Operating Costs for Trucks

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Abstract

This study estimates the operating costs for commercial vehicle operators in Minnesota. A survey of firms that undertake commercial truck road movements was performed. The average operating cost per kilometer for commercial vehicle operators was calculated from the survey responses. Results show that the translog and Cobb-Douglas models have approximately equal explanatory power in estimating the total cost from the data. The models also revealed the presence of nearly constant returns to scale, a finding consistent with earlier studies; an increase in output (total truckloads) of 1% increases total costs by 1.04%.

Introduction

Commercial trucking firms in the United States have costs that depend upon a number of factors including the types of commodities hauled, the length of hauls, the types of equipment used, the proportion of truckload (TL) or less than truckload (LTL) traffic, and the regions they serve (McMullen, 1987). In addition, policies that restrict the routes and weights of commercial vehicle traffic can have an impact on a firm's operating costs. Using data collected from a survey of truck operators, the average operating cost per kilometer is calculated. In addition, the average and marginal truck operating costs in Minnesota are calculated using models estimated from the survey data to determine if trucking firms exhibit economies of scale in their operations.

The question of truck operating costs has been of long interest. In general, firms seek to minimize their cost including truck operating cost. Truck operating cost for each firm can be divided into fixed and variable costs. Fixed costs are insensitive to the volume of output, but variable costs change with the level of output. Daniels (1974) divided vehicle operating cost into two different categories, running costs (includes fuel consumption, engine oil consumption, tire costs and maintenance cost) and standing costs (license, insurance and interest charges). Daniels identified speed as the most important factor in fuel consumption and found maintenance costs rise with increasing speed. If fuel consumption and maintenance cost change, operating cost will change as well. Vehicle size is another factor that affects fuel consumption and thus influences operating cost. By using average axle numbers for each firm, vehicle size can be included in the model. Watanatada (1987) divided the variables that affect truck operating cost into truck characteristics (weight, engine power, maintenance), local factors (speed limit, fuel price, labor cost, drivers attitude), and road characteristics (pavement roughness, road width). Operating cost is considered to be a function of road characteristics and thus is policy sensitive. Barnes (2003) estimated operating cost for commercial trucks based on fuel, repair, maintenance, tires and depreciation costs. He also considered adjustment factors for cost, based on pavement roughness, driving conditions and fuel price changes. He estimated an average truck operating cost per kilometer of $0.27, excluding labor cost. If it is assumed that labor cost is around $0.22 per kilometer, total operating cost using Barnes model is $0.49 per kilometer. This number can be used as a check for operating cost per kilometer obtained from the survey. Berwick (1997) develops a spreadsheet simulation model that projects operating costs (in terms of per mile, per hour, per trip (truckload) and per ton-mile) for various truck types and trip movements based on interest rate, fuel price, payload, trip distance, maintenance and repair, wages, owner/operator and lease status, miles per year, and truckloads per year.

Waters (1997) explains different costing methods that are useful to estimate the relationship between outputs and costs. One of the methods that has been used in transportation studies is the statistical costing method. In this method the relationship between outputs and costs is estimated using different statistical techniques. Multiple regression analysis shows how costs change by changing any of the variables. We employ this approach here.

McMullen (1987) estimates a log-linear truck costing model for truckload firms (TL) using ton-miles, average length of haul, average load, average shipment size, insurance payments (per ton-mile) and the utilization of brokerage firms (rented ton-miles divided by total ton miles) as dependent variables. The results presented evidence of constant returns to scale. TL firms may produce the same output in terms of ton-miles, but may carry different commodities with varying weight loads and lengths of haul. McMullen and Stanley (1988) attempt to account for this by framing the cost function as a function of outputs, input prices, and firm attributes. The measure of output they used was ton-miles, the input prices included prices of capital, rented capital, fuel, and labor. Cost estimates were obtained by employing a translog model. They found evidence of increasing returns to scale prior to deregulation, and nearly constant returns to scale afterward.

Later work by McMullen and Tanaka (1995) use a translog cost function to examine the differences between large (less-than-truckload or LTL) and small (truckload or TL) motor carriers. Their results revealed significant differences in cost structures between large and small carriers. For large firms, there were significant economies associated with increasing average load, average length of haul, and average shipment size. Smaller firms, they claimed, showed no increases in costs due to increases in average shipment sizes, lengths of hauls and loads, indicating they have already taken advantage of these economies.

Managers need to have enough information about their costs to make the right decision about the type of services to provide and the prices to charge (Braeutigam, 1999). Economies of scale have been analyzed for a variety of modes. Studies in the 1970s (differing from earlier work) found increasing returns and economies of traffic density for large railroads (Keeler, 1983). In the airline industry, cost studies have found that the unit cost of service within any city-pair market decreases quickly, there are roughly constant returns to scale for U.S. trunk carriers, and there are economies of scale for smaller airlines (Keeler, 1983). Most of the studies for motor carriers for example Winston et al. (1990) and Allen and Liu (1995), found they operate subject to constant returns to scale, however smaller carriers may operate with some increasing retunes to scale (Braeutigam, 1999).

This paper contains four following parts. The next section discusses the framework and process of the survey and provides descriptive results. The third section estimates cost models from the survey data. Then the results are presented, including economies of scale in the trucking industry by sector. The final section summarizes the findings and presents conclusions.

Survey

The objective of the mail-out/mail-back survey was to obtain values to enable us to estimate truck operating costs, appraise the effect of spring load restrictions (SLR) on freight transportation among different sectors of the freight industry, collect some general information about their operation, and their willingness to participate in an in-depth interview. Spring load restrictions are imposed in Minnesota for 8 weeks each year, typically in March, April, and May, to limit loads on low-volume low-strength rural roads during the time of the year they are thought to be most vulnerable to damage (Levinson et al. 2005). The survey collected data that was believed to affect value of time and operating cost, such as size of company, type of trucks and company strategy.

Data were collected for different trucking companies in Minnesota. The target was the decision maker in each company, who was thought to be able to give accurate information of how their trucks operate. Contact information was obtained from different sources: Minnesota Department of Transportation (Mn/DOT) Freight Facilities Database, Minnesota Trucking Association (MTA) board of directors, Mn/DOT overweight permit list, Mn/DOT filed insurance list, and a list of significant local trucking company in Minnesota identified by city and county engineers. They were mailed out over the spring of 2003 in three waves: before SLR, during SLR, and after SLR. Table 1 displays our response rates.

The mail-out/mail-back survey comprised two different types of questionnaires: about half of the firms received a long form consisting of 19 questions, the others received a short form consisting of 7 of those same 19 questions. It was estimated it would take twenty minutes for a person to complete the long form questionnaire. The two different forms were used to test the loss in responses due to survey fatigue, as some respondents might be unwilling to spend significant time answering the questionnaire. Results show there is a difference between the response rates for these two forms, (Table 2), the long form resulted in 18% response rate (both overall and for the subjects obtained from the freight facility database), while the short form had a 25% rate. No follow-up contacts with potential respondents were made to increase the response rate.

Survey questionnaires were mailed in three different waves, pre-SLR, during SLR and post-SLR, to study the difference between responses. Results show the response rate is higher before SLR (26%) than during (18%) or after (20%) the period of SLR, while controlling for subjects from the same source database.

Important information was obtained from the survey, including: type of trucks and number of axles, overall distance traveled by a firm's trucks, number of employees, type of products that a firm hauls, if the company is assessed financial penalties for late or missed delivery, who chooses the route, total truckloads per year, operating cost per unit distance, if they impose a fuel surcharge, and how do they pay their drivers. These descriptive results from the survey are summarized in Appendix C.

Table 3 summarizes the results of average trip length per truckload by industry. Truck loads are assumed to be round trips. Results show food products have the most km per truckload compared to other industries. Table 3 also summarizes the percent of trip length that a firm's trucks spend on roads subject to SLR (Based on Question 15 of the Long Form).

The average cost from data collected was \$0.69/km (\$1.11/mile). This was for a sample of 186 different trucking companies. The answers ranged between \$0.087/km and \$2.98/km, which shows the diversity of cost per km by industry and size of company (see Figure 1). Typical labor cost for commercial trucks is around \$0.22/km, values below \$0.31/km may exclude or undervalue labor cost. We suspect that the data around \$0.69/km more accurately represents the total cost of operating a truck per km, such that the respondents correctly interpreted the question as total cost including labor. A follow up study was conducted to get a better result for cost per km. All respondents who reported operating cost per km less than \$0.31/km were re-contacted by phone to verify their answers. There were total of 26 responses less than \$0.31/km. We were able to verify seven of them. Five of them changed after the follow up study. The other 14 respondents could not be reached and have been left in the survey, which may bias the results downward, though these possible problem responses comprise less than 10% of the total survey size.

Owner/operators have higher operating cost compared to non owner/operators, as shown in Table 4, perhaps a result of having fewer trucks to distribute their fixed operating costs over. If economies of scale exist, it makes sense that smaller firms have higher operating cost. Figure 1 displays a histogram of costs.

Operating Cost Models

As noted in the introduction, there are many approaches to estimate the cost per kilometer for trucks. Each of them employs a different methodology and models to calculate the variable costs of operating trucks. Fuel, repair and maintenance, tire, depreciation, and labor cost are the most important costs that are considered in the estimation of operating cost per kilometer.

In this study the statistical method described by Waters (1997) will be used to estimate the effect of different variables on cost. Like McMullen and Stanley (1987), we believe that costs are a function of output and firm characteristics. However, because we are dealing with largely a single point in time, we cannot measure how changes in input prices affect cost (aside from documenting this through firm strategy variables), and those differences are neglected here. The factors which are posited to be important in estimating total operating cost for different firms follow:

Size of firm:
Economies of scale in larger firms would reduce cost so that larger companies would have a lower cost per unit distance. In this study two variables are used to measure firm size: kilometers per truckload and number of truckloads. *Km/Truckload* (*K/T*) is calculated by dividing the total kilometers traveled by a firm's trucks in a year by total annual truckloads. It measures average length of haul for each firm. Total cost should increase by increasing km/load. The *Number of Truckloads* (*T*) was requested from each firm and is another indicator of the size of the firm. The total cost increases with number of truckloads.

Firm Strategy:
Each firm has its own strategy based on management policy, which may lead to differences in operating costs for firms. In the survey each firm was asked if they were assessed financial penalties by customers for late or missed delivery. They were also asked how they determined driver compensation, and if compensation was linked to on time delivery, and if the firm has a fuel surcharge. All these customer and firm policies could be used as variables in the model. *Financial Penalty* (*P*) indicates the company was assessed a financial penalty by customers for late or missed deliveries. By paying a financial penalty to the customer, operating costs should increase, so the expected relationship is positive.

Type of Firm:
Owner/operator (*O*) indicates the company owns and operates its own trucks. The survey results indicated a difference in operating cost for owner/operators versus non-owner/operators. Owner/operators have larger cost per kilometer. The reason for this may be the absence of economies of scale and that they have fewer trucks over which to distribute their firm's fixed costs. The models are estimated separately for each type of firm.

Economies of Scope:

A firm is said to operate with economies of scope if for outputs y_1 and y_2

$$C(y_1, y_2) < C(0, y_2) + C(y_1, 0) \qquad (1)$$

That means the cost of producing two outputs with one firm is less than the cost of producing each output with two different firms. In this case economies of scope are tested by considering the number of goods that a firm hauls as an output. An indicator for multi-product firms (*H*) indicates if a firm hauls more than one good. *H* is used as a dummy variable in the model to determine if economies of scope exist in the trucking industry.

Total Cost Model

To measure the effects of the hypothesized independent variables, statistical models with total operating costs as the dependent variable are estimated. Total operating cost (*C*) is calculated using the following formula:

$$C = K * (C / K) \quad (2)$$

Where: C is cost, K is total kilometers, and C / K is cost per kilometer.

Linear Regression Model

First a linear model is tested with Ordinary Least Squares (OLS) regression. The following model has been generated using total cost as a dependent variable and kilometers, the number of truckloads, financial penalties, owner/operator status, and whether or not the firm hauls more than one good as independent variables.

$$C = \mathrm{A}_0 + \mathrm{A}_1(K / T) + \mathrm{A}_2 T + \mathrm{A}_3 P + \mathrm{A}_4 O + \mathrm{A}_5 H \quad (3)$$

Where:
C is Total Annual Cost
K is kilometers
T is number of truckloads
P is 1 if firm is assessed a financial penalty for late delivery, 0 otherwise
O is 1 if the firm is owner/operator, 0 otherwise
H is 1 if the firm hauls more than one product, 0 otherwise

Cobb-Douglas Model

Cobb-Douglas models are often used to estimate cost functions and may provide a better fit than the linear model.

The Cobb-Douglas model used is in equation (4):

$$C = e^{\beta_0} (K / T)^{\beta_1} T^{\beta_2} (e^P)^{\beta_3} (e^O)^{\beta_4} (e^H)^{\beta_5} \quad (4)$$

The coefficient β of the independent variable is the elasticity of cost with respect to that independent variable such as output. It shows the percentage change in total cost resulting from a 1 percent increase in the variable.
After the Cobb-Douglas model is transformed to log linear form it is as follows:

$$Ln(C) = \beta_0 + \beta_1 Ln(K / T) + \beta_2 Ln(T) + \beta_3 P + \beta_4 O + \beta_5 H \quad (5)$$

Translog Model

Translog models have been increasingly popular in production and cost function estimations (Greene, 2000). The two factor input translog model has the generalized form of:

$$\ln Y = \delta_0 + \delta 1 \ln X_1 + \delta_2 \ln X_2 + 0.5\delta_3 (\ln X_1)^2 + 0.5\delta_4 (\ln X_2)^2 + \delta_5 \ln X_1 \ln X_2 + \varepsilon \quad (6)$$

Where: X_1, X_2 are the factor inputs,
ε is the normally distributed standard error term

The truck operating cost model employed in this study has the form:

$$\ln C = \delta_0 + \delta_1 \ln(K/T) + \delta_2 \ln T + 0.5\delta_3 (\ln(K/T))^2 + 0.5\delta_4 (\ln T)^2 + \delta_5 \ln(K/T)\ln(T) + \delta_6 P + \delta_7 O + \varepsilon \quad (7)$$

Note that the variable H is dropped from the model. In the linear and Cobb-Douglas models, the p-value for H was 0.603 and 0.927, respectively.

Box-Cox Model

The Box-Cox transformation can be used to correct for non-normality in the data and has an advantage over the translog model in that it is computable for cases when the output (Y) is zero. Box-Cox models are popular for production functions, and have proved useful in modeling transportation related phenomena (Greene, 2000). The Box-Cox transformation (Box and Cox, 1964) transforms the variable X into the variable X^{-} according to:

$$X^{\lambda} = \frac{(X^{\lambda} - 1)}{\lambda} \quad (8)$$

The transformation of the variables (K/T) and (T) yields a model of the form:

$$\ln C = \phi_0 + \phi_1 \frac{((K/T)^{\lambda} - 1)}{\lambda} + \phi_2 \frac{(T^{\lambda} - 1)}{\lambda} + \phi_3 P + \phi_4 O + \varepsilon \quad (9)$$

Empirical Results

The results from the fitted models are shown in Table 5. The linear model is not a good fit to the data, just two of the independent variables are significant and the R-squared is 0.203. In the Cobb-Douglas model three independent variables are statistically significant with p-values less than 0.05, and R-squared is about 0.95. In the Translog model four independent variables are statistically significant (p-values less than 0.05) but the R-squared is improved by less than 0.01. The Box-Cox models performed worse than the translog and Cobb-Douglas models. Because the translog and Box-Cox models offered no significant improvement over the Cobb-Douglas model, the Cobb-Douglas model was used to calculate elasticities of total cost with respect to km/truckload and truckloads.

Results of the Cobb-Douglas model show the elasticity of total cost with respect to the km/load and truckload is close to 1, (the coefficient on $Ln(K/T)$ and $Ln(T)$), which means that as the km/load or truckload increase by 1%, the total cost will increase roughly by 1% as well. However coefficients are slightly greater than 1, indicating the possibility of overall diseconomies of scale. The coefficients of β_3 and β_4 show the elasticity of total cost with respect to the two dummy variables: O and P. Total cost increases with both variables. Because the coefficients are smaller than 1 (both are around 0.3), it means if the variables increase by 1%, cost increases about 0.3%. The coefficient β_5 on H is statistically insignificant and indicates no economies of scope.

Figure 2 illustrates the fit of the Cobb-Douglas model, showing actual values versus predicted values. Results show the predicted total cost by using the Cobb-Douglas model is close to the actual values.

To determine if economies of scale exist in the trucking industry, each industry type can be analyzed individually. Tables 6 and 7 show the results of the Cobb-Douglas and translog models for four industry types that had a relatively large number of observations.

The coefficients of km/truckload and number of truckload for Agriculture and General Products are greater than 1, indicating there are diseconomies of scale in Agriculture and General Products. Diseconomies of scale in Agriculture and General Products may be the result of smaller firms, more owner/operators or having shorter hauls. However there are economies of scale in Food Products and Aggregate which may be a result of larger firm size, longer hauls, and the fact that these firms tend to operate as TL firms (McMullen, 1987).

Average Cost Function

The average cost function is found by computing total costs per unit of output. Assuming *total truckloads* is the output of each firm, the average cost function for each firm can be calculated as follows:

Average cost = (total cost) / (total truckload)

Average cost: $C/T = (e^{\beta_0}(K/T)^{\beta_1} T^{\beta_2} e^{\beta_3 P} e^{\beta_4 O} e^{\beta_5 H})/T$ (10)

Average cost: $= e^{\beta_0} K^{\beta_1} T^{\beta_2 - \beta_1 - 1} e^{\beta_3 P} e^{\beta_4 O} e^{\beta_5 H}$ (11)

$= e^{-1.037} K^{1.015} T^{-0.972} e^{0.297P} e^{0.312O} e^{-0.012H}$ (12)

Using the mean of each variable in equation (12), gives an average cost of $232 per truckload.

To compare this value with the average cost from survey data, the mean of cost per km and the mean of overall kilometers can be used to calculate the average total cost. Average cost can be calculated by dividing average total cost by average truckload (output). This gives an average cost of $249 per truckload. One can see the average cost calculated from model is slightly less than the average cost that was obtained from the survey.

Assuming *total kilometers* is the output of each firm, the average cost function for each firm can be calculated as follows:

Average cost = (total cost) / (total kilometers)

Average cost: $C/K = (e^{\beta_0}(K/T)^{\beta_1} T^{\beta_2} e^{\beta_3 P} e^{\beta_4 O} e^{\beta_5 H})/K$ (13)

Average cost: $= e^{\beta_0} K^{\beta_1 - 1} T^{\beta_2 - \beta_1} e^{\beta_3 P} e^{\beta_4 O} e^{\beta_5 H}$ (14)

$= e^{-1.037} K^{0.015} T^{0.028} e^{0.297P} e^{0.312O} e^{-0.012H}$ (15)

Using the mean of each variable in equation (15), gives an average cost of $0.64 per km.

Marginal cost function

The marginal cost function is found by computing the change in total costs for a change in output. If output is total truckloads then:

Marginal cost = (change in total cost) / (change in truckloads)
The marginal cost function is:

$$\partial C / \partial T = (\beta_2 - \beta_1) e^{\beta_0} K^{\beta_1} T^{\beta_2 - \beta_1 - 1} e^{\beta_3 P} e^{\beta_4 O} e^{\beta_5 H} \quad (16)$$

Using coefficients from Table 5, the marginal cost function will be

$$MC = (1.043 - 1.015) e^{-1.037} K^{1.015} T^{-0.972} e^{0.297P} e^{0.312O} e^{-0.012H} \quad (17)$$

Using the mean of each variable in equation (17), gives an overall marginal cost per truckload of \$6.51. The average cost per truckload is much higher than the marginal cost, indicating significant economies of scale in truckloads.
Assuming total kilometers is the output of each firm, the marginal cost function for each firm can be calculated as follows:

The marginal cost = (change in total cost) / (change in kilometers)
The marginal cost function is:

$$\partial C / \partial K = \beta_1 e^{\beta_0} K^{\beta_1 - 1} T^{\beta_2 - \beta_1} e^{\beta_3 P} e^{\beta_4 O} e^{\beta_5 H} \quad (18)$$

Using coefficients from Table 5 the marginal cost function will be:

$$MC = 1.015 e^{-1.037} K^{0.015} T^{0.028} e^{0.297P} e^{0.312O} e^{-0.012H} \quad (19)$$

Using the mean of each of the variables in equation (19), gives an overall marginal cost per kilometer of \$0.65. The marginal cost is slightly higher than the average cost, indicating slight diseconomies of scale with trip length. Table 8 summarizes economies of scale by variable and industry classification.

Summary and Conclusions

The average cost per kilometer for commercial trucks in Minnesota is \$0.69. This number is the result of using data collected from 186 firms in Minnesota. This value was input into the freight demand model developed for the SLR study. The cost to truckers from detouring during SLR was estimated to cost more than the benefit of pavement life savings to the road owners.

Cobb-Douglas and translog models give the best fit to estimate the total cost from the survey data. Total truckloads represent the size of firm in the total cost model. From the model one can see roughly constant returns to scale. If output (total truckloads) increases by 1%, total cost will increase by 1.04%. Results from the model for each commodity type show there are economies of scale in food product and aggregate transport. It may be result of having longer length of hauls, larger firms, and the likelihood the firms are TL firms. Most TL firms are owner/operators, and have a higher cost as a result of having less output to distribute their fixed cost over (McMullen, 1995). Thus, the impact of a SLR policy could be greater on these types of firms, especially if they must operate more trucks and/or are subjected to a significant amount of detouring.

Average cost for trucks obtained from the model is $0.64/km. That is very close to the average cost from the survey of $0.69/km. Average cost per truckload is about $250 per truckload in the survey and $232 from the model. Marginal cost per truckload is $6.51 and marginal cost per kilometer is $0.65. Therefore there are economies of scale in additional truckloads and slight diseconomies in additional kilometers.

The use of truckloads and kilometers per truckload is not the most commonly used independent variable in trucking cost estimation exercises. Many studies (McMullen, *et al*) have used tons and ton-miles (or ton-kilometers) as output measures. The survey lacked such data. It is recommended that future studies include this data, as well as variables such as average load sizes, percentage of time running empty (backhaul) and the prices of labor and overhead.

The total operating cost model estimation also does not show the impact of road quality on operating cost. It may be an important factor in operating cost as low quality roads can reduce the life of tires, increase fuel consumption and also increase the maintenance cost. It may also reduce travel speed, thereby increasing labor cost.

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Figure 1: Histogram of Reported Operating Cost Per Kilometer

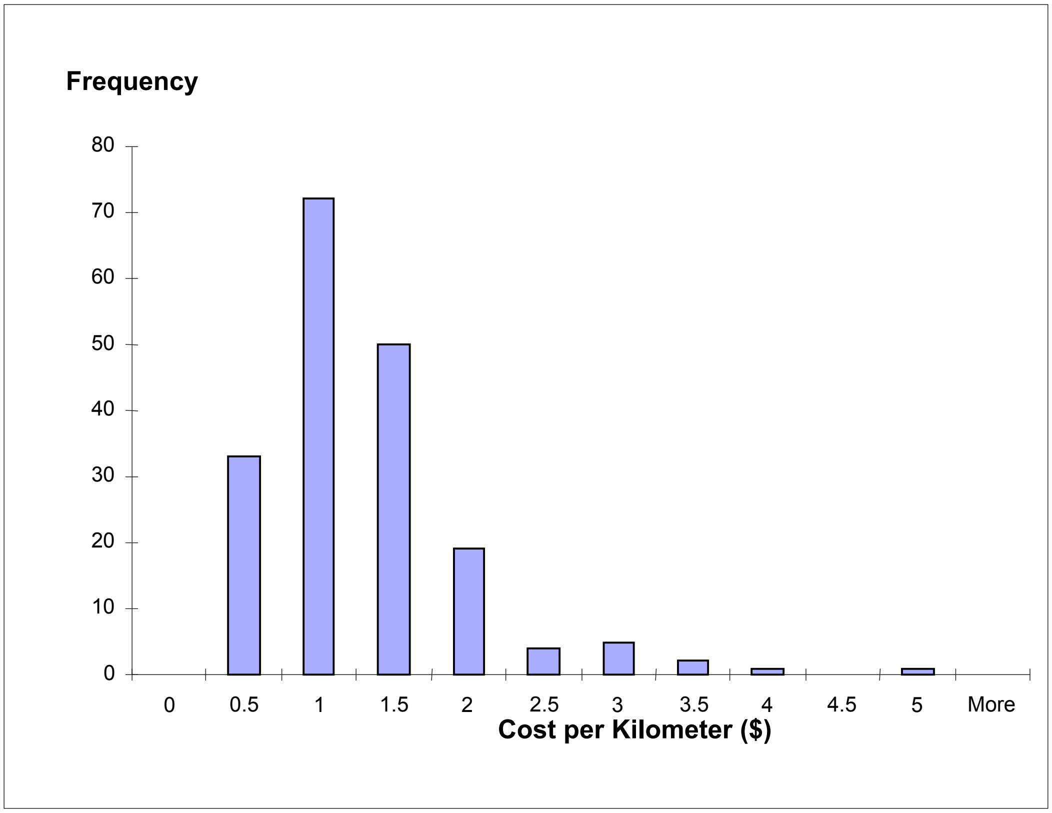


Figure 2: Actual Total Costs versus Predicted Total Costs from Cobb-Douglas Model

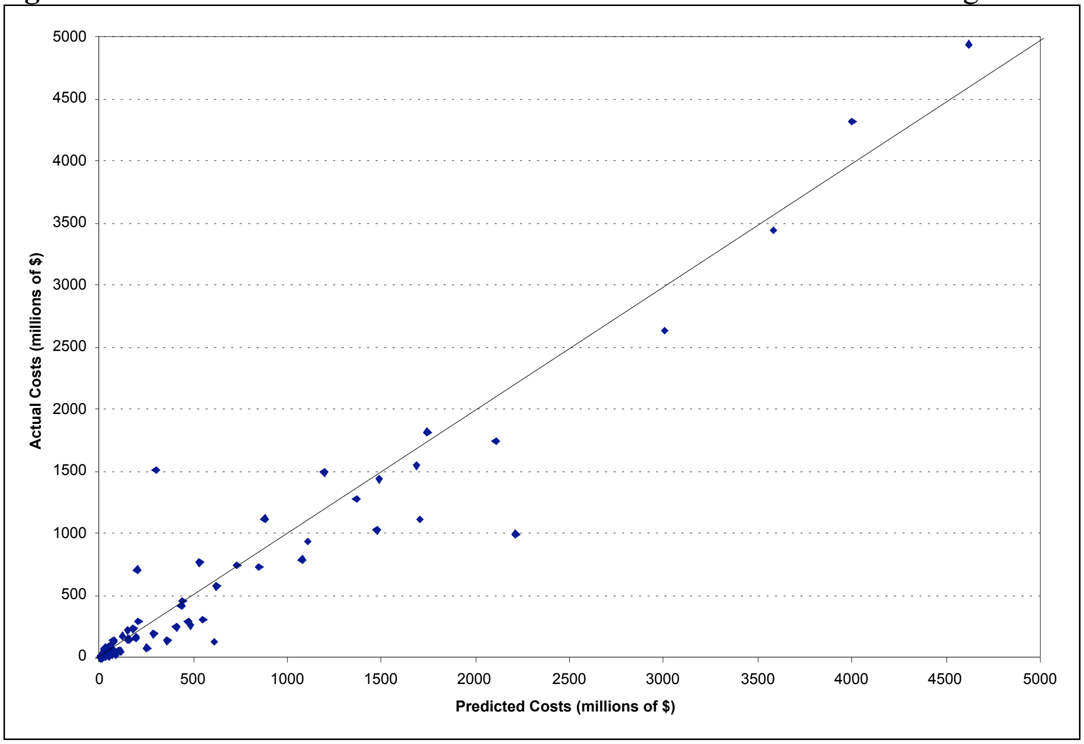


Table 1 Response Rates For Mail-Out/Mail-Back Survey

Sample	Count Response Rate By Survey Group	Total Returned	Return Rate	Bad Addresses	Bad Address Rate	Actual Responses	Actual Response Rate	Actual Response Rate (Adjusted)
MTA February 2003 - Pre SLR, Long Form	34	12	35.3%	0	0.0%	12	35.3%	35.3%
FF March 3 2003 - Pre SLR, Long Form	165	45	27.3%	27	16.4%	18	10.9%	13.0%
FF March 3 2003 - Pre SLR, Short Form	200	76	38.0%	31	15.5%	45	22.5%	26.6%
FF March 6 2003 - Pre SLR, Long Form	51	24	47.1%	12	23.5%	12	23.5%	30.8%
FF March 6 2003 - Pre SLR, Short Form	50	27	54.0%	4	8.0%	23	46.0%	50.0%
FF March 10 2003 - Pre SLR, Long Form	50	24	48.0%	6	12.0%	18	36.0%	40.9%
FF March 10 2003 - Pre SLR, Short Form	50	23	46.0%	11	22.0%	12	24.0%	30.8%
FF March 21 2003 - SLR, Long Form	300	79	26.3%	39	13.0%	40	13.3%	15.3%
FF March 21 2003 - SLR, Short Form	300	103	34.3%	51	17.0%	52	17.3%	20.9%
MnDOT April 4 2003 - SLR, Long Form	459	104	22.7%	53	11.5%	51	11.1%	12.6%
FF May 23 2003 - Post SLR, Long Form	300	98	32.7%	56	18.7%	42	14.0%	17.2%
FF May 23 2003 - Post SLR, Short Form	300	96	32.0%	39	13.0%	57	19.0%	21.8%
CC June 5 2003 - Post SLR, Long Form	264	77	29.2%	18	6.8%	59	22.3%	24.0%
	2523	788	31.2%	347	13.8%	441	17.5%	20.3%

Note: MTA refers to Minnesota Trucking Association as the mailing list source, FF refers to the Mn/DOT Freight Facilities database as the source, Mn/DOT refers to the filed insurance and overweight permit lists as the source, and CC refers to the city/county engineer surveys as the source.

Table 2 Summary Response Rates For Survey

	Count	Total Returned	Return Rate	Bad Addresses	Bad Address Rate	Actual Responses	Actual Response Rate	Actual Response Rate (Adjusted)
Response Rate By Form Type								
Long Form	1623	463	28.5%	211	13.0%	252	15.5%	17.8%
Short Form	900	325	36.1%	136	15.1%	189	21.0%	24.7%
Response Rate By Wave								
Pre SLR (MTA, FF)	600	231	38.5%	91	15.2%	140	23.3%	27.5%
SLR (FF & MnDOT)	1059	286	27.2%	143	13.5%	143	13.5%	15.6%
Post SLR (FF, CC)	864	271	31.4%	113	13.1%	158	18.3%	21.0%

Table 3 Responses by Industry Type.

	Km/Truckload	Miles/Truckload	% of Trip Length Affected by SLR	Response Count
Ag Chem	151	242	38.5%	14
Aggregate	66	106	20.6%	23
Agricultural	312	499	28.7%	61
Beverages	259	414	15.0%	3
Construction	392	627	12.6%	10
Dairy	635	1016	1.8%	3
Food Products	1446	2314	9.7%	15
General Products	989	1582	6.3%	23
Industrial Supplies	1058	1693	5.6%	16
Paper	354	566	1.7%	4
Petroleum	235	376	35.1%	12
Rubbish	161	258	100.0%	3
Timber	379	606	45.8%	10
Average	503	805	22.2%	198

Note: % Of Trip Affected by SLR from Long-Form respondents only.

Table 4: Cost Per Kilometer by Industry

	Response Count	Average	Mode	Median	Standard Deviation
Overall	186	$0.69	$0.62	$0.60	$0.44
By Industry					
Rubbish	2	$1.54		$1.54	$1.30
Dairy	3	$1.03		$0.84	$0.47
Food Products	18	$0.90	$0.60	$0.64	$0.66
Paper	4	$0.85		$0.86	$0.29
Petroleum	11	$0.81	$1.86	$0.78	$0.62
Timber	5	$0.76		$0.56	$0.40
Aggregate	22	$0.70	$0.31	$0.61	$0.37
Industrial Supplies	12	$0.68	$0.56	$0.59	$0.43
Construction	13	$0.67	$0.40	$0.59	$0.35
Ag Chem	15	$0.62	$0.31	$0.48	$0.45
Agricultural	55	$0.61	$0.50	$0.55	$0.32
General Products	24	$0.60	$0.78	$0.65	$0.29
Beverages	2	$0.50		$0.50	$0.54
Owner/Operator					
Owner/Operator	21	$0.84	$0.93	$0.50	$0.69
Non Owner/Operator	165	$0.67	$0.80	$0.61	$0.39

Table 5: Estimated Models of Total Operating Cost

Model		Linear Model	Cobb-Douglas Model	Box-Cox	Translog
Variable					
K/T	ß	45.27	1.015**	1.001**	1.123**
	Std-Error	117.13	0.033	0.033	0.22
	T-stat	0.39	30.62	30.02	5.11
	p-value	0.7	0	0.000	0.000
T	ß	117.34**	1.043**	0.836**	1.384**
	Std-Error	28.8	0.029	0.023	0.168
	T-stat	4.07	35.87	36.269	8.26
	p-value	0	0	0.000	0.000
					0.341**
P	ß	3973163*	0.297*	.279*	0.118
	Std-Error	1791364	0.118	0.12	2.89
	T-stat	2.22	2.52	2.32	0.004
	p-value	0.028	0.013	0.022	
					0.374*
O	ß	-43952	0.312	0.288	0.171
	Std-Error	2597629	0.172	0.174	2.19
	T-stat	-0.02	1.81	1.653	0.030
	p-value	0.987	0.072	0.101	
H	ß	1095115	-0.012		
	Std-Error	2100002	0.13		
	T-stat	0.52	-0.09		
	p-value	0.603	0.927		
(K/T)^2	ß				0.003
	Std-Error				0.03
	T-stat				0.1
	p-value				0.917
T^2	ß				-0.033
	Std-Error				0.018
	T-stat				-1.83
	p-value				0.069
(K/T)(T)	ß				-0.018
	Std-Error				0.015
	T-stat				-1.23
	p-value				0.221
R-Squared		0.18	0.945		0.948
N		147	147	147	147

 *Statistically significant at 0.05 level
**Statistically significant at 0.01 level

Table 6: Cobb-Douglas Estimate of Total Cost for Different Commodities

Industry		Agriculture	General Product	Aggregate	Food Product
Variable					
K/T	ß	1.047**	1.023**	0.718**	0.509**
	Std-Error	0.050	0.145	0.120	0.227
	T-stat	20.910	7.070	5.960	2.240
	p-value	0.000	0.000	0.000	0.055
T	ß	1.102**	1.125**	0.809**	0.905**
	Std-Error	0.043	0.083	0.119	0.182
	T-stat	25.630	13.500	6.800	4.980
	p-value	0.000	0.000	0.000	0.001
P	ß	0.214	0.355	0.712	0.128
	Std-Error	0.161	0.440	0.354	0.446
	T-stat	1.330	0.810	2.100	0.290
	p-value	0.191	0.433	0.075	0.782
O	ß	0.659**	0.179	-0.317	0.364
	Std-Error	0.227	0.353	0.626	0.657
	T-stat	2.910	0.510	-0.510	0.550
	p-value	0.006	0.622	0.625	0.595
H	ß	-0.339	-0.498	0.250	0.807
	Std-Error	0.191	0.302	0.428	0.470
	T-stat	-1.780	-1.650	0.580	1.720
	p-value	0.084	0.124	0.574	0.124
Constant	ß	-1.404**	-1.390	2.016	3.026
	Std-Error	0.441	1.171	1.299	2.481
	T-stat	-3.180	-1.650	1.550	1.220
	p-value	0.003	0.124	0.155	0.257
R-Squared		0.970	0.967	0.917	0.944
n		45	19	15	14

 *Statistically significant at 0.05 level
**Statistically significant at 0.01 level

Table 7: Translog Estimate of Total Cost for Different Commodities

Industry		Agriculture	General Product	Aggregate	Food Product
Variable					
K/T	ß	1.239**	2.631*	-1.265	-0.037
	Std-Error	0.412	1.003	3.120	6.110
	T-stat	3.009	2.624	-0.401	-0.006
	p-value	0.005	0.022	0.697	0.995
T	ß	1.005**	1.481*	1.967	-1.479
	Std-Error	0.238	0.559	2.665	4.262
	T-stat	4.228	2.648	0.738	-0.347
	p-value	0.000	0.021	0.484	0.740
(K/T)^2	ß	-0.082	-0.207	0.002	0.029
	Std-Error	0.062	0.144	0.145	0.727
	T-stat	-1.325	-1.441	0.016	0.039
	p-value	0.193	0.175	0.988	0.970
T^2	ß	-0.008	-0.010	-0.193	0.258
	Std-Error	0.037	0.061	0.182	0.344
	T-stat	-0.230	-0.165	-1.060	0.751
	p-value	0.820	0.872	0.325	0.481
(K/T)(T)	ß	0.029	-0.064	0.230	0.059
	Std-Error	0.034	0.057	0.358	0.285
	T-stat	0.856	-1.108	0.642	0.206
	p-value	0.397	0.289	0.542	0.844
P	ß	0.232	0.505	0.950*	-0.220
	Std-Error	0.167	0.488	0.379	0.572
	T-stat	1.393	1.036	2.506	-0.385
	p-value	0.172	0.321	0.041	0.713
O	ß	0.624*	0.030	0.819	-0.975
	Std-Error	0.240	0.384	0.826	1.690
	T-stat	2.602	0.078	0.991	-0.577
	p-value	0.013	0.939	0.355	0.585
R-Squared		0.970	0.974	0.944	0.935
N		45	19	15	14

*Statistically significant at 0.05 level
**Statistically significant at 0.01 level

Table 8: Economies of Scale by Variable and Commodity Classification

Industry	Agriculture	General Product	Aggregate	Food Product
Variable				
AC per truckloads	188	597	20	588
MC per truckloads	9.94	60.93	1.80	233.18
Economies of Scale	18.90	9.79	11.11	2.52
AC per km	0.67	0.76	0.54	0.66
MC per km	0.70	0.78	0.37	0.33
Economies of scale	0.95	0.97	1.46	2.00

AC = Average Cost
MC = Marginal Cost

Appendix Mail-Out/Mail-Back Survey

Please complete:

Contact Name ______________________________

Name of Firm ______________________________

Street Address ______________________________

City, State, Zip ______________________________

Phone Number (____) _______________________

E-mail Address ______________________________

Date Completed _____________

1. How many trucks does your firm operate?

Truck Type	Total Number of Axles						
	2	3	4	5	6	7	8
Pickups/Light Duty Trucks	____	____					
Unibody Dock Truck	____	____					
Platform & Flatbed	____	____	____	____	____	____	____
Dry Bulk (Hopper, dump, etc.)	____	____	____	____	____	____	____
Liquid/Gas Tank	____	____	____	____	____	____	____
Refrigerated Van	____	____	____	____	____	____	____
Livestock Van	____	____	____	____	____	____	____
Dry Van	____	____	____	____	____	____	____
Grain Body	____	____	____	____	____	____	____
Dump Truck	____	____	____	____	____	____	____
Concrete Mixer	____	____	____	____	____	____	____
Pole & Logging	____	____	____	____	____	____	____
Other, please specify__________	____	____	____	____	____	____	____

2. How many miles did your firm's trucks travel over the course of 2002?

   Total? __________, in Minnesota? __________

3. Please list general types of major commodities/products that your firm hauls.

   __________, __________, ___________, __________, __________

4. How many direct employees does your firm have? __________
5. How many of the direct employees are drivers? __________
6. How many drivers are contracted / leased by your firm? __________

7. Who chooses the routes traveled by the trucks? Please indicate choice by circling.

Management Dispatcher Driver Other, please specify

8. Is your company assessed financial penalties by clients for missed/late delivery or pickup time? Please check one. _ Yes _ No

9. How is driver's compensation determined? Please indicate choice by circling.

Load Time Miles Other, please specify

10. Is driver compensation linked to on-time deliveries? _ Yes _ No

11. Do you change the rate you charge clients to account for the fluctuations in gas/diesel price? _ Yes _ No

12. What is your approximate cost of operating each truck per mile? __________

13. How many truck loads did your firm carry in the past year? ___________

14. Do spring load restrictions affect your firm, and if yes please answer in which ways you change your operations to conform to the seasonal restrictions?

_ Shift the seasonal timing of shipments
_ Reduce load size / weight per vehicle
_ Increase the number of vehicles used
_ Change the kind of vehicles used
_ Change routes
Other, please specify _______________

15. Roughly, what is the percentage of miles that your firm's trucks spend on roads subject to spring load restrictions? __________

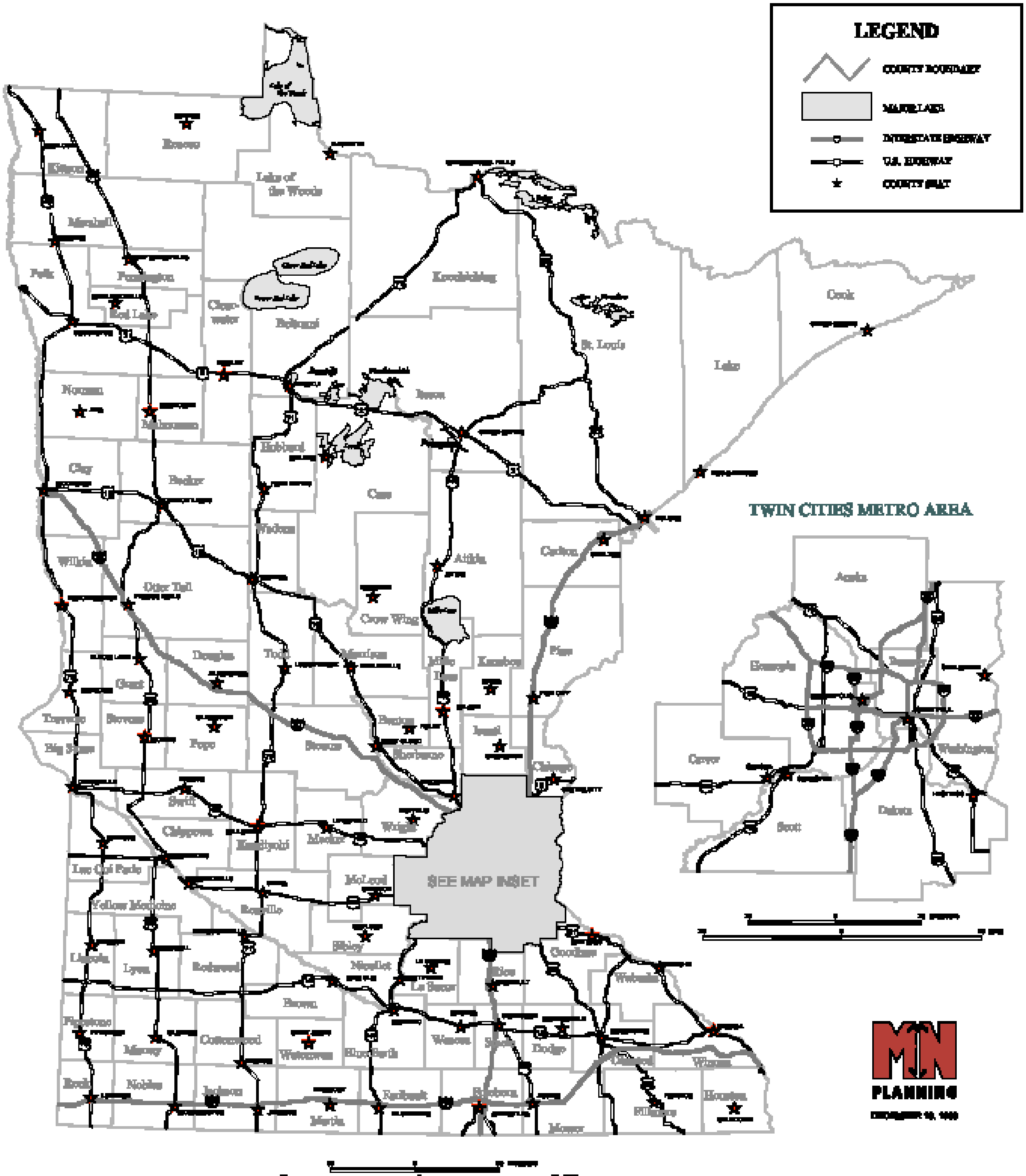
16. How many times were your firm's trucks cited last year for weight violations during the period of spring load restrictions? __________

17. Which road(s) are problematic for your firm during spring load restrictions (specific roads, and/or classifications, 5-ton, 7-ton, 9-ton)? Please list.

___________, __________, ___________, ___________, __________

18. Can we contact you at a later date to set-up an interview for additional questions? The interview should take no more than 30 minutes. _ Yes _ No

19. Please indicate by highlighting on the map provided on the back of this page, which counties your firm's trucks typically drive in?



LEGEND
TWIN CITIES METRO AREA
SEE MAP INSET
Roseau
Kittson
Lake of the Woods
Marshall
Polk
Pennington
Red Lake
Clearwater
Beltrami
Koochiching
Cook
Lake
St. Louis
Norman
Mahnomen
Itasca
Hubbard
Clay
Becker
Cass
Wadena
Carlton
Wilkin
Otter Tail
Aitkin
Crow Wing
Douglas
Todd
Morrison
Mille Lacs
Kanabec
Pine
Grant
Traverse
Stevens
Pope
Stearns
Benton
Sherburne
Isanti
Chisago
Big Stone
Swift
Chippewa
Kandiyohi
Meeker
Wright
Lac Qui Parle
Yellow Medicine
Renville
McLeod
Sibley
Lincoln
Lyon
Redwood
Nicollet
Le Sueur
Rice
Goodhue
Wabasha
Brown
Pipestone
Murray
Cottonwood
Watonwan
Blue Earth
Waseca
Steele
Dodge
Olmsted
Winona
Rock
Nobles
Jackson
Martin
Faribault
Freeborn
Mower
Fillmore
Houston
Anoka
Hennepin
Ramsey
Washington
Carver
Scott
Dakota
PLANNING