk

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milk assembly. At Tulsa, the Pure Milk Producers Association of Eastern Oklahoma was selected for study, since it was the largest commercial bulk milk assembly operation in that milkshed. Major emphasis was on operations in the Oklahoma City milkshed, since bulk milk assembly started earlier there than in Tulsa and was a larger scale operation at the time of the study.

Two types of data were obtained; time and motion data, and accounting data.

The time and motion data were obtained by surveyors who rode with the drivers on the daily pickup routes. In Oklahoma City, observations were obtained during the summer of 1956 for a sample of 44 route days involving 11 drivers on 14 different routes. In Tulsa, observations were obtained during January 1958 for a sample of 14 route days involving 8 drivers on 7 different routes. The time required to perform each operation by each driver was recorded and summarized for each milkshed.

The accounting data were obtained from annual and monthly audits and other records of the firms. Frequently the cost data from these records were aggregated on the basis of usual accounting procedures and were not sufficiently detailed for this analysis. When this occurred, cost data for individual items were estimated by the management of the firms in consultation with the authors. Generally, the time and motion data were used as the basis for allocating cost data to the specific functions performed.[1]

Time Requirements

The total time used by drivers in bulk milk assembly was divided into three major groups: Fixed functions (T_1), farm stop functions (T_2), and driving functions (T_3). Each major group was subdivided for further analysis into the specific functions performed by drivers.

Fixed Functions

Fixed functions were defined as those functions performed by drivers for which the time was about the same for each route. Fixed functions were classified as follows:

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[1] A study of each firm's operation was also completed. See Walter B. Rogers, *Costs and Charges for Bulk Milk Assembly in the Oklahoma City Milkshed*, unpublished PhD dissertation, Oklahoma State University, May 1959, and John W. Goodwin, *Cost of Bulk Milk Assembly for the Pure Milk Producers Association of Eastern Oklahoma*, unpublished M.S. thesis, Oklahoma State University, May 1959.

T_{11} = Check-in
T_{12} = Lunch and coffee
T_{13} = Unload
T_{14} = Wait
T_{15} = Repairs
T_{16} = Other fixed functions

Check-In. The two firms did not have the same check-in requirements for drivers. In Oklahoma City, drivers were required to check instructions; check the truck; drive to the main building; sterilize the tank; assemble and sterilize the pump; obtain ice, producers' supplies, and sample bottles; and perform a few odd jobs. The average time used in all check-in operations, excluding waiting, was 32.3 minutes. Individual time requirements are shown in Table I.

In Tulsa, drivers were required only to check instructions, check the truck, obtain sample bottles, and install a tachograph card. The average time was 13.2 minutes.

A weighted average of the check-in times in Oklahoma City and Tulsa was used in this study. This average was 26.7 minutes per route; thus $T_{11} = 26.7$ minutes.

Lunch and Coffee. The routes were sufficiently long that most drivers stopped for meals or a coffee break. Approximately 26.4 minutes per route was used, which sometimes included refueling. The time was about the same in both milksheds. Thus $T_{12} = 26.4$ minutes.

Unload. Ordinarily there were from one to three stops for any route to unload the milk. Routes terminating at the milk receiving plant were designated as terminal pump-off stops. All routes in Oklahoma City and a few in Tulsa had terminal pump-off stops at the time of the survey. Routes involving a stop to transfer milk from one truck to another truck were designated as enroute pump-off stops. The majority of the routes in Tulsa had enroute pump-off stops. On these routes, there were either two or three pump-offs, depending on whether the enumerator remained with the driver or with the truck when drivers exchanged trucks, the number of routes per day for each driver, and the final destination of the milk.

The average time spent on all routes in unloading milk was 41.2 minutes per route in Oklahoma City and 52.9 minutes per route in Tulsa. These differences reflected the number of pump-offs per route, the quantities of milk pumped, and the capacity of the pumps. They also reflected differences in the testing programs for the two firms. At the time of the survey in Oklahoma City, the unloading operation was performed simultaneously with the milk testing operation. Generally, the testing for butterfat content required slightly more time than unloading and may have resulted in the allotment of more time to the unloading operation than was actually used. Drivers were not required to test milk in the Tulsa milkshed.

For the two markets the weighted average unloading time was 44.0 minutes per route. Thus $T_{13} = 44.0$ minutes.

Wait. Several instances of waiting were observed in the sample routes. In Oklahoma City, waiting was involved in the check-in operations since space and equipment were available to permit simultaneous sterilization of tanks and pumps for only two trucks. Also, waiting was involved in most pump-off operations but the amount of time usually was less if the pump-off occurred at a receiving plant. Many enroute pump-offs required waiting either for arrival of the transport tanker or for arrival of the truck which was assembling milk directly from farm tanks.

The average waiting time was 27 minutes per route in Tulsa and 9.2 minutes per route in Oklahoma City. This difference reflected the greater number of enroute pump-offs. The weighted average waiting time was 13.5 minutes per route (T_{14}=13.5 minutes).

Repairs. The average time used in correcting flat tires and other mechanical breakdowns was 33.1 minutes per route in Tulsa and 3.5 minutes per route in Oklahoma City. The Oklahoma City data were obtained during favorable summer weather, while the Tulsa data were obtained during unfavorable winter weather. It was assumed that the weighted average of these times, 10.7 minutes per route, was representative of average repair time. Thus T_{15}=10.7 minutes.

Other Fixed Functions. Some time could not be directly classified into the previous groups. In Oklahoma City, for example, each driver spent an average of 36.23 minutes in cleanup and checkout operations, whereas most of the cleanup operations were not required of the Tulsa drivers. The weighted average other function time was 27.5 minutes per route (T_{16}=27.5 minutes).

The total fixed function time per route represented the summation of the times for each function. It is listed as follows:

$$(1.1)\ T_1 = T_{11}+T_{12}+T_{13}+T_{14}+T_{15}+T_{16}$$

Therefore:

(1.2) $T_1 = 26.7 + 26.4 + 44.0 + 13.5 + 10.7 + 27.5 = 148.8$ minutes per route.

Farm Stop Functions

The procedures followed by drivers at the farm were standardized, but actual times varied from driver to driver. Generally, differences in times between Oklahoma City drivers for performing individual farm stop functions were statistically significant, but the total time at the farm showed no statistically significant differences between drivers. Therefore, differences between Tulsa drivers in performing the farm stop function were not analyzed.

Farm stop functions were defined as follows:

T_{21}=Hook-up

T_{22}=Weigh the milk

T_{23}=Sample the milk

T_{24}=Write the ticket

T_{25}=Pump the milk

T_{26}=Wash the farm tank

T_{27}=Other farm stop functions

Hook-up. The average time required for a hook-up operation was 1.56 minutes per farm stop in Oklahoma City (T_{21}=1.56 minutes). The average times for individual drivers ranged from 1.17 to 2.04 minutes per stop.

Weigh the Milk. The average time required for obtaining the milk weight was 0.96 minutes per farm stop in Oklahoma City (T_{22}=0.96 minutes). The average times for individual drivers ranged from 0.40 to 1.318 minutes.

Sample the Milk. The average time required for obtaining a milk sample was 0.66 minutes per farm stop in Oklahoma City. The range for individual drivers was from 0.25 to 0.84 minutes. In addition it required an average of about 0.33 minutes for agitation. The total time for sampling and agitation was 0.99 minutes. Thus T_{23}=0.99 minutes.

Write Ticket. This was the most flexible of all the duties performed at the farm stop. The ticket might be partially completed before arrival at the farm and completed during some phase of another operation. On the other hand it might be completed at the farm as the first step, the last step, or some intermediate step. The major reason for this variation in sequence was the volume of milk to be pumped. If the quantity of milk picked up was large, then the ticket usually was written during the pump-out period. If the quantity of milk was small, then the ticket was written just after the weights were established or at the end of the pump-out period.

The average net additional time required for writing the ticket was 0.83 minutes per farm stop (T_{24}=0.83 minutes). For individual drivers the average net additional time ranged from 0.08 to 1.24 minutes.

Pumping Milk. Pumping milk from farm tank to truck tank was the only operation which varied directly with the quantity of milk picked up. The average pump-out time in the Oklahoma City milkshed was 0.214 minutes per hundredweight of milk pumped. For the average producer, this was equivalent to about 2.89 minutes per farm stop (T_{25}=2.89 minutes).

Unhook. The average time required to unhook was 1.39 minutes per farm stop (T_{26}=1.39 minutes). The range for individual drivers was 1.11 to 1.77 minutes.

Wash the Farm Tank. Drivers ordinarily rinsed the farm tank with water after the milk had been pumped out, although occasionally the producer performed this operation. The average time required to rinse the farm tank was 1.24 minutes per farm stop (T_{27}=1.24 minutes).

Other Farm Stop Functions. Interruptions of the driver's normal sequence of operations and the performance of other driver functions were occasionally encountered at the farm stops. These included finding the agitator turning upon arrival at the farm, talking with producers, waiting for producers to finish milking, and delivery of supplies.

The agitator was turning at 5.5 percent of all farm stops in Oklahoma City. The times at these stops were compared with the times at the same (or comparable) farms with the agitator off. On this basis, a net addition of 3.9 minutes per stop was used when the driver found the agitator on. This was statistically significant at the 99 percent probability level.

Producers sometimes detained drivers, either by talking to them or by interrupting the driver schedule in some other manner. The producer was at the barn and interrupted the driver's routine at 3.1 percent of the farm stops in Oklahoma City. This interruption added an average of 4.9 minutes for each of the farm stops where the interruption occurred and the additional time was statistically significant at the 99 percent probability level.

Occasionally, the drivers had to wait or re-route while producers finished milking. The net time used while waiting was 8.2 minutes per farm stop. This was statistically significant at the 99 percent probability level but was observed at only 1.4 percent of all farm stops in the Oklahoma City milkshed.

Delivery services were performed on some routes. Such items as milk strainers, detergents, disinfectants, and small quantities of feed were delivered by the drivers at 2.6 percent of the farm stops in the Oklahoma City milkshed. Although a net additional time of one minute per stop was observed, it was not statistically significant at the 99 percent probability level. However, delivery services to a larger number of producers might increase the time and trouble.

The average amount of time used in these other farm stop operations was 0.53 minutes per stop ($T_{28}=0.53$ minutes.)

Total Farm Stop Functions. The total farm stop time in Oklahoma City represented the summation of the times for each function. It is listed as follows:

(1.3) $T_2=T_{21}+T_{22}+T_{23}+T_{24}+T_{25}+T_{26}+T_{27}+T_{28}$

Therefore:

(1.4) $T_2 = 1.56+0.96+0.99+0.83+2.89+1.39+1.24+0.53=10.39$ minutes per stop

The time required for performing all functions with the exception of pump-out (2.89 minutes in Equation 1.4) may be about the same for each farm stop. For potential use by other firms, an equation was formulated for farm stop time which considered the volume of milk as the only factor which caused variation in the total time at the farm for each route. The least squares regression equations for total time were as follows:

(1.5) Oklahoma City $T_2 = n(7.5)+ \underset{(.015)=S_b}{0.214x}$; d.f. = 563

(1.6) Tulsa $T_2 = n(6.0)+ \underset{(.018)=S_b}{0.205x}$; d.f. = 151

(1.7) Combined Data $T_2 = n(7.4)+ \underset{(.012)=S_b}{0.190x}$; d.f. = 716

where: n = the number of farm stops
x = hundredweight of milk pumped.

The last equation (1.7) is a hybrid equation for the two markets. The Oklahoma City data included a large number of small volumes; the quantity of milk picked up averaged 1368 pounds. On the other hand, the Tulsa data included a large number of large volumes; the quantity of milk picked up averaged 1976 pounds. Generally, the Oklahoma City data resulted in relatively more time for performing the fixed functions (in equation 1.7), since few functions could be performed simultaneously with the pump-out of small volumes. Also it resulted in an understatement of the actual pump-out time based on data for either milkshed. For these reasons the following formula was used to represent the farm stop time:

$$(1.8)\quad T_2 = n(7.4) + 0.21x$$

where n = the number of farm stops
x = hundredweight of milk pumped.

This formula may be used to estimate the individual farm stop time, or it may be used to estimate the total farm stop time for a given route. For example, if an individual producer had 1500 pounds of milk, formula 1.8 indicates that 10.5 minutes would be required at this farm [7.4 + 15 (0.21)]. If there were 10 producers on the route with 14,000 pounds of milk picked up, the farm stop time would be 103 minutes [10 (7.4) + 0.21 (140.)].

Driving Functions

Detailed time and mileage observations were obtained for the driving function in each milkshed. Observations were obtained for 4,789 miles of travel on bulk milk routes in the Oklahoma City milkshed and 3,044 miles in the Tulsa milkshed. These observations related the time required for travel to the number of miles traveled on each particular road classification.

Roads were classified into three major types: paved, gravel, and dirt. A paved road was defined as a hard surfaced road consisting of an asphalt or concrete base. A gravel road was defined as one with some form of special rock or other material placed on the surface to make it an all-weather road. A dirt road was defined as a road of any other type and usually could not be considered as an all-weather road.

Within each major type, roads were further classified into conditions of good, fair and poor. Each classification of road condition was made by the enumerator in consultation with the driver as the road was traversed. The classifications attempted to cover the roughness of the road and the ability of the driver to maintain a desired speed consistent with proper care of the equipment.

Road Classification and Travel Time for Oklahoma City. About 68 percent of all travel in the Oklahoma City area was on roads classified as paved (Table II). Within this class, about one-half was good and one-half was fair. Only a small proportion of the travel was on poor paved roads. About 23 percent of all travel was on gravel roads, distributed fairly equally between fair and poor conditions. Significantly, about 9 percent of all travel was on roads classified as dirt. The proportion of travel on poor dirt roads was slightly greater than on fair dirt roads. Few dirt roads were classified as good.

An average of 1.84 minutes was used in traveling an average mile in the Oklahoma City area. This was equivalent to a speed of 33 miles per hour for driving on all types and conditions of roads. Less time was required for traveling on paved than on gravel or dirt roads. Also less time was generally required for traveling on gravel than on dirt roads.

Within each road type, time varied inversely with the condition of the road. On a mile of a paved road, for example, the minutes required for travel with good condition were 1.58 as compared with 2.02 for poor condition. This was a difference of about 8 miles per hour.

The differences in time per mile on the eastern side as compared with the western side of Oklahoma City were quite small. In most cases, the difference in the actual time required per mile ranged from 0.06 minutes per mile to 1.02 minutes per mile. Expressed in speed, the differences averaged about one-half mile per hour for the good highway classification to about 11 miles per hour for good dirt classification. The differences were not statistically significant. However, there was a higher percentage of dirt roads on the western side of Oklahoma City. About 9 percent of all roads were classified as dirt and most of this was west of Oklahoma City. This fact indicates that more travel difficulties, and greater costs, may be associated with the western routes.

Road Classification and Travel Time for Tulsa. About 79 percent of all travel in Tulsa was on roads classified as paved, with about 60 percent on good pavement, 16 percent on fair pavement, and 3 percent on poor pavement (Table II). About 18 percent of all travel was on gravel roads, with slightly more travel on fair gravel roads than on either good or poor gravel roads. Travel on dirt roads was about 3 percent of all travel, only one-third as large as in Oklahoma City.

About 1.79 minutes were used in traveling an average mile in the Tulsa milkshed. This was slightly faster (one mile per hour) than in Oklahoma City. In general, the estimates for the two milksheds appeared consistent. The times were about the same for each road type and condition. The larger times for the poor gravel and poor dirt road conditions in Tulsa reflected the increase in time because of a greater proportion of wet road conditions in January.

Average Travel Time for Specified Roads. A weighted average time per mile for the two milksheds was computed to represent general Oklahoma travel conditions. These times are also included in Table II.

If these times are used as indicators of speed for the respective road types and conditions, the following formula would summarize the time to travel a given number of miles (T_3) with various percentages of each specified road type (R) and road condition (C).

$$(1.9)\quad T_3 = D(1.53\ R_1C_1 + 1.61\ R_1C_2 + 2.07\ R_1C_3 + 2.10\ R_2C_1 + 2.19\ R_2C_2 + 2.80\ R_2C_3 + 2.23\ R_3C_1 + 2.28\ R_3C_2 + 2.66\ R_3C_3)$$

where

D = distance in miles
R_1C_1 = percentage of roads classified as good highway
R_1C_2 = percentage of roads classified as fair highway
R_1C_3 = percentage of roads classified as poor highway
R_2C_1 = percentage of roads classified as good gravel
R_2C_2 = percentage of roads classified as fair gravel
R_2C_3 = percentage of roads classified as poor gravel
R_3C_1 = percentage of roads classified as good dirt
R_3C_2 = percentage of roads classified as fair dirt
R_3C_3 = percentage of roads classified as poor dirt.

For any given route in Oklahoma, equation (1.9) could be used to estimate the driving time. For example, if there were a 100-mile route on a good highway road, the driving time would be 153 minutes or about 2½ hours. The driving time for combinations of road types or conditions would be calculated from data included in the equation 1.9 or Table II. For example, consider a route which consisted of one-half good highway and one-half good gravel roads. With half of all roads traveled classified as good highway, a net of approximately 76 minutes would be required to travel the good highway part of an average mile [1.53 (.50) = .76]. A similar calculation for the gravel portion of this mile would give 1.05 minutes [2.10 (.50) = 1.05]. The driving time for an average mile is obtained by summing the parts to get a total of 1.81 minutes. This is a weighted average number of minutes per mile. For the hypothetical 100-mile route, the driving time would be 181 minutes or about three hours. This same procedure is applicable to all road types and conditions in determining driving time on typical routes.

For the routes in the Tulsa sample taken in early 1958, the time totaled approximately 312 minutes or about 5¼ hours to drive an average route distance of 175 miles. For routes in the Oklahoma City sample, the time totaled about 267 minutes or about 4½ hours to drive an average route distance of 145 miles. The weighted average driving time would be 277.2 minutes for a route length of 152.4 miles. Thus T_3=277.2 minutes.

Effect of Size of Load. There was no way to estimate the net effect of relative size of load on driving time. Heavy traffic conditions were directly correlated with relative size of load. The trucks were empty or had small loads in the early morning hours at the beginning of the route and had relatively large loads on return to the processing plants during the afternoon and evening hours. Consequently only a gross effect was obtained.

An average of 1.54 minutes per mile was required in Oklahoma City for driving from the Association headquarters to the first farm stop. This compares with 1.72 minutes per mile required for driving from the last farm stop to the scales or point of unloading. The gross effect of relative size of load plus traffic conditions increased the time of travel by about 12 percent. This is equivalent to a reduction in speed of about 4 miles per hour when the truck is returning with a load as compared with the empty truck in early morning travel. This estimate may be used to indicate the upper limits to the effect of a loaded truck as compared with an empty truck on time or cost of pickup.

Route overhead travel was defined as the distance from the Association to the first producer plus the distance from the last producer to the Association's plant. The average for these distances was 76.1 miles per route. Almost all this travel was on paved roads. If road type and conditions are assumed to be 50 percent good pavement and 50 percent fair pavement, this driving would require 119.5 minutes or about 2 hours.

Costs for Specific Functions

The costs of performing the fixed functions, the farm stop functions, and the driving functions were determined from the times reported in the previous section and from estimated costs for labor and trucks. In general, the costs relate to an average obtained from the two firms.

The three major cost items in bulk milk assembly were (1) labor, (2) truck and tank costs, and (3) other costs. Some of these costs varied directly with the quantities of the items used; these were defined as variable costs. Some did not vary with use and were defined as fixed costs. Generally, use was defined in terms of potential variation in costs as related to time or to road types and conditions. This may differ from the usual economic classification of fixed and variable costs.

Cost Items

Labor costs consisted of such items as driver salaries, driver payroll taxes, group insurance, uniforms, laundry, supplies, driver training and other items. Variable labor costs were defined to include only driver salaries and the corresponding payroll taxes. Because of differences in the method of payment to drivers by the two firms, the total time used by drivers in a given accounting period was estimated from the sample and a weighted average cost per minute was determined. On this basis, the variable labor cost was 3.13 cents per minute or about $1.88 per hour.

Fixed labor costs were defined to include all other items directly related to labor. These included salaries of personnel directly concerned with bulk milk assembly operations but excluded mechanics' wages. The weighted annual fixed labor cost for the two firms was $8,752.20, equivalent to about 0.625 cents per minute of time used in the sample period. The fixed labor cost ranged from $977.07 per truck to $1,448.52 per truck for the two firms.

Truck and tank units were the major equipment costs. Variable truck and tank costs were defined to include fuel, oil, truck and tank maintenance, truck rentals, sanitation supplies, and truck and tank depreciation. Depreciation costs generally are not classified as variable costs in economic analyses. However, for purposes of longer range planning, it was felt that such costs did vary with use—particularly as related to road types and conditions. In addition, such costs should be considered in any decision which relates to the expansion of bulk milk assembly operations.

Variable truck and tank costs were computed from total expenditures during a specific accounting period and from the estimated total miles of travel for the same period. For the two firms, the weighted average variable truck and tank cost was 15.80 cents per mile. Truck and tank depreciation was 4.33 cents per mile or 27 percent of this weighted average.[2]

Fixed truck and tank costs were defined to include all other items directly related to this equipment such as insurance, licenses, liquified petroleum equipment and interest. These items averaged $1,628.90 per truck. In addition, maintenance may be purchased directly from a commercial shop or indirectly by hiring a mechanic. The latter case was used by one firm and an annual average fixed cost of $5,971.44 was incurred for the mechanic. The total fixed truck and tank cost was then $1,628.90 per truck plus $5,971.44 for the mechanic. These were the equivalent of 4.16 cents per mile for the sample period.

Other Costs. All costs incurred by the firms for bulk milk assembly, other than direct labor and direct truck and tank costs, were classified as other costs. Some of the items in this classification included depreciation on a portion of the Association buildings, furniture and fixtures, land and driveway improvements, interest, and certain office overhead items. The average of these costs for the two firms was $1,189.71 per truck which was equivalent to 2.44 cents per mile.

Cost of Fixed Functions

It was assumed that labor costs were the only costs involved in performing the fixed functions on bulk milk assembly routes. On the sample routes a total of 148.8 minutes was required to perform these functions. With a variable labor cost of 3.13 cents per minute, the total variable labor cost was $4.66 per route day. The costs for individual functions are included in Table III.

The fixed functions required about 27.1 percent of the total driver time. If fixed labor costs are allocated to these functions on the basis of the proportion of time required, then an annual fixed labor cost of $2,371.85 would be allocated to the fixed functions of bulk milk assembly. Since there were 2,518 route days per year for the sample,

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[2] Depreciation based on 1959 prices of new trucks and new tanks would be somewhat higher than 4.33 cents per mile because of the higher initial costs. Estimates based on information supplied by Rex Williams of Ryder Truck Rental, Inc., Oklahoma City, Oklahoma, indicate that depreciation would be 10 to 15 percent higher at the present time than at the time of this study. Moreover, the increase was greater for some types and sizes of equipment than for others. In addition, the LP fuel cost has increased about 0.3 cents per mile for LP-equipped trucks.

this would be equivalent to about $0.94 per route day. The total cost for performing the fixed functions averaged $5.60 per route day.

Cost of Farm Stop Functions

It was assumed that labor costs were the only costs involved in performing the farm stop functions. For the average size stop in Oklahoma City, the variable labor cost was 32.5 cents per farm stop. However, this included pump-out time which varied with the quantity of milk picked up. Excluding the pump-out time, the variable labor cost was 23.5 cents per stop in Oklahoma City. The comparable weighted average variable labor farm stop cost for the two firms was 23.2 cents per stop. (Table IV). The variable labor cost was $0.66 per hundredweight of milk pumped, based on the pump-out time of 0.21 minutes per hundredweight of milk.

The farm stop functions required about 22.5 percent of the total driver time. If fixed labor costs are allocated to these functions on the basis of this percentage, then an annual fixed labor cost of $1,969.24 would be allocated to the farm stop functions of bulk milk assembly. There were approximately 2,518 route days with 12 farm stops per route for the sample. On the basis of these data the share of fixed labor cost for performing the farm stop functions would be 78.2 cents per route day or 6.5 cents per farm stop. The total cost (fixed plus variable) for each route would be $4.78 or about 40 cents for each farm stop.

Cost of Driving

The cost of driving was defined to include labor costs, truck and tank costs, and other costs. Variable costs of driving included variable labor and variable truck and tank costs. Fixed costs of driving included a portion of fixed labor costs, all of the fixed truck and tank costs, and all of the other costs associated with bulk milk assembly operations.

Variable labor costs per mile were obtained by multiplying the labor cost of 3.13 cents per minute by the number of minutes required per mile. The formula for variable labor cost for roads with various percentages of each road type and condition is:

$$(2.1)\quad VLC = D[4.79\ R_1C_1 + 5.04\ R_1C_2 + 6.48\ R_1C_3 + 6.57\ R_2C_1 + 6.85\ R_2C_2 + 8.76\ R_2C_3 + 6.98\ R_3C_1 + 7.14\ R_3C_2 + 8.33\ R_3C_3]$$

where VLC = variable labor cost per mile

D = the number of miles

R_iC_i = the percentage of roads in each type and condition classification.

Variable truck and tank costs were 15.80 cents per mile. If these costs are related directly to the travel or driving time, then the variable truck cost would be equivalent to 8.69 cents per minute. The formula for variable truck and tank costs related to actual time of travel would be as follows:

$$(2.2)\ VTC_1 = D[13.30\ R_1C_1 + 13.99\ R_1C_2 + 17.99\ R_1C_3 + 18.25\ R_2C_1 + 19.03R_2C_2 + 24.33R_2C_3 + 19.38R_3C_1 + 19.81R_3C_2 + 23.12R_3C_3]$$

where VTC_1 = variable truck and tank costs based on actual time of travel

D = the number of miles

R_iC_i = the percentage of roads in each type and condition classification.

Variable truck costs based on actual time of travel appeared to overstate the cost of travel on paved roads and to understate the cost of travel on gravel and dirt roads. On the latter roads, equipment will have a shorter expected life and a higher maintenance cost. In addition, extra time may be used for travel when the roads are wet and muddy. For these reasons, an alternative set of estimates was made for variable truck costs on the basis of the following assumptions:

1. Each minute of paved road travel time would constitute one unit of cost.
2. Each minute of gravel road travel time would constitute 1.5 units of cost.
3. Each minute of dirt road travel time would constitute 2.0 units of cost.

On the basis of these assumptions, a unit cost of 7.06 cents would be equivalent to a variable cost of 15.80 cents per mile for the travel time used in the sample. The formula for this variable truck and tank cost definition is:

$$(2.3)\ VTC_2 = 10.80\ R_1C_1 + 11.37\ R_1C_2 + 14.61\ R_1C_3 + 22.24\ R_2C_1 + 23.23\ R_2C_2 + 29.65\ R_2C_3 + 31.49\ R_3C_1 + 32.19\ R_3C_2 + 37.56R_3C_3$$

VTC_2 = variable truck and tank costs based on assumed unit costs

D = the number of miles

R_iC_i = the percentage of roads in each type and condition classification.

Fixed Labor Cost. About 50.4 percent of the total driver time was used in actual driving operations. If fixed labor costs are allocated on the basis of actual driving time, then an annual fixed labor cost of $4,411.11 would be allocated to the function of driving for the scale of operations of the firms in the sample. This was an average of $566.40 per truck per year and was equivalent to $1.55 per route day or about 1.0 cent per mile.

Fixed truck and tank costs averaged $1,628.90 per truck per year for the firms in the sample. This was equivalent to $4.46 per route day or about 2.9 cents per mile. These costs exclude a fixed charge for a mechanic if one is hired. For the scale of operations of firms in the sample, hiring a mechanic would add about $766.75 per truck to the annual fixed truck and tank cost or about 1.4 cents per mile.

Other costs associated with bulk milk assembly operations averaged $1,-189.71 per truck per year. This was equivalent to $3.26 per route day or about 2.1 cents per mile.

Total costs of driving were computed from two sets of variable costs plus the fixed costs. For the first estimate of total cost, the variable labor cost per mile was added to the variable truck and tank cost per mile based on actual travel time. The fixed labor, truck and tank, and other costs were aggregated on the basis of annual costs per truck and added to the variable costs. The equation for this estimate is:

$$(2.4)\quad TC_1 = T(\$3{,}385.01) + D(18.09\ R_1C_1 + 19.03\ R_1C_2 + 24.47\ R_1C_3 + 24.82\ R_2C_1 + 25.88\ R_2C_2 + 33.09\ R_2C_3 + 26.36\ R_3C_1 + 26.95\ R_3C_2 + 31.45\ R_3C_3)$$

where TC_1 = total cost of driving based on actual time estimates

T = total number of trucks

D = total number of miles

R_iC_i = the percentage of roads in each type and condition classification.

For the second estimate of total cost, the variable labor cost per mile was added to the variable truck and tank cost per mile which was based on assumed unit costs. The equation for this estimate is:

(2.5) $TC_2 = T(\$3{,}385.01) + D(15.59\,R_1C_1 + 16.41R_1C_2 + 21.09\,R_1C_3 + 28.81R_2C_1 + 30.08R_2C_2 + 38.41R_2C_3 + 38.47R_3C_1 + 39.33\,R_3C_2 + 45.89\,R_3C_3)$

where TC_2 = total cost of driving, based on assumed unit cost estimates
T = total number of trucks
D = total number of miles
R_iC_i = the percentage of roads in each type and condition classification.

Consideration of driving costs for individual routes may require a different type of estimate for the fixed cost items. Based on the use of time and the scale of operations of bulk milk assembly operations of the two firms sampled, the total fixed costs of $3,385.01 per truck may be expressed in equivalents of either $9.27 per route day or 6.0 cents per mile.

The average cost of travel for each road type and condition, based on formula (2.5), is illustrated in Figure 1 and Table V. The addition of a proportion of the fixed cost to each mile results in a range of travel

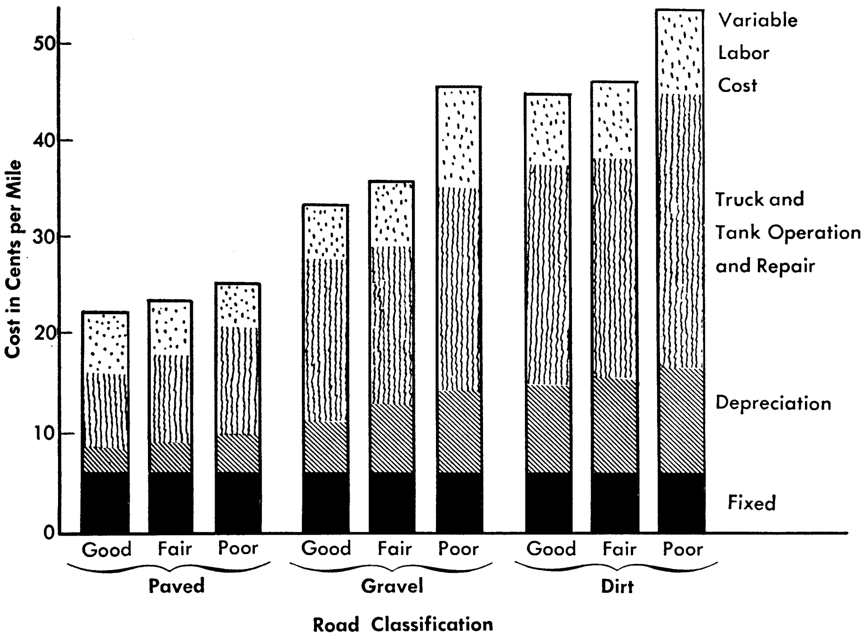

Figure 1. Average cost of travel for each road type and condition, based on formula (2.5). Costs ranged as high as 52¢ per mile for poor dirt roads.

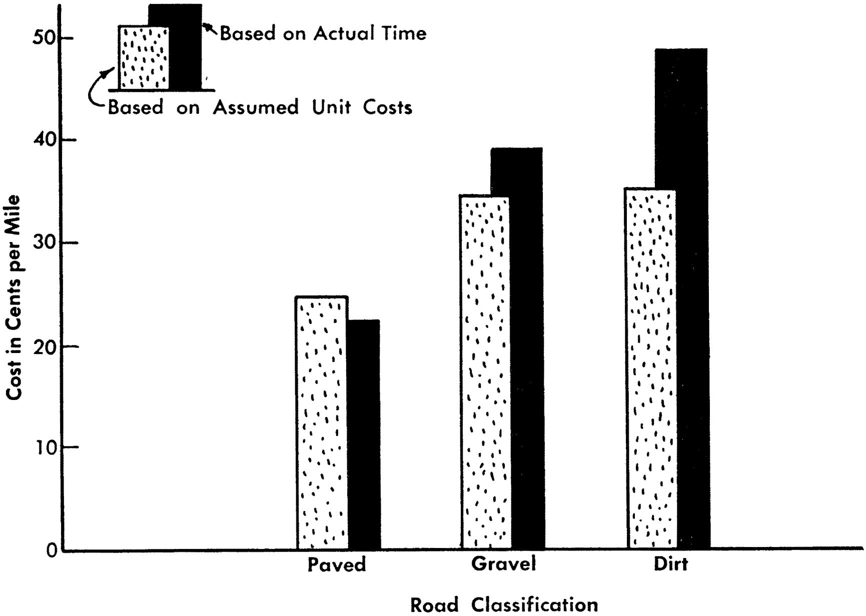

Figure 2. Costs of travel on the three road types derived from formulas (2.4) and (2.5).

costs from 21 cents per mile for good paved roads to 52 cents per mile for poor dirt roads.

The costs of travel on the three road types, derived from formulas (2.4) and (2.5), are shown in Figure 2. The general effect of using the assumed unit costs (costs in equation 2.5 weighted by the percentage of roads traveled) is to decrease the cost of travel on paved roads and to increase the cost of travel on gravel and dirt roads relative to cost estimates based on actual time of travel. The difference is greatest for travel on dirt roads.

Cost of Driving Alternative Tank and Truck Size Units. There is flexibility in the sizes of transportation equipment that may be used in bulk milk assembly. However, four major sizes appeared to be most important for Oklahoma conditions. These were (1) a 1600- to 1800-gallon tank on a single-axle truck, (2) a 2500- to 2600-gallon tank on a tandem-axle truck, (3) a 2800- to 3000-gallon tank on a single-axle trailer, and (4) a 4000- to 5000-gallon tank on a tandem-axle trailer. Only the first three sizes have been used extensively for farm pickups in Oklahoma.

The costs of driving reported in the previous sections were average cost for all size units in the sample. However, they were approximately the same as those which would be experienced with a 2500-gallon tank on a tandem-axle truck. Estimates for the other size tanks and trucks were obtained by applying percentages to the costs for the 2500-gallon tank and corresponding truck which was considered as a base.[3]

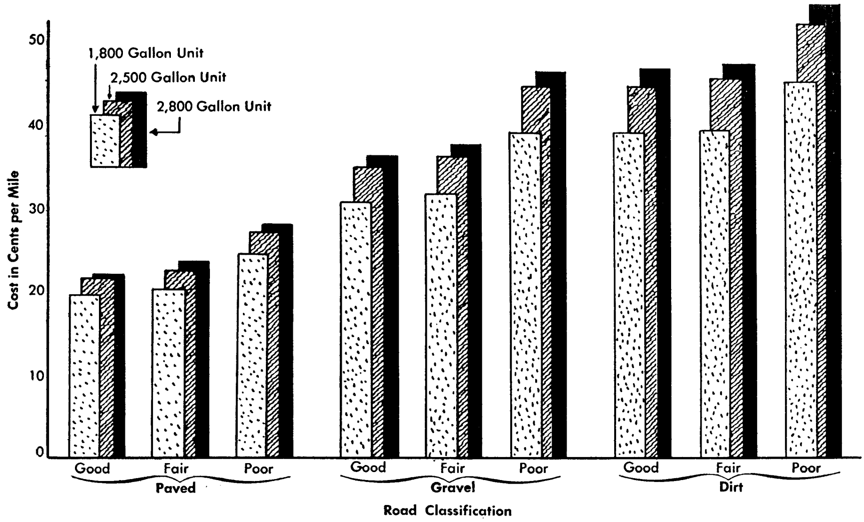

Figure 3. Estimated costs for driving 1800-, 2500- and 2800-gallon units on various types and conditions of roads.

An 1800-gallon tank on a single-axle truck required the smallest total investment. It was assumed that the depreciation on this size unit was only 78 percent of investment for the 2500-gallon unit, equivalent to 3.3 cents per mile. The operating costs were also lower. It was assumed that the operating costs were 18 percent less than the base or 9.4 cents per mile. The estimated costs for driving on various types and conditions of roads are shown in Figure 3 and Table VI.

A 2800-gallon tank on a single-axle trailer required a larger tank and trailer investment but a smaller truck investment as compared with the 2500-gallon unit. However, both the total investment and the total operating cost were higher than for the base unit. For the 2800-gallon unit, it was assumed that the depreciation was 5 percent higher and the operating cost was 7 percent higher than for the 2500-gallon

[3] These percentages were derived from data from potential lease contracts submitted by Baker Truck Rental (now Ryder Truck Rental, Inc.) to one of the firms. The estimated cost for 1959 price levels would be higher than reported in this section. See footnote on page 16.

unit. This was equivalent to 4.6 cents per mile for depreciation and 12.3 cents per mile for operation. The estimated costs for driving on the various types and conditions of roads are also shown in Figure 3.

A 5000-gallon tank on a tandem-axle trailer required the largest investment of all units considered. It was assumed that this unit was equipped with a diesel power unit and that the unit was used on travel of 95 to 100 thousand miles of paved roads per year. Under these assumptions the depreciation cost would be about 7 cents per mile. However, operating costs would be less because of the differential in the cost of fuel and the less frequent repairs. Operating costs were assumed to be about 9 cents per mile. The total cost, including depreciation, operation and maintenance, labor, and a share of the fixed costs of the firm was about 28 cents per mile.

Analysis of Routing Procedures

The distance traveled, the types and conditions of roads, the number of producer stops, the volume of milk, and the size of the tank and truck units are important factors determining the bulk milk assembly costs per route and costs per hundredweight. In this section, the detailed breakdown of labor and truck costs involved in bulk milk assembly will be used to (1) evaluate costs under alternative routing systems, and (2) illustrate how to determine costs associated with adding new producers to existing routes.

Alternative Routing Procedures

Visual inspection of the geographical location of bulk milk producers indicated that producer stops could be grouped into zones or sectors for analysis. A sector was defined as a circle around an actual pump-off stop or a potential enroute pump-off stop. For this analysis, a circle with a 20-mile radius was selected. Since all milk was scheduled to be delivered to a central city (Oklahoma City or Tulsa in this study), the first sector was associated with that city. The second sector was defined as the area within a 20-mile radius circle around a city approximately 52 miles from the central city. The third sector was defined as the area within a 20-mile radius circle around a city approximately 82 miles from the central city. The fourth sector was defined as the area within a 20-mile radius circle around a city approximately 105 miles from the central city. The distances associated with these sectors were similar to actual distances associated with enroute pump-off stops for one of the firms.

The total cost of completing a given route will depend on the amount of overhead cost allocated to each route, the number of producer stops, the volume of milk, the density of producers, the number of miles between producer stops, the distances traveled, and the size of the tank and truck unit. For simplification of the problem of routing, a number of assumptions were made. These were:

(1) The cost of the fixed functions is $5.60 per route.

(2) The average volume of milk picked up is 250 gallons (21.5 cwt.) per farm stop and the cost is 44 cents per stop [$29.7+0.66\ (21.5) = 44$ cents].

(3) The average distance between producer stops is 5 miles and the cost per mile is determined on the basis of 50 percent paved roads and 50 percent gravel roads.

(4) For overhead miles, the average distance traveled within each zone is 40 miles and the cost per mile is determined on the basis of 100 percent paved roads.

(5) Travel from an outlying sector to the central city is equivalent to a round trip from center of sector of pickup to center of sector of pump-off and the travel is on paved roads.

(6) A 5000-gallon transport can be used as a mobile receiving station and only the cost of driving this unit is computed. No extra labor costs are included for check-in, pump-off, or check-out operations.

The budgeted costs per route for the various size tank and truck units under these assumptions are included in Table VII.

Generally, only small differences were noted between costs for the 2500-gallon unit and for the 2800-gallon unit. However, the 1800-gallon tank and truck unit had lower costs per mile but greater costs per hundredweight for each sector as compared with the larger size units. The differential in costs per hundredweight increases with the distance of the sector of pickup from the central city. For this reason, one of the larger size units appears to provide the lowest costs of bulk milk pickup in Oklahoma where density of producers and road conditions permit the use of this size of equipment.

The relationships between density, route length, and costs for the 2500-gallon tank and truck unit are illustrated in Figure 4. In section A, the curved line (a rectangular hyperbola) translates the route length (X_1) into an equivalent density of milk in gallons per mile (X_2). Associated with a given density (X_2) in each of four sectors was a total cost per

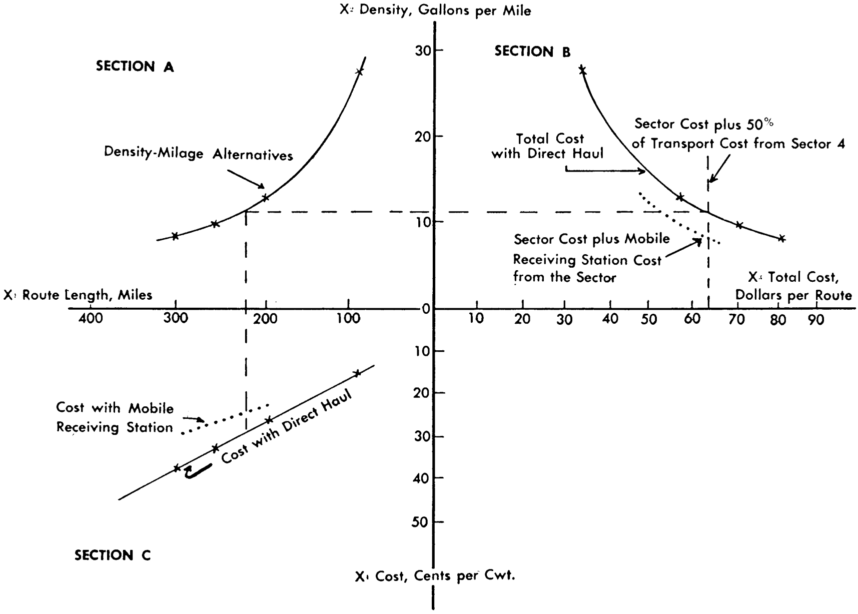

Figure 4. Relationships between density, route length and costs for a 2500-gallon tank and truck unit.

route (X_3). The curved solid line in section B was obtained by connecting the points representing costs for these four sectors. In section C, the solid line shows the bulk milk assembly cost per hundredweight (X_4) as related to the route length (X_1). This relationship was approximately linear for the four sectors under study.

The cost per hundredweight for bulk milk assembly can be reduced if density can be increased. One way of increasing density is by use of mobile receiving stations. This may be accomplished by stationing a truck in the outlying sectors for farm milk assembly, then pumping the milk into a transport for hauling to the central city.

Two estimates of costs were made for bulk milk assembly using the mobile receiving station concept. A 2500-gallon unit stationed in the sector and a 5000-gallon transport unit were used for both estimates.

For the first estimate, it was assumed that the transport would travel 210 miles from the central city to the center of sector 4 and return. It was also assumed that a 2500-gallon load in any sector should bear 50 percent of the transport cost. Thus, the total cost for a 2500-gallon load would be \$34.21 for the 2500-gallon unit plus \$29.40 for one half the cost for the 5000-gallon unit, or \$63.61. This cost is represented by the dash line in section B. The intersection of the dash line with the solid line in section B can be used to determine the maximum length of route from the central city for these density, volume, and cost conditions. In this case, the maximum length is 220 miles of which 75 miles is associated with travel in the sector and the sector is located 72 miles from the central city. For any route longer than 220 miles, cost per hundred weight can be reduced by using a mobile receiving station even though 50 percent of the cost of the transport for 210 miles is allocated to this route.

For the second estimate, it was assumed that the transport would make one round trip from the central city to the center of any one of the sectors and haul a full load. Two 2500-gallon trucks stationed in this sector could provide the necessary volume. The total cost for a 2500-gallon load would be $34.21 for the 2500-gallon unit plus one of the following: $14.56 for transport cost from sector 2, $22.96 for transport cost from sector 3, or $29.40 for transport cost from sector 4. These estimates of total route costs were connected and are shown by the dotted line in section B of Figure 4. The comparable estimates of costs per hundredweight are shown by the dotted line in section C. Savings which result from use of the mobile receiving station transport are 4 cents per cwt. in sector 2, 6 cents per cwt. in sector 3, and 8 cents per cwt. in sector 4. These savings are shown as the difference between the solid line and the dotted line in section C for the original route length from the central city.

Similar computations were made for other tank and truck size units. The maximum length of route was about 180 miles for the 1800-gallon unit if this unit shared 36 percent of the cost of the 5000-gallon transport for 210 miles. The savings by using the mobile receiving station transport rather than direct hauls with the 1800-gallon unit into the central city varied from 6 cents per cwt. in sector 2 to about 13 cents per cwt. in sector 4. The maximum length of route and the potential savings with use of the 5000-gallon transport were slightly less for the 2800-gallon unit than for the 2500-gallon unit.

Costs for other types of routes could be determined from these assumptions. For example, it may not be feasible to station a truck in an outlying sector but it may be possible to have that truck pick up one load in the sector, pump-off into a transport at the center of that sector, and then pick up another load in that sector and return to the central city. In this case, the extra costs for the last load would include costs for additional producer stops, additional travel between producers and some increase in overhead mileage. For the assumptions used in this section, the extra costs for the last load would total about $30 for the 2500-gallon unit for each of the sectors, or about 14 cents per 100 pounds.

Cost of Adding A New Producer to An Existing Route

Costs and returns from adding a new producer can be determined from the costs of fixed functions, farm stop functions, and the driving functions. For example, suppose a producer was considering the installation of a bulk tank and that he is now shipping about 400 pounds of milk per day in cans. However, if he converts to bulk, there is reason to believe that he may increase present production by 25 percent. If he succeeds in increasing production, he will ship about 1,000 pounds per pickup on an every-other-day basis. For this production he may have a herd of about 26 cows averaging 7,000 pounds per cow per year. Assume that this producer is located in a zone in which he will be charged 30 cents per 100 pounds for hauling. At this rate, the hauling agency would gross $3.00 per pickup.

Can the hauling firm afford to agree to haul this producer's milk at this rate? This answer depends, of course, on a number of cost factors. First, how many extra miles of travel would be necessary? Assume that this producer is located 6 miles from the established route and that, in view of the road conditions, it will be necessary to back track on the route. A total of 12 miles would be added to the route for this producer stop.

Second, what kinds of roads must be traveled? In this example, assume that two miles are fair highway, one mile is poor highway, two miles are fair gravel, and one mile is poor gravel. Since the road must be back tracked, total travel will be four miles on fair highway, two miles on poor highway, four miles on fair gravel and two miles on poor gravel.

The added costs to the hauling firm can be determined from either equation (2.4) or equation (2.5) if the route involves a 2500-gallon tank and truck unit. If equation (2.5) is selected as the appropriate estimate of costs, the following costs would be incurred for this producer stop:

Fair highway	4 miles at 16.41 cents =	$0.66
Poor highway	2 miles at 21.09 cents =	0.42
Fair gravel	4 miles at 30.08 cents =	1.20
Poor gravel	2 miles at 38.41 cents =	0.77
Extra cost of driving		3.05
Extra labor cost at the farm		.30
Total of extra costs		$3.35

These extra costs include labor, truck and tank operation, and wear and tear on trucks and tanks, but they do not include any contribution to other overhead costs of running the bulk tank pickup service. In addition, they do not provide for the fixed labor costs such as laundry and driver supplies.

With income at $3.00 per pickup and extra costs at $3.35 per pickup, a loss to the hauling agency would be inevitable. It is not so much the actual distance which will make this unprofitable as it is the kind of roads traveled. If the gravel roads were paved, the total extra costs would have been $2.36, which would be less than income. In this case some contribution would be made to the share of the overhead cost items.

If the overhead costs were included, a greater total cost would be incurred by adding this producer. Such costs based on the average share for 12 producers might include: $1.18 for fixed costs of driving, 6 cents for fixed costs of labor at the farm, and $0.47 for an average share of fixed functions. The total cost would be $5.06. However, if these costs are determined on the basis of 13 producers per route rather than the average of 12, then the total cost would be $4.93.

Obviously, the hauling firm could not afford to add this bulk tank producer on the basis of the road conditions and distances assumed. Three alternatives are open to make costs equal to revenue for this producer stop. First, the hauling rate for this particular producer may be increased to at least 34 cents per hundredweight. A 34 cent hauling charge would increase revenue to $3.40—five cents greater than total extra costs. However, an increase in the hauling rate to about 50 cents per hundredweight of milk would be necessary for the producer to assume his full share of costs.

Second, the producer may increase production. An increase of 60 pounds per day or 120 pounds per stop would increase income to $3.36 per stop. This would be approximately the same as the extra costs involved in the pickup. However, the producer would have to increase production to about 822 pounds per day (1644 pounds per stop) to cover his full share of $4.93.

Third, if an additional producer of equal size were located near this producer and would install a bulk tank, the revenues from both producers would exceed the extra costs. For two producers, the firm would receive $6.00 income for the combined volume of 2000 pounds every other day. The extra cost of adding one producer was $3.35. However, in this case, the extra cost of adding two producers would be $3.35 plus $0.30 extra labor cost at the second farm plus some small extra cost of driving from one barn to the other. This would result in a total extra cost of $3.65. If each is to share equally with all other producers in the overhead costs, $1.49 must be added to each producer's cost.[4] This would bring the total cost for both producers to $6.63. These producers would still lack 63 cents paying their full share of costs, but they would make a substantial contribution to fixed costs of the running of the route. Three producers of this size located in close proximity would result in total costs which were less than total receipts provided the present truck had enough excess capacity to add these producers to the route.

Analysis of Alternative Hauling Rate Systems

There are several basic methods which might be used for determining the bulk milk transportation charges to producers. Among these basic methods are: (1) a standard flat rate per 100 pounds of milk, (2) a zone rate per 100 pounds of milk with zones related to distances from a central point in the milkshed, and (3) a flat charge per stop.

When bulk milk pickup was initiated by the Central Oklahoma Milk Producers Association, a standard flat rate of 25 cents per 100 pounds of milk was used. This method had the advantage of simplicity in administration and in producer understanding. However, it did not reflect the costs involved in transporting milk from producer farms to plants when these farms were not equally distant from the plants.

The can-type pickup service which was being displaced was priced on the basis of distance traveled and charges varied from about 25 cents per 100 pounds for producers relatively close to the plants to as much as 50 cents per 100 pounds for producers relatively far from the plants. On the basis of these charges, the incentive for producers to change to the bulk system was greatest at the periphery of the milkshed and these distant producers actually were first to make the transition. This resulted in a concentration of farm stops at greater than average distances from the plants which, in turn, caused relatively high transportation costs per 100 pounds of milk hauled. Under these conditions, either the producers who were located relatively close to the plants were helping to defray the transportation costs of producers located further from the

[4] This assumes that 14 producers would share the overhead costs of each route, rather than 12 producers.

plants, or, if deficits to the Association occurred, all members of the Association were helping to defray these costs. Either situation appeared unacceptable for the long-run interests of the Association.

In April, 1956, the Association changed its pricing procedure from a standard flat rate to a zone rate per 100 pounds of milk. Zones were established on the basis of 20-air-mile intervals. Producers who were located in the interval between two concentric circles were charged the same rate per 100 pounds of milk. The zones and charges per hundredweight per zone for Oklahoma City were as follows: 0-20 miles, 25 cents; 21-40 miles, 30 cents; 41-60 miles, 35 cents; and over 60 miles, 40 cents.

This method represented a compromise between a standard flat rate per 100 pounds and a rate based on distance. As such it incorporated both advantages and disadvantages of each method. The 20-air-mile zone rate system required somewhat more effort to establish transportation charges which were applicable to individual producers; but, once established, it was relatively easy to administer. In addition, it was more equitable among producers than the standard flat charge and most producers understood this pricing system. However, problems of equity among producers still existed. Costs of transportation were greater for producers located at the outer fringe of the zone than for producers located at the inner fringe of the zone, particularly for zones established on 20-air-mile intervals. Also, any zone may have resulted in different charges to neighboring producers who were located on opposite sides of the same road. In addition, there was also the question of whether air-miles or miles from the producer to a central point with travel on the most direct hard surfaced road should determine the zone rate.

In the analysis which follows, standard flat-rate, 20-air-mile zone, and 5-air-mile zone systems are considered. The analysis is based on conditions in the Oklahoma City milkshed.

Income and Costs for Standard Flat Rate

During the 1956 calendar year, a total of 46,732,376 pounds of bulk milk was picked up from farms by the Association. At 25 cents per 100 pounds, this would indicate a gross income of $116,831. The budgeted costs totaled $156,632. Using these costs, a net loss of $39,801 would have occurred for the bulk milk hauling operations of the Association in 1956 under the 25-cent flat rate. This would be a loss of 8.5 cents for each 100 pounds of milk, or about $13.28 per route day. This would be equivalent to about $1.00 for each producer per pickup or about $186 per producer per year.

These cost and income figures indicate that the flat rate charge must be at least 33.5 cents per 100 pounds for 1956 density of producers and road conditions if the bulk milk hauling operations are to break-even. At a charge less than 33.5 cents per 100 pounds, a deficit would exist which would require a transfer of funds from some other segment of the Association activities.

Even with the same producers and no reorganization of routes, it would appear that each producer would have to increase his daily average volume of production by about 400 pounds if the Association were to break-even on the hauling operations under this pricing system. This extra volume, of course, could not be handled on the present routes and would require additional routes which would incur extra costs.

A variation of the standard flat rate method is a standard charge per stop plus a flat rate per 100 pounds of milk. The premise for such a pricing system is that it would cost almost as much to stop for a small volume producer as for a large volume producer.

In the analysis of costs by functions, the average cost per stop was 29.7 cents plus 0.66 cents times the volume. This indicates that a cost of about 30 cents was associated with the usual operations of picking up milk at the farm even if no pump-out time were required. Thus, a charge of 30 cents per stop might be levied against each producer. Such a charge in 1956 would have decreased the potential deficit of the standard flat rate pricing method to $28,113 per year or to 72 cents per pickup.

This portion of the average cost per stop does not allow for overhead items such as check-in, testing, lunch, time at scales, and check-out. Nor does it allow for an average quantity of milk picked up. As an average for all routes sampled, with these overhead costs and the volume of milk included, the cost per stop would amount to about 82 cents. Under the rate structure for the sample of producers, 82 cents per stop would substitute for five cents of the hauling rate so far as income to the Association is concerned. If this charge were levied against each producer for each stop plus a standard flat rate charge per 100 pounds of milk, the deficit would have been cut to 20 cents per producer for 1956 conditions. The hauling rate under this system would be 82 cents plus 25 cents per 100 pounds. A fixed charge of $1.00 per stop would be required to make income and costs approximately equal so long as the rate remained at 25 cents per 100 pounds.

The inclusion of an 82-cent stop charge would have the effect of increasing the effective rates for small volume producers and decreasing the effective rates for large volume producers. For a volume of 500 pounds this would be 82 cents plus $1.25 for a total charge of $2.07 per stop, or about 41 cents per 100 pounds. For a volume of 8000 pounds, this would be 82 cents plus $20.00 for a total charge of $20.82 per stop, or about 26 cents per 100 pounds.

This pricing system would recognize the close relationship existing between cost and volume, but it would not reflect the costs associated with distance. Instead, the rate per 100 pounds of milk under this system must be high enough to cover costs associated with an average distance. Such rates generally do not result in equitable pricing of the service for producers unless those producers are located at approximately equal distances from the central delivery point.

Income and Costs for 20-Air-Mile Zone Rate

An attempt was made to use the sample routes to evaluate income and costs for zone pricing of the transportation service. It was assumed that generalizations derived from income and cost data applied to the sample routes would be applicable to the total operations of the Association.

Generally, the sample routes were distributed geographically in the same proportion as the total of all routes. Also, these routes were about average in volume of milk hauled per mile. Data from the 44-route sample indicated that 773,302 pounds of milk were picked up at the farm and that total travel was 7,161.4 miles. This was about 108 pounds of milk hauled per mile in the sample as compared with the Association average of 107 pounds per mile for the calendar year 1956.

Income received by the Association for milk transportation under the zone pricing method was computed from the sample routes. A zone rate based on 20-air-mile intervals was determined for the geographical location of each producer on each sample route. This rate was multiplied by the actual volume of milk on the day of the sample to obtain the gross income for each producer. These gross incomes were summed to obtain a gross income of $2,378. for all sample routes.

Total costs were computed from the total miles driven on the sample routes and the average budgeted cost per mile for the calendar year 1956. These costs totaled $2,578. for the sample routes.

The 20-air-mile zone pricing procedure would have resulted in a net deficit of $200 for the 44 routes or about $4.55 per route. The dificit per producer stop would be approximately 35 cents and the deficit for the calendar year would be about $13,636.

There is economic justification for pricing the transportation service in line with the cost of providing this service on the basis of a per stop cost plus a zone rate per 100 pounds of milk pickup. Accordingly, an attempt was made to evaluate the effect of this pricing procedure. An average per stop cost of 82 cents was used as in the previous section. This average cost was defined in such a way as to include driver labor costs at the farm plus a proportionate share of the labor costs involved in the fixed functions such as check-in and unloading. If the charge of 82 cents per stop were levied against each producer, then the hauling rate in each zone could have been reduced by two cents per 100 pounds to keep income and costs approximately equal. Actually, a net return of $32, or 73 cents per route, would have been realized on the 44 routes.

This pricing procedure would have the effect of increasing the effective rate for small volume producers and decreasing the effective rate for large volume producers. For example, a producer with a pickup volume of 500 pounds in Zone 2 (250 pounds daily) would pay 82 cents plus $1.40 (500 pounds at 28 cents per cwt.) or a total of $2.22. This would be about 44 cents per 100 pounds as compared with 30 cents under the regular zone pricing procedure which was not breaking even. The large producer, on the other hand, would have a reduced rate relative to the regular zone pricing. A producer in Zone 2 with 8,000 pounds would pay $0.82 plus $22.40 (8000 pounds at 28 cents per cwt.) or a total of $23.22. This would be about 29 cents per 100 pounds as compared with 30 cents under the deficit producing regular zone pricing. An average producer in Zone 2 with 1,368 pounds would pay 82 cents plus $3.82 or a total of $4.65. This would be about 34 cents per 100 pounds which is slightly higher than under the regular zone pricing procedure but is about the same as under a zone pricing system which entailed no loss to the Association for the bulk milk hauling operation.

Generally, the addition of a per stop cost plus the reduced zone rate would increase the transportation charges more for small producers located relatively close to Oklahoma City than for small producers located at greater distances from Oklahoma City. This occurs because of the nature of adding a fixed element to the variable zone pricing. A fixed charge of 82 cents on a 500 pound volume would be equivalent to an effective rate of about 16 cents. In percentage terms, this would be a greater increase for a low zone rate than for a high zone rate. For example, the 500-pound volume in Zone 1 would have an effective rate (based on the per stop charge and 23 cents per 100 pounds) of about 39 cents per 100 pounds. This would be 14 cents higher than the regular zone price of 25 cents and would represent an increase of about 56 percent. The 500-pound volume in Zone 4 would have an effective rate of about 54 cents per 100 pounds ($0.82 per stop charge and 38 cents per 100 pounds) which would be 14 cents higher than the regular zone rate but an increase of only 35 percent.

Income and Costs for 5-Air-Mile Zone Rate

Zones smaller than 20-air-mile intervals would minimize the problem of inequitable charges for transportation as related to distance within zones. Consequently, an attempt was made to construct estimated income and cost data for zone pricing on 5-air-mile intervals. These zones would be similar to those used in the Tulsa milkshed.

Income received by the Association for milk transportation under a given zone system was calculated at $2,465 from the sample routes. This would represent a net loss on the hauling operation of $113 for 44 routes, or about $2.57 per route. The schedule of charges which would cover costs was determined on the basis of producer locations and volumes on the sample routes and is presented in Table VIII. In order to keep rates in terms of cents rather than fractions of a cent, the possible income under this system was allowed to increase from $2,465 to $2,619 for the 44 routes. Actually about one-half cent per hundredweight would be made on bulk hauling, since the charges were rounded to the nearest cent.

For the first zone, the rate would be one cent per 100 pounds more than the 20-air-mile zone rate. For distances from 20 to 25 miles, the rates would be less than the 20-air-mile zone rate; but for distances greater than 25 miles there would be a higher rate. These higher rates reflect the larger income necessary for a break-even position of the hauling agency.

If a per-stop charge of 82 cents per producer were combined with the 5-air-mile zone rate system, then each zone rate could be reduced by about 6 cents per 100 pounds of milk (Table VIII). Income from these routes would be slightly in excess of costs. Generally, the rates under the smaller zones would be more equitable among producers and the rates would be somewhat higher for distances greater than 85 miles as compared with the 20-air-mile zone system.

The inclusion of a per-stop cost under the 5-air-mile zone system of pricing would increase the effective rate for hauling milk from small volume producers and decrease the effective rate for hauling milk from large volume producers. It would also result in a greater percentage increase in hauling rates for producers located relatively close to Oklahoma City than for the same size producers located at greater distances from Oklahoma City.

Summary and Conclusions

This study was concerned with the costs of bulk milk assembly and with the charges to producers for the transportation service in Oklahoma. It is based upon a combination of time and motion data and accounting data for the two largest firms involved with bulk milk assembly operations in the state, one at Tulsa and the other at Oklahoma City.

Fixed functions performed by drivers in bulk milk assembly operations required about 149 minutes per route day and cost about $5.60 per route day. This cost included $0.94 as a share of the fixed labor costs of the firms.

Farm stop functions performed by drivers required an average time of about 7.4 minutes plus 0.21 times the hundredweight of milk pumped. For an average volume this was equivalent to a cost of about 40 cents per stop.

Driving time and cost varied with the type and condition of roads traveled and with the size of the tank and truck unit. Travel time averaged 1.82 minutes per mile. Truck and tank costs, based on an assumed relationship between time and costs for various road types, varied from a low of 11 cents per mile for good paved roads to 38 cents per mile for poor dirt roads. By type of roads, the average truck and tank costs were 11 cents per mile for pavement, 26 cents per mile for gravel, and 35 cents per mile for dirt. Costs for an 1800-gallon unit would be only about four-fifths of these costs. Costs for a 2800-gallon unit would be about six percent greater than these costs. Total driving costs for a 2500-gallon unit, including a share of the fixed costs, were 22 cents per mile for paved roads, 39 cents per mile for gravel roads, and 49 cents per mile for dirt roads.

The cost estimates may be used to evaluate alternative routing procedures. If all milk must be delivered at a central city and if all trucks are stationed at that city, bulk milk assembly costs can be reduced by using a large transport tank and truck unit with pump-offs from the smaller trucks. With a proportionate share of the cost of a 5000-gallon transport traveling for 104 miles (52 miles one way), savings would range from four cents per hundredweight for the 2500-gallon unit to six cents per hundredweight for the 1800-gallon unit. Savings would be larger for the greater distances from the central city. With a 5000-gallon transport traveling out 105 miles from the central city, the maximum total route length for the smaller units (measured from the central city) would be 180 miles for an 1800-gallon unit and 220 miles for a 2500- or 2800-gallon unit. Routes longer than these could be completed at lower cost with the smaller size truck stationed in an outlying area and pumping-off into the transport.

The addition of producers to bulk milk assembly routes requires careful consideration, particularly if travel on dirt roads will be necessary. Travel on dirt roads and dirt driveways is costly and in many instances where individual producers located on dirt roads have been added to routes the extra costs have been greater than the extra returns. The procedure for estimating the costs and returns from the addition of a new producer to an existing route is illustrated herein, using data obtained in the study.

Estimates of income and costs were made for alternative hauling rate systems of the Oklahoma City firm. Under a flat-rate system, hauling rates would have to be about 33.5 cents per 100 pounds. Zone systems of pricing the hauling service appeared to be more equitable than the flat rate system. Rates under the 20-air-mile zone system in use from April 1956 through January 1959 would have to be increased by about 3.0 cents per 100 pounds for the Association to cover costs for the sample of routes. A proposed system of 5-air-mile zone rates appears to be more equitable for bulk milk assembly in Oklahoma than the 20-air mile zone rate system.

The addition of a per stop charge to the rate structures would contribute to more equitable charges among large and small producers. It appears that many producers adopting the bulk tank system in Oklahoma will have small volumes of milk. If this occurs, the costs of hauling may increase enough to force an increase in the rates for all producers. A greater proportion of small volume bulk milk producers could result in a continuous upward adjustment in hauling rates which would be independent of general price level changes.

Table I.—Average Time for Operations Performed by Drivers During the Check-in Period, Central Oklahoma Milk Producers Association

Operation	Average Time (minutes)
Check instructions	3.13
Check truck	1.83
Drive to building (includes warm-up time)	2.85
Sterilize tank	5.61
Assemble pump	4.52
Sterilize pump	3.70
Obtain ice	2.95
Obtain producer supplies	2.66
Obtain sample bottles	2.56
Waiting	2.54
Other	2.55
Total time	34.90

Table II.—Total Miles and Minutes Per Mile for a Sample of Roads Traveled on Oklahoma Bulk Milk Assembly Routes, Classified by Road Type and Condition

	Tulsa			Oklahoma City			Total		
Road Type	Miles	Percent of Total	Minutes Per Mile	Miles	Percent of Total	Minutes Per Mile	Miles	Percent of Total	Minutes Per Mile
Paved Roads									
Good	1,817.6	59.72	1.48	1,609.0	33.60	1.58	3,426.6	43.74	1.53
Fair	479.9	15.77	1.39	1,504.0	31.40	1.68	1,983.9	25.33	1.61
Poor	97.4	3.20	2.15	161.8	3.38	2.02	259.2	3.31	2.07
Average	2,394.9	78.69	1.49	3,274.8	68.38	1.65	5,669.7	72.38	1.58
Gravel Roads									
Good	120.8	3.97	2.10	57.4	1.20	2.10	178.2	2.28	2.10
Fair	242.1	7.95	2.16	557.9	11.65	2.20	800.0	10.21	2.19
Poor	195.2	6.41	4.08	466.4	9.74	2.27	661.6	8.45	2.80
Average	558.1	18.34	2.82	1,081.7	22.59	2.23	1,639.8	20.94	2.43
Dirt Roads									
Good	14.0	.46	2.76*	23.9	.50	1.92*	37.9	.48	2.23
Fair	49.0	1.61	2.47	170.3	3.56	2.22	219.3	2.80	2.28
Poor	27.5	.90	4.27	238.6	4.98	2.48	266.1	3.40	2.66
Average	90.5	2.97	3.06	432.8	9.04	2.35	523.3	6.68	2.47
All Roads	3,043.5	100.00	1.79	4,789.3	100.00	1.84	7,832.8	100.00	1.82

* Samples of less than 25 miles considered unreliable for reporting.

Table III.—Costs of Performing Fixed Functions on Oklahoma Bulk Milk Assembly Routes

Function	Variable Cost	Share of Fixed Cost	Total Cost
		(dollars per route day)	
T_{11} Check-in	.84	.17	1.01
T_{12} Lunch	.82	.16	.98
T_{13} Unload	1.38	.28	1.66
T_{14} Wait	.42	.09	.51
T_{15} Repair	.34	.07	.41
T_{16} Other functions	.86	.17	1.03
T_1 Total Fixed Function	4.66	.94	5.60

Table IV.—Costs of Performing Farm Stop Functions on Oklahoma Bulk Milk Assembly Routes

Function	Variable Cost	Share of Fixed Cost	Total Cost
		(cents)	
Assumed for Individual Farm Stops:			
$T_{21}+T_{22}+T_{23}+T_{24}$ $+T_{26}+T_{27}+T_{28}$	23.2	6.5	29.7
T_{25}	0.66x*		0.66x*
Assumed for Individual Days:			
$T_{21}+T_{22}+T_{23}+T_{24}$ $+T_{26}+T_{27}+T_{28}$	n(23.2)	n(6.5)	n(29.7)
T_{25}	0.66x*		0.66x*
Estimated Cost for Sample Route Day**			
$T_{21}+T_{22}+T_{23}+T_{24}$ $+T_{26}+T_{27}+T_{28}$	277.9	78.2	356.1
T_{25}	121.8		121.8
Total	399.7	78.2	477.9

* Hundredweight of milk pumped.
** Based on 12 producer stops and a total volume of 185.4 hundredweight per route.

Table V.—Cost of Driving on Various Types and Conditions of Oklahoma Roads*

Road Type and Condition	Fixed Cost	Variable Cost				Total Fixed and Variable Cost
		Truck and Tank		Labor	Total	
		Depreciation	Operation			
				cents per mile		
Paved						
Good	6.00	2.92	7.88	4.79	15.59	21.59
Fair	6.00	3.07	8.30	5.04	16.41	22.41
Poor	6.00	3.94	10.67	6.48	21.09	27.90
Weighted average	6.00	3.02	8.16	4.95	16.13	22.13
Gravel						
Good	6.00	6.00	16.24	6.57	28.81	34.81
Fair	6.00	6.27	16.96	6.85	30.08	36.08
Poor	6.00	8.01	21.64	8.76	38.41	44.41
Weighted average	6.00	6.94	18.77	7.59	33.30	39.30
Dirt						
Good	6.00	8.50	22.99	6.98	38.47	44.47
Fair	6.00	8.69	23.50	7.14	39.33	45.33
Poor	6.00	10.14	27.42	8.33	45.89	51.89
Weighted average	6.00	9.42	25.46	7.73	42.61	48.61
All Roads	6.00	4.33	11.50	5.67	21.50	27.50

* Based on assumed unit costs for the average size (2500 gallon) tank and truck unit.

Table VI.—Total Cost of Driving Various Tank and Truck Size Units by Type and Condition of Road*

	Size of Tank and Truck Unit			
	1800	2500	2800	5000
	(cents per mile)			
Paved Roads				
Good	19.53	21.59	22.18	----
Fair	20.24	22.41	23.04	----
Poor	24.30	27.09	27.90	----
Weighted average	20.00	22.13	22.74	28.00
Gravel Roads				
Good	30.57	34.81	36.04	----
Fair	31.65	36.08	37.37	----
Poor	38.75	44.41	46.05	----
Weighted average	33.44	39.30	40.73	----
Dirt Roads				
Good	38.46	44.47	46.22	----
Fair	39.19	45.33	47.12	----
Poor	44.72	51.89	53.97	----
Weighted average	41.95	48.61	50.54	----

* Based on assumed unit costs.

Table VII.—Estimated Costs Per Route for Three Sizes of Tank and Truck Units and Four Sectors

	Sectors			
	1	2	3	4
	1800 Gallon Unit			
Route length (miles)	75	179	239	285
Density (gal/mi)*	24.0	10.1	7.5	6.3
Route Cost (dollars)				
Fixed functions	$ 5.60	5.60	5.60	5.60
Producer stops (7)	3.08	3.08	3.08	3.08
Travel between producers (35 miles at 26.72¢)	9.35	9.35	9.35	9.35
Overhead travel within sector (at 20¢/mile)	8.00	8.00	8.00	8.00
Overhead travel between sectors (20¢/mile)	----	20.80	32.80	42.00
Total Cost	$26.03	46.83	58.83	68.03
Cost per mile	.347	.262	.246	.239
Cost per cwt.*	.169	.302	.380	.440
Cost with Mobile Receiving Station				
Share of transport cost to central city (36 percent)	---	10.48	16.53	21.17
Total Cost	26.03	36.51	42.56	47.20
Cost per cwt.*	.169	.236	.274	.305

Continued

Table VII.— Estimated Costs Per Route for Three Sizes of Tank and Truck Units and Four Sectors (Continued)

	Sectors 1	2	3	4
		2500 Gallon Unit		
Route length (miles)	90	194	254	300
Density (gal/mi)*	27.8	12.9	9.8	8.3
Route cost (dollars)				
Fixed functions	5.60	5.60	5.60	5.60
Producer stops (10)	4.40	4.40	4.40	4.40
Travel between producers (50 miles at 30.72¢)	15.36	15.36	15.36	15.36
Overhead travel within sector (22.13¢/mile)	8.85	8.85	8.85	8.85
Overhead travel between sectors (22.13¢/mile)	----	23.01	36.29	46.48
Total Cost	34.21	57.23	70.51	80.69
Cost per mile	.380	.295	.278	.269
Cost per cwt.	.159	.266	.328	.376
Cost with Mobile Receiving Station				
Share of transport cost to central city (50 percent)	----	14.56	22.96	29.40
Total Cost	34.21	48.77	57.17	63.61
Cost per cwt.*	.159	.227	.266	.295
		2800 Gallon Unit		
Route length (miles)	95	199	259	305
Density (gal/mi)*	29.5	14.1	10.8	9.2
Route Cost (dollars)				
Fixed functions	5.60	5.60	5.60	5.60
Producer stops (11)	4.84	4.84	4.84	4.84
Travel between producers (55 miles at 31.74¢)	17.46	17.46	17.46	17.46
Overhead travel within sector (22.74¢/mile)	9.10	9.10	9.10	9.10
Overhead travel between sectors (22.74¢/mile)	----	23.65	37.29	47.75
Total Cost	37.00	60.65	74.29	84.75
Cost per mile	.389	.305	.287	.278
Cost per cwt.*	.154	.252	.308	.352
Cost with Mobile Receiving Station				
Share of transport cost to central city (56 percent)	----	16.31	25.72	32.93
Total Cost	37.00	53.31	62.72	69.93
Cost per cwt.*	.154	.221	.260	.291

* Based on total capacity of tank and truck unit.

Table VIII.—Schedule of Hypothetical Zone Rates Based on 5-Air-Mile Intervals, Central Oklahoma Milk Producers Association

Zone Number	Miles Inclusive	Rate per 100 Pounds: Without Stop Charge	Rate per 100 Pounds: Wi'h Stop Charge (82¢)
1	0-20	26	20
2	20.1-25	29	23
3	25.1-30	31	25
4	30.1-35	33	27
5	35.1-40	35	29
6	40.1-45	37	31
7	45.1-50	39	33
8	50.1-55	40	34
9	55.1-60	41	35
10	60.1-65	42	36
11	65.1-70	43	37
12	70.1-75	44	38
13	75.1-80	45	39
14	80.1-85	46	40
15	85.1-90	47	41
.	.	The rates increase one cent	
.	.	per cwt. for each additional	
.	.	5-mile zone.	