ANALYSIS OF ECONOMIES OF SIZE AND DENSITY FOR SHORT LINE RAILROADS

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ABSTRACT

After the Staggers Rail Act, Class I railroads were allowed more flexibility to sell and abandon sections of rail track. These sections of track were less profitable and had limited density per mile. Much of this track was taken over by rail carriers known as short lines, which have had mixed results, with many of them being viable while others were not.

This study examines these short lines to determine what makes them viable and efficient. Previous research studies have not addressed this issue adequately because of the data used and the advancements in techniques that have taken place since. There has not been a recent study on the short line railroad industry that has utilized the Translog Cost Function. Furthermore, the data used in this study were supplied by the short lines through use of the American Short Line Database, which was compiled by the Upper Great Plains Transportation Institute.

This study demonstrated that short lines could achieve greater cost savings if they were to increase their density (revenue ton miles per mile) and their size (mile of road). Size is an important criterion that a short line must examine when evaluating the purchase of a new section of track. However, existing railroads may have difficulty increasing their size because of their connections to Class I railroads and limited financial resources. Density is critical to the short line operations, and by increasing their density on the rail, track short lines could decrease their average cost. The cost analysis in this study demonstrates a need of longer hauls and/or larger train configurations for them to remain viable.

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INTRODUCTION

Background

The Staggers Rail Act of 1980 helped to deregulate the railroad industry, which lessened government restrictions on the railroads. According to Grimm and Sapienza (1993), the Staggers Act provided firms with greater flexibility and incentives to determine their prices, their service quality, and the geographic markets they served. They also pointed out that with this act, downsizing or abandonment, in the form of selling off portions of light density lines in the rail network, occurred in many regions. Much of this light density network was taken over by smaller railroads known as short lines. Authors such as Wolfe, Babcock, Due, and several others have examined what makes short lines profitable and what causes them to fail. Their conclusions vary about what makes a short line viable and effective.

To fully understand this problem, it is important to understand the definition of a short line railroad. The Surface Transportation Board classifies railroads by their operating revenues and the miles of road they operate. Class I railroads are the largest rail carriers in the United States. Using the 1997 definition, Class I railroads are defined as railroads with an operating revenue of more than $256.4 million. The operating revenue threshold is indexed to a base year of 1991, $250 million, and is adjusted each year in conjunction with the change in the "Railroad Freight Rate Index," which is published by the Bureau of Labor Statistics. A railroad can be declassified as a Class I railroad, if it fails to meet the Class I criteria for three consecutive years. A regional railroad is a non-Class I railroad defined as having 350 miles of road and/or $40 million in revenue. A local railroad also is a non-Class I railroad, defined as having neither 350 miles of road or $40 million in operating

revenue. Local railroads can be divided further into either line haul carriers or switching and/or terminal carriers. In this report, short lines are defined as railroads other than Class I.

After the Staggers Rail Act, there was a proliferation of short lines. This growth in the short line rail industry was unlike any other time period. Babcock et al. (1997) stated that 227 short lines were created between 1980-89. Many of the short lines established early after the Staggers Rail Act had unrealistic business plans, according to Wolfe (1988). He suggested that it is more expensive to start the average short line than another average business. Wolfe further stated that short lines may exist longer than they should because of this substantial investment. With this large amount of money invested, the short line will continue to operate in an attempt to make back the initial investment even though it may not be economically sound. Under normal conditions, and with the increased information on short lines available today, these railroads may not have been established. However, after the Staggers Act many railroads started up and received funding that would not be available under today's conditions.

Short lines are in existence today because of a phenomenon called rationalization. Rationalization is defined by Wilson and Tyrchniewicz as "the adjustment in the size or components of a plant so that the same output can be produced with less resources" (p.745). Wilson and Tyrchiniewicz also defined rationalization as "the process of bringing an industry into sounder economic structure in terms of organization and operation" (p.745). As the authors demonstrated in the early 1900s, there was a need for an extensive branch line network of rail lines. During this time farmers and other bulk commodity producers relied on the extensive rail network to transport their products. Farmers did not possess an

effective method of transporting their commodities over long distances. Therefore, elevators were established close to farmers and the rail network serviced these elevators. However, when motor carriers replaced horse and wagon, grain elevators no longer needed to be located so close to the farmers, making extensive branch rail network obsolete. Farmers and other commodity producers could transport their products over farther distances, which many times were at a junction on the main line. Rationalization for Class I railroads would mean the elimination of portions of the branch line network that were not essential to the system. This rationalization would include light density lines, many of which are currently operated by short line rail carriers.

Problem Statement

Today, the extensive branch network system is not as essential as it was in the past, and motor carriers can perform many of the functions that only rail carriers could perform in the past. This causes the motor carrier industry and short line carriers to be in direct competition with one another, and both carriers have advantages and disadvantages. Motor carriers' strengths are their abilities to offer door to door service and the reliability of their services (Babcock 1995). Short lines' advantages are 1) their ability to move large quantities at one time, 2) their customer service, and 3) the fact that a shipment does not need to be transferred to a railcar like with motor carriers. Reliability and door to door service are valuable service characteristics, which many shippers value greatly. The value placed by shippers on reliability and door to door service forces the short line to be highly competitive or be forced out of business.

Short lines have established their role in the rail industry. Class I railroads operate long distances over corridors with high traffic densities. Short lines, on the other hand, provide short-haul gathering service to the main lines. Some short lines, classified as switching and terminal railroads, transport rail cars between two different railroads. Short lines, in general, help to generate more traffic for Class I carriers. Short lines do not possess the capabilities to originate and terminate most shipments. For the most part, short lines must rely on Class I railroads to originate or terminate a shipment. Both Class I railroads and short lines have established roles in the rail industry and perform these specialized roles.

Class I railroads have sold or abandoned portions of their light density rail networks to improve efficiency and increase profits. Short lines offer an alternative to abandonment, because they can operate on a track that would otherwise be abandoned. Abandonment is the loss of service to a section of track. Class I railroads abandon lines for several reasons, which can include the light density of the line (low profitability) and the costs associated with repair or upgrade of a particular section of track. Once service is no longer available, there may be many negative consequences.

Babcock et al. (1995) illustrated the effects that abandonment can have on the communities these railroads serve. The negative effects include the following:

1. Farmers could receive lower grain prices.
2. Transportation costs could increase and profits for rural rail shippers could be reduced.
3. Market options for rural shippers would be lost.

4. Economic development options would be reduced in the communities affected by the abandonment.
5. Highway maintenance and reconstruction costs may be higher.

These are some of the key consequences of abandonment. However, some communities may experience other effects.

Competition forces motor carriers and short lines to be cost competitive or be forced out of business. If competition forces a short line out of business, the community and the customers who use the short-line services will be greatly affected. With short line service no longer available, the motor carrier industry will be able to raise their transportation rates, since they basically are the only mode of bulk transportation still available in many areas. Increase in transportation costs could cause prices of a particular commodity to fall at the local elevator. This fall in commodity prices is caused by the added transportation rate the elevator incurs when shipping the commodity to its ultimate destination. This added transportation expense is a cost that must be borne by the consumers or the farmers. Since the farmer's elasticity of supply is low, the cost is borne largely by the farmer. Abandonment simply creates less options for shippers located in the affected communities.

Another effect of abandonment is the damage caused to the roads of local communities and to the interstate highway system. The loss of rail service will result in a substantial increase in truck traffic for bulk commodities to be shipped to their destination. This increase in truck traffic can result in greater congestion on the roadways, resulting in longer travel time and higher accident rates. Further, with this increase in truck traffic, road deterioration accelerates. This means that road structures need more maintenance, and

must be replaced earlier. Increased road maintenance is a cost borne by highway users and taxpayers.

The negative consequences of rail line abandonment should be of concern to governmental officials. If a small subsidy allows the short line to remain in service, there is an incentive for a government to supply the public subsidy. If the subsidy is less than the cost of road damage and the price reduction in commodities (since impacts must be discounted over time), the subsidy is worthwhile to pursue. The government would save money by subsidizing the railroad in this circumstance. However, if the subsidy costs more than the expenses associated without having the railroad remain in service, the subsidy would be a bad investment. When considering financial assistance by the government to a private firm, it is important for the government to be fully informed of the cost structure of the firm and the industry in question.

Objectives and Overview of Thesis

This thesis will examine factors essential to the viability of the short-line rail industry. The study has three main objectives:

1. Determine the cost structure of the short-line industry.
2. Assess the extent of economies of density for the industry.
3. Assess the extent of economies of size for the industry.

These factors will explain cost effectiveness of short lines and will be useful to railroad executives, government officials, investors, and others. Explaining cost structure of the short line rail industry will give railroad executives and investors a better understanding of short-line operations and how they can become more cost effective. When a new

railroad proposes to take over an existing section of rail line, the information will enhance the knowledge of cost effectiveness of that particular railroad. Government officials also will be better informed in decision making situations pertaining to subsidies and regulations associated with short lines.

The main part of the thesis begins with a Review of Literature. In the Review of Literature there will be a discussion of previous costing studies, economies of size studies, economies of density studies, the profitability of the industry, and the importance of short lines to the communities they serve. After the Review of Literature, the thesis will proceed with a theory section that explains the methodology used in this study.

After the theory section, the empirical methods will be discussed. This section also explains how the model will be set up and how density and scale returns will be determined. The Empirical Methods section utilizes this theory in the development of an empirical model, and describes the variables to be used. After this section, the study will move into a descriptive data section. This section will describe characteristics of the data and give an explanation of how some variables were calculated. Then, the thesis will move to a discussion of results and implications. This section will show the extent of economies of size and density in the industry, and explain the cost structure. The final section includes the summary and conclusions.

REVIEW OF LITERATURE

This chapter reviews the findings of previous railroad studies. The first section examines several previous railroad costing studies. The second section reviews studies that pertain to economies of density and economies of size. The third section examines the profitability of short lines. The fourth and final section examines advancements that can be accomplished through this study, which have not been previously accomplished. While many of the studies fall into more than one category, the sections are simply used to explain literature that is pertinent to this study in a logical manner. Extra emphasis was given to studies pertaining to short lines.

Previous Railroad Costing Studies

Previous costing studies have varied in scope and methods. The methods vary from qualitative methods to empirical estimation, with various functional forms. Railroad costing models have been examined for many years, and the earliest models, although simple representations of railroad costs, still are useful to examine. This section of the literature review briefly identifies the econometric or statistical studies and techniques examining costs of the railroad industry.

One of the first major studies to examine railroad costs was written by Borts (1960). Borts examined the problems of using cross-sectional data in railroad costing models. He believed that previous studies had errors due to the incorrect use of a firm's production capacity (size) and also due to the regression fallacy. Borts believed the size variable should be used as a measure of excess capacity. By utilizing size in this manner, a study can determine if a firm is producing on the long run cost curve. A firm could increase or

decrease its size depending on the sign of the coefficient. Borts also defined the regression fallacy, which he defined as the difference between the observed expenditures for a certain level of output and the minimum cost for producing that level of output. At any time, railroads could operate at a level above or below the planned rate.

In this study, Borts categorized railroads by regional location and size. He used a simple linear regression equation with a dependent variable of freight operating expenditures. The independent variables consisted of total loaded and empty freight car-miles and total freight carloads. Using various models and criteria for the independent variables, and using cross sectional data, Borts determined that there are differences between sizes and regions in the railroad industry. Therefore, Borts believed we must separate railroads by size and region when evaluating their cost structure.

As railroad studies progressed, they became more advanced in their methods. In one of the next major studies, Keeler (1973) explained that most previous railroad studies estimated a linear relationship using total costs as a function of output and track mileage. Because of the limited ability of railroads to abandon their track, due to government regulation, Keeler argued that railroads could not adjust to a long run equilibrium. Keeler also disagreed with previous studies, which assumed that factor portions between track and other inputs were fixed. To correct this problem, Keeler formulated a Cobb-Douglas production function where output (gross ton-miles) was a function of track miles (physical plant), rolling stock investment, fuel consumed, and labor. Keeler used cross section data consisting of American Railroads and excluded firms with less than 500 miles of track. From this production function, Keeler developed a short run cost function and found that there is an enormous amount of excess capacity of traffic on the U.S. rail network. If this

capacity was reduced, Keeler believed there would be substantial savings for the railroads. However, Keeler did acknowledge that it would be difficult to abandon some portions of the track because of the indivisibility of the network involved.

Several other authors used non-linear relationships between independent variables and the dependent variable to explain the cost structure of the short line rail industry. Sidhu, Charney, and Due wrote an article in 1977, which illustrated various forms of cost as a function of the reciprocal of volume and reciprocal of distance. The authors demonstrated that maintenance of way and transportation rail line costs were shown to decrease with volume, but not with distance. They also found that increases in traffic volume generated more efficient uses of manpower and fuel. With increases in distance and volume, the railroads were shown to better utilize maintenance of equipment and traffic administration expenses. In these studies, the authors illustrated that the long run marginal cost was less than the average cost. These findings demonstrate that increases in traffic volume cause marginal costs to decrease, which also drives down average costs, indicating economies of density.

Therefore, if a railroad was to charge marginal costs, the railroad would need a subsidy to survive. This subsidy is not necessary or required at higher traffic densities where average costs equal marginal costs. Sidhu et al. (1977) pointed out that the viability of short lines is a function of the cost of competitive transportation modes, the cost of transferring a commodity from truck to rail, the cost of haul per ton mile on the main line, and the length of haul on the main line. Sidhu et al. demonstrated how a nonlinear function using the independent variables of distance and volume assist in explaining the cost structure of a railroad.

Hirshey (1979) studied the cost elasticities of light density lines. He used the United States Railway Association (USRA) data of 1973 saying that this data collection was done on a property specific basis. This allowed the author to test on- and off-branch cost models. Hirshey divided railroads into their on-branch and off-branch characteristics. He used a second order Taylor series expansion in logarithms (translog) to model the costs of the railroads. The author explained costs with output variables, such as quantity, distance, bulk, and frequency. Hirshey's model found significant returns to density for on-branch traffic with returns between 0.24 and 0.32. There were not significant returns to density for the off-branch lines where elasticity was close to 1.0.

Friendler and Spady (1980) also contributed much to the study of the rail industry. These authors found various weaknesses in previous studies. Their book distinguished the differences between way and structure capital and route mileage. Way and structure capital was defined as a factor of production, while route mileage was defined as an increase in the obligations of the carrier. When utilizing way and structure capital as a factor of production, one would find that if a railroad was to increase way and structure expenditures, there would be a decrease in other factors of production, holding everything else constant. The authors also found that previous studies overlooked effects on the costs of independent variables, such as traffic mix by the type of commodity, average length of haul, and the distinction of high versus low density route miles. Making these distinctions in their rail cost function improved the cost functions of future studies.

Friendler and Spady also were two of the first authors to use a transcendental logarithmic (translog) function to estimate the nature of the rail industry. The translog function was another advancement in the costing methodology of the rail industry. The

translog function is more flexible than other methods and does not require as many restrictions to be placed on the costing function. As Ray (1982) pointed out, the translog function allows for specific characteristics of technology to be tested by estimating the parameters of the model. Friendler's and Spady's translog function included five variable factors including equipment, general and maintenance labor, traffic and transportation labor (other than train), on-train labor, and fuel and material. The fixed factor in the model was the way and structures capital. The model also included four technological conditions: freight route-miles operated, low-density route-miles, average length of haul, and the ratio of ton-miles of manufactured commodities to ton-miles of other commodities. In addition, the model included two output variables: passenger miles and revenue ton miles. Using this model, the authors found long-run increasing returns to density, but not for firm size.

Several other authors also demonstrated effectiveness of the translog function. One of those authors, Bitzan (1999), estimated a translog function to determine if railroads are natural monopolies. Bitzan also showed the impact of factor input prices, technology, and different multi-product outputs on costs for a railroad. This study examined data from the Class I's Annual Reports to the Interstate Commerce Commission and found Class I railroads to be natural monopolies over a fixed network. This demonstrated that for Class I railroads, parallel mergers are beneficial from a cost perspective. Many of the authors who used the translog cost function demonstrated flexibility and usefulness of the findings that the function can illustrate. These authors demonstrated importance of the coefficients, how economies of scale and density can be illustrated, and how elasticities can be derived from the translog function. The cost functions in previous studies have varied greatly from linear regression, to simple Cobb Douglas functions, to the translog cost function. Many

different authors have stressed the importance of variables that influence total costs, average costs, and marginal costs. Some of the more commonly stressed variables for the railroad industry are labor, fuel, maintenance of way and structures, equipment, and administration expense. Some factors that influence average costs include density and size. A review of previous cost studies demonstrates the various cost functions used in examining the railroad industry and various factors that influence the railroad's costs.

Economies of Density and Size

Nearly every cost function study of the rail industry examines how size and density influence costs. The results and methods used, however, vary substantially. Most rail studies attempt to determine the impact of size and density on the cost function and whether the influence is significant statistically. Economies of size exist when increases in the size of the network result in a decrease in the railroad's average costs. Economies of density involve an increase in traffic volume for the railroad, holding the size of the railroad constant. Most studies have found that density is significant in reducing total average costs. The results for economies of size or scale are mixed, with some authors indicating that returns to scale economies exist while others do not.

Sidhu, Charney, and Due (1977) stressed the importance of traffic density for the viability of short lines. They examined the financial viability of short lines and categorized the viability of short lines according to density:

1. Less than 50,000 ton miles per mile: typically have higher costs and likely to be justified only if the line is short (under 10 miles) or under special conditions.

2. Between 50,000 to 200,000 ton miles per mile: may be justifiable depending on the main line haul, length of the line, and the railroad's ability to control costs.
3. Between 200,000 to 800,000 ton miles per mile: if under 25 miles, these lines are economically justifiable unless the main line is short or the transfer from truck to rail is low.
4. More than 800,000 ton miles per mile: likely to be economically justifiable even without a main line haul.

Sidhu et al. used 1968 data from Interstate Commerce Commission-published statistics. The authors also used 1973 data from reports filed by the railroads with ICC. Short lines usually have large fixed costs, and higher density allows them to spread the fixed costs over a larger volume. With this categorization of density by Sidhu et al. it is easy to see the importance of density to the short line rail industry.

Harris (1990) studied the issue of economies of density in the rail freight industry using ICC's annual statistics for Class I railroads for 1972 and 1973. Only firms which derived less than 1 percent of their total revenue from passenger miles were included within the data set. The author used an average cost function to determine the impact of economies of density on various cost criteria. Harris concluded that the high fixed operating costs, per the railroad's miles of road, amount to two-thirds of the economies of density that the railroad can experience. He also found that maintenance of way and structure accounts for 15 percent of the economies of density. Thirty-nine percent of the economies of density is accounted for by transportation expense. Harris demonstrated that fixed costs in the rail industry are high and it is important for railroads to have significant traffic to overcome high fixed costs.

Keaton (1990) also examined the impact of density on the rail industry by examining three postulated rail networks. Using these networks, he varied the amount of traffic to examine the impacts of traffic density. Keaton found that by increasing density, it is possible to better utilize labor and equipment. He found that with increased density the average transit time decreases. Keaton believed that increases in density may result in more direct movement (less switching in movement) causing the average transit time to decrease. The economies of density also explain why parallel mergers may be beneficial in reducing costs by spreading out more of the fixed costs. With higher densities, the railroad usually is more viable and also capable of offering direct shipments.

Dooley (1991) used nine synthesized model short lines when he examined the impacts of economies of size and density in the short-line rail industry. The author found that increasing the traffic density of a railroad from 20 to 30 cars per mile can reduce average total costs per car by 30 percent. Density can be of utmost importance in reduction of the average costs for a short line. Dooley also found that when increasing the miles of road from 56 to 129, the railroad only reduces average costs per car by 6.9 percent. Economies of size are not a major factor in reducing average costs of the short line. Therefore, short-line operators should focus their attention on increasing traffic volume instead of increasing the size of the network. In this way, the short line will become more cost effective.

Resor and Smith (1993) also examined the impacts of economies of density on the cost function of the railroad industry. They found it to be important to have increases in traffic volume to reduce average total costs. The authors stated that spikes, plates, bolts, joint bars, and special work costs increase more with tonnage than do tie costs. Increases in

traffic will result in increases in maintenance costs. However, it is important to note that it is more economical for the rail line to deteriorate because of train usage than because of natural erosion by weather. Resor and Smith stated that it is important to have an increase in traffic density. However, if traffic volume increases beyond a certain level, it will result in congestion. With congestion, the service of the railroad will decrease and the ability to perform maintenance of way repairs will become difficult. Importance of traffic density is critical in determining railroad costs. Railroads have high fixed costs and it is necessary to spread these fixed costs over a large volume to be cost effective. Size is shown as being less valuable. Many studies have demonstrated that short lines must increase their traffic densities to reduce their average total costs and remain or become viable. Also, increases in traffic density will result in deterioration of the rail line by usage instead of erosion. This increase in traffic density also will allow the short lines a better opportunity to repair and improve their track condition because of the expected increase in revenue.

Profitability and Importance of Short Lines

For a short line to continue to provide service, it must be able to cover its costs. The profitability of short lines varies greatly from one short line to the next. Also, the importance of short lines are different for various shippers. Babcock et al. (1995) examined the importance of short-line railroads. The authors interviewed shippers to see if short lines were a viable alternative to motor carriers. They collected data from shippers who used 13 short lines in Iowa and Kansas. The sample included 184 Kansas and 125 Iowa shippers. The shippers responded to survey questions by ranking the importance of a certain factor on a scale of one to five. Babcock et al. found that shippers preferred the short line service to

that of the former Class I. The primary disadvantage that short lines experience is that they do not have access to major markets. The most intense competition that short lines face is from the motor carrier industry. The shippers surveyed perceived the motor carrier industry as having an advantage in dependable transit, door to door service, and lower rates for short movements. Short lines have advantages for slightly longer movements, since the commodity does not need to be transferred to rail cars like with motor carrier movements. Also, short lines can ship larger shipments, have faster payment processing, less paperwork, and less congestion during peak periods. For short lines to be viable, they must be competitive with other modes and provide services that are not available or not currently performed by competitors.

Eric Wolfe (1988) wrote various articles on the success and failure of local and regional railroads. He identified failure as "the cessation of reliable transportation service due to changes in economic conditions"(p. 125). In his study, "The Downside Risk: An Analysis of Local and Regional Railroad Service Failures," Wolfe identified 12 key factors associated with the failure of a short-line railroad:

1. limited traffic
2. economies of size and density
3. single factor reliance
4. traffic balance
5. high rehabilitation cost
6. loss of financial aid
7. competition of other modes
8. insurance

9. general economic conditions

10. loss of key management personnel

11. inexperienced management

12. reliable business planning and flexible instruments

Wolf determined that economies of size and density were extremely important when determining the success of a short line. Another key factor in the success of a short line was the balance of traffic between originated and terminated traffic. Wolfe found that successful railroads originated 2.5 rail cars to every terminated rail car, while the unsuccessful short lines had a ratio of 3.3. Insurance cost also was demonstrated as burdensome to the short lines while the Class I railroads did not have as much difficulty paying the insurance cost. Wolfe illustrated that there are many different cost factors that short lines must control to be cost effective.

Grimm and Sapienza (1993) also examined the issue of short line rail performance by examining how economic and demographic variables explain variations in their profitability. To get data on these variables, the authors surveyed several short line railroads. The authors asked the short lines various questions on performance and managerial variables. They used a subjective method for the lack of a sound objective method. From this data, the authors determined that traffic density was related positively to profitability; however, profitability declined the more the short line was dependent on a particular commodity. Originated traffic also was a significant variable, illustrating the importance of the railroads' generating adequate levels of originated traffic. The financial leverage of the short line was related negatively to profitability. Finally, larger operations and proactive management philosophy were related positively to performance. The

importance of the variables mentioned illustrate what factors could be modified to make a short line more profitable.

Harris and Keeler (1981) studied the profitability of railroads for 1972 - 1975. The authors identified some major factors that hindered profitability of railroads. One of the factors is the excess capacity that railroads possess, such as redundant main lines, excess yard and terminal facilities, and light density branch lines. Separateness of the railroads also causes the railroads to suffer sub-optimal profitability. For Class I railroads, the labor union rules hinder optimal profitability. Short lines do not have the same stringent labor rules as Class I railroads. Rules and regulations restrict profitability of the railroads. Harris and Keeler believe that rail industry could be much more profitable if the rail industry was to merge into one nationwide railroad.

Babcock et al. (1997) also examined profitability of the short line industry. The authors obtained financial data from 34 short lines from 17 states for the fiscal years of 1986 through 1995. Through sensitivity analysis, they determined key variables to profitability to be the number of carloads per mile of main-line track lagged one year, total real operating expense minus maintenance of way expense lagged one year, the gross miles of main-line track operated by the railroad, and the percentage of traffic in the top three Standard Industrial Classification codes. The two most important variables were lagged carloads per mile (density) and lagged real operating expenses per mile less real MOW expenses per mile (ability to control costs). Both variables are easily identified for their importance. Density is important since the more cars the railroad can handle, the greater the revenue it should generate. Also, the ability to control costs to make a greater profit is self explanatory. Through this study, the authors determined that the profitability for short

lines is low and that governmental assistance for many short lines would be necessary for their survival.

Due and Meyer (1988) examined the success and failure of new railroads. The authors stressed the importance of adequate traffic for survival. There are fixed costs that railroads inherit no matter how much traffic they generate. Therefore, they must have adequate traffic to cover these fixed costs. The authors also pointed out that success can be determined by the number of shippers - fewer shippers serviced will result in lower transactional costs. Other factors stressed by the authors were flexibility of labor, the wage rate, freight rates, management ability, and physical disasters.

Through the various studies relating to profitability and performance of short lines, we gain some valuable insight into the viability of short lines. Like any business, the short-line industry must perform a service that creates value for its customers. This valuable service is the ability to ship large quantities of commodities to the main line more efficiently and at less expense than their competition. Also, they often are more efficient in their payment, processing, and their shipping ability during peak periods. For short lines to provide this valuable service, they must be able to make some profit to remain viable. There are many different factors that go into the profitability of the short lines. One of the most important factors is their financial leverage. Short lines must not have a substantial amount of debt; it makes recovery nearly impossible. The major cost that creates this substantial debt, in many cases, is the purchase of the rail line itself. Other factors that affect profitability include density, ability to control costs, labor restrictions, reliance on one commodity, and miles of track. Of these variables, density and the ability to control costs are the most important. Since profit is revenue minus costs, it only makes sense that

the two most important variables are the amount of traffic the short line has and its ability to control costs.

Advancements from Previous Literature

Previous studies added a substantial amount of information to understanding the short line rail industry. There are, however, improvements that can be made to broaden our knowledge. In reviewing studies relating to short lines, there was no study that used a flexible cost function like the translog cost function for the short line industry. A flexible cost function imposes less restrictions on technology and improves estimates for the parameters in question. The various authors who used the translog function demonstrated effectiveness of this method. The translog function is a more accurate representation of cost than a typical linear function. A linear function imposes many restrictions upon the cost function. The translog function is non-linear and flexible in its application. The use of the translog function will be an improvement on the previous studies and will more accurately represent costs of the short lines.

This study will focus on the cost structure of the short lines. Profitability is defined as total revenue minus total costs. Revenues per car are similar for most of the short lines. The short lines' revenues are subject to constraints by the Class I railroads and by the amount that motor carriers charge. Short lines cannot charge substantially more than motor carriers or the short line will lose all of its business to the competition. Moreover, short lines cannot transport their shipments to destination, and must rely on Class I railroads to ensure termination of the shipment. Profits of short lines are a function of their ability to control costs. Density is an accurate way to demonstrate revenue for the short line.

Assuming that most short lines receive about the same revenue per car, the short line will realize greater revenue with greater density.

A major contribution of this study is the data it utilizes. There has not been a recent cost study, especially a translog function, for the short-line rail industry. The cost structure of the rail industry is much different today than it was prior to the Staggers Rail Act. Many of the effects from this policy can be seen today and may not have been observed in previous studies. Using data from the mid 1990s, a more accurate cost function of today's short lines will be presented.

The data of previous studies is questionable because many studies used average data or hypothetical data. Studies with hypothetical data have achieved substantial findings when explaining the problems that short lines face. Even though these studies have made substantial findings, because they used hypothetical data it is unknown how these studies relate to the actual short-line industry. Average data also presents problems. With average data, there is a strong possibility that the findings will be biased. Large or small values can alter the averaged values significantly. To correct these problems, this study will examine data from the short lines themselves. By using this data, the study will examine cost structure of the industry with actual costs of short-line operations supplied by the short lines themselves. This will provide an accurate estimation of costs and factors that influence cost structure of the short-line rail industry.

METHODOLOGY

To estimate an accurate cost function, it is necessary to use a method that will represent the true cost function of the industry. Past studies have represented cost function of the short-line industry with a linear or log linear form. By examining the cost curve of most industries, it is easily seen that the cost function rarely is a linear relationship. A basic non-linear form is an improvement; however, it is not as accurate as the transcendental logarithmic function (translog). Both the linear and log linear functions impose restrictions on production technology. The translog function imposes fewer restrictions on the cost function. This section will examine the properties of a valid cost function, the usefulness of the transcendental logarithmic function, and the criteria of economies of size and density.

Properties of a Valid Cost Function

When designing a cost function to represent the nature of cost for any industry, the function must be valid. For the cost function to be valid, it must theoretically have the correct characteristics of costs. If the cost function is not valid, the nature of cost for the industry is not well represented. Four properties make a cost function valid (Varian).

The first property is the fact that the cost function must be non-decreasing in factor prices. As factor prices increase, total costs of the firm also should increase. Therefore, if a firm produced two bundles of outputs with the same inputs, the bundle of outputs with more expensive factor prices would incur more costs to the firm.

The second property of a valid cost function is that it is homogeneous of degree one in factor prices. This means that the regression coefficients of the first order factor prices

should add up to one. Therefore, a 1 percent increase in all factor prices leads to a 1 percent increase in costs.

The next property is the fact that a valid cost function must be concave in factor prices. This concavity happens because as one of the firm's inputs increase in price, and the rest remain the same, the firm will tend to move away from increasing input to the other less costly inputs.

The fourth property is the continuous nature of prices. The fact that a function is concave also makes the function continuous. Continuous means that the cost function is twice differentiable, and this factor allows for using derivatives to explain many other attributes of the cost structure of an industry.

Transcendental Logarithmic Function (Translog)

The short line industry's technology can be represented by a production function. With this production function, a short line will attempt to produce a given output at minimum cost, which allows the railroads to achieve their greatest profit. Furthermore, short lines must be cost effective to compete effectively and stay viable when competing against the motor carrier industry. An accurate cost function will demonstrate the minimum cost that a short line can achieve at a given output.

The translog function has been used by many authors, such as Bitzan, Nganje, and Ray. They demonstrated that it is an excellent representation of the cost structure of an industry. Ray (1982), in fact, stated that the translog is a quadratic approximation to the unspecified "true" cost function. This translog function even allows for the testing of multi-output firms. In this short line rail study, there will be just one output variable. The

translog functionality also will demonstrate improvements that have not been used in previous studies.

The translog cost function can be represented by the cost function demonstrated below:

$$\ln C = a_o + \sum_{i=1}^{n} \alpha_i \ln P_i + \sum_{j=1}^{n} \beta_j \ln Y_j + \chi \ln K + \sum_{l=1}^{n} \delta_l \ln T_l$$
$$+ \frac{1}{2}\sum_{i=1}^{n}\sum_{k=1}^{n} \varepsilon_{ik} \ln P_i \ln P_k + \frac{1}{2}\sum_{j=1}^{n}\sum_{h=1}^{n} \phi_{jh} \ln Y_j \ln Y_h + \frac{1}{2}\varphi \ln K \ln K$$
$$+ \frac{1}{2}\sum_{l=1}^{n}\sum_{g=1}^{n} \gamma_{lg} \ln T_l \ln T_g + \sum_{i=1}^{n}\sum_{j=1}^{n} \eta_{ij} \ln P_i \ln Y_j + \sum_{i=1}^{n} \iota_i \ln P_i \ln K$$
$$+ \sum_{i=1}^{n}\sum_{l=1}^{n} \kappa_{il} \ln P_i \ln T_l + \sum_{j=1}^{n} \lambda_j \ln Y_j \ln K + \sum_{j=1}^{n}\sum_{l=1}^{n} \mu_{jl} \ln Y_j \ln T_l + \sum_{l=1}^{n} \nu_l \ln K \ln T_l + \in$$

C=Cost-dependent variable

P = Factor Price of input *i*

Y = Output of product *j*

K = Fixed Capital

T = Technology Condition *l*

By examining this equation, we can see many of the features that the translog cost function can offer. It is easily seen that the equation expands rapidly with the addition of each new variable. The model incorporates the effect between variables. By imposing symmetry conditions, $\gamma_{lg} = \gamma_{gl}$ or $\kappa_{il} = \kappa_{li}$, the model assumes that these coefficients are the same. Regardless of the order of the interaction variable, η_{ij} is considered the same as η_{ji}. The symmetry restriction can be imposed because of Young's Theorem (Jehle). Young's Theorem states that if a function is differentiated by $\partial x_i \partial x_j$, it is the same as if the

function was differentiated by $\partial c_i \partial c_j$, as long as both cross partial derivatives are continuous.

The model also must be homogeneous to degree one in factor prices. This is a condition of a valid cost function, which was mentioned earlier. To impose this restriction on the model, the sum of the first order coefficients of the factor price are set equal to one, $\sum_{i=1}^{n} \alpha_i = 1$, $\sum_{i=1}^{n} \varepsilon_{ik} = 0$ for all *k*, $\sum_{i=1}^{n} \eta_{ij} = 0$ for all *j*, $\sum_{i=1}^{n} \iota_i = 0$, and $\sum_{i=1}^{n} \kappa_{il} = 0$ for all *l*. This condition imposed on the model is extremely important; without this restriction the model might not adhere to one of the properties of a valid cost function.

The translog function, however, has a problem with degrees of freedom. It is easy to see by the way the model is configured, there is an explosion of variables. Consider a function with m-outputs and n-inputs; one needs to estimate ½(m+n)(3+m+n) parameters (Ray, 1982). For the model in this study there will be 53 variables and a constant. By simply adding one more variable, the model will then have 65 parameter estimates. This explosion of parameters creates the need for a large database to run the model. For many studies, a research effort using the translog function would not be possible simply because there would not be enough data to run a model.

To help with this problem of degrees of freedom and, more importantly, to add efficiency in the estimation of the model, most studies using a translog cost function have included cost share factor equations. Ray (1982) stated that estimating a full dual system, the cost function model, and the cost share equations together result in greater efficiency of

the model. Nganje stated that this procedure resolves the problem of specification error resulting from degrees of freedom needed for a small sample size. Using the translog cost function and property of Sheppard Lemma, we can derive the cost share equations for the factor prices. Sheppard's Lemma is the property that states that "a firm's conditional factor demands can be obtained from the cost function by simple differentiation with respect to factor prices" (Jehle,1991, p.231). The full dual system allows for greater efficiency and resolves part of the problem of the need for an extensive data set to utilize a translog function by itself.

Short Run Versus Long Run Costs

Basic economics courses draw the distinction between short run and long run costs and their variable natures. In the long run, all costs are variable. A firm in the long run would adjust all inputs to minimize costs. In the short run, not all costs are variable; some costs are fixed. By examining the long run total cost curve, it can be seen that the curve is tangent to the minimization points of many short run total costs' curves. The total costs curves are used in this section to explain the relationship between long run costs to that of short run costs. Figure 1 shows the relationship between the short run total cost curves and that of the long run total cost curve.

X1, X2, and X3 represent the short run total cost curves of a firm. XX represents the long run total costs curve. The short run total costs curves assume some of the inputs are fixed. The diagram shows the long run total cost curve as a minimization curve with a firm having an opportunity to adjust all costs. A long run cost function would assume a fairly mature firm that has reached or is near to its long run minimization point. This could

be characterized by a firm with experienced management with many years to alter its inputs to reach its cost minimization optimal level. This description applies to the Class I railroads more than the short lines, since they are well established railroads with experienced management.

This study will examine short-run variable costs because analyses are based on a single period with cross sectional data from 1995. Also, short-run costs are used since the model assumes that short lines are not at their optimal capital stock levels. Short run firms choose variable inputs to minimize costs. The combination of inputs that the short line uses is an illustration of the short line's technology. Technology in this manner can be represented by a short run variable cost function.

In any given year, short lines can be characterized by their short run costs. Short lines usually are not established for as many years as Class I railroads. Also, Wolfe (1988) pointed out that most managers of short lines are inexperienced since they do not have much previous railroad experience. This would cause managers to constantly alter their inputs to reach their long run minimization point. Since management is not experienced, it will take a substantial amount of time to reach this point. The planning horizon also plays a key factor in the cost function. Many authors have questioned the viability of short lines; therefore, they may not be planning for the long run, but simply operating in the short run. By operating in the short run, the short line is more concerned with staying viable than with actually making adjustments, to be cost effective in the long run. Babcock (1997) noted that many short lines were purchased with an overestimation of profits. This is another aspect that makes the short run cost function more appropriate. With this overestimation

and lack of profitability, the short lines have difficulty receiving funds for further improvements or expansion of their systems that could optimize their rail lines.

Economies of Size and Density

Economies of size and density are the two most common criteria examined in railroad cost functions. Economies of size are defined as an increase in output resulting from an increase in size that leads to a less than proportional increase in total costs. To determine whether the economies of size of a short line exist, the elasticity of costs with respect to size can be used. Elasticities of cost with respect to size can be defined as the change in total cost due to the change in output and length of haul, resulting from an increase in miles of roads. Length of haul is used in this calculation because of the network structure of most short lines. Most short lines operate on a straight line section of track without any sections of their track branching off from this main section. Therefore, with this assumption, as the short line increases miles of road it will most likely experience an equal or similar proportional increase in average length of haul.

$$\frac{\partial TC}{\partial MR} + \frac{\partial TC}{\partial RTM} + \frac{\partial TC}{\partial ALH}$$

TC = Total Costs

MR=Miles of Road

RTM=Revenue ton miles

ALH=Average Length of Haul

If this partial derivative is equal to one, it is known to have constant returns to size. If the elasticity is less than one, there are economies of size, and if the elasticity is greater than one, there are diseconomies of size.

Economies of density are defined as an increase in output resulting in a less than proportional increase in total costs. Economies of density can be defined as the change in total costs due to the change in the output of the short line, holding network size and length of haul constant.

$$\frac{dTC}{dRTM}$$

TC = Total Costs

RTM = Revenue Ton Miles (Output for short line)

If this elasticity is equal to one, there are constant returns to density. When this elasticity is less than one there are economies of density, and if the elasticity is greater than one there are diseconomies of density.

An alternative way to measure the elasticities is to examine economies of size and density directly, which is the inverse of the descriptions above. In this manner, if the value is greater than one there are economies, if less than one there are diseconomies, and if equal to one there are constant returns. Also, there is the need for a capital adjustment when calculating economies of size and density. This is needed since this model is a variable cost function. By using a capital proxy, as an adjustment in the economies of size and density equation, we can get a better understanding them. Without this adjustment, economies of density and size would be understated with the variable cost function.

The elasticities of size and density are important factors for the short-line rail industry. If economies of size are significant, it shows that as the short line increases its miles of road, the short line's average costs will decrease. This will become a key ingredient in assisting railroads to become more cost effective. Many previous studies have found the significance of economies of density. If, as many past studies have indicated, economies of density are significant, it can be shown that short lines could be more cost effective if they were to increase their output.

Cost Share Factor Prices

The translog function also is valuable because of the information that it provides from the cost share factors. If the cost share factor price coefficient of labor is 0.35, then labor accounts for 35 percent of costs. This understanding provides us with the information that costs are the most significant for the short lines. By understanding these costs, railroads could make better decisions on judging which costs affect their cost structure the most.

EMPIRICAL METHODS

The theory section explained concepts and techniques that will be used in the empirical model. The theory section does not explain the actual model used in the study and does not explain variables that will be used. This chapter will explain the variables that will be used in this thesis and where the variables originated. This chapter also will explain the empirical model. With an understanding of the empirical model, we will be able to use the data and have a better understanding of cost structure of the short-line rail industry.

Model Variables

To analyze cost effectiveness of the short line rail industry, this thesis will use variables from a short line database compiled by the American Short Line Railroad Association and the Upper Great Plains Transportation Institute. This database project attempts to survey all firms that qualify as short lines. A fairly high response rate was received from the short lines surveyed. This is most likely the best database on the short line rail industry, due to the reputations of the collecting organizations. The names of the short lines used in this study will not be stated for proprietary reasons. The data used in this model will result in an aggregate model and will not be used to evaluate individual railroads. The short line cost function can be represented by the cost function on the following page using the corresponding variables:

$$C = f(f, l, e, t, d, r, q, a, m)$$

f=Factor price of fuel

l=Factor price of labor

e=Factor price of equipment

t=Factor price of materials

d=Dummy variable (1=Switching and Terminal, 0=others)

r=Revenue ton miles

q=Quality of track

a=Average Length of Haul

m=Miles of Road

The dependent variable used in this thesis is total operating expenses. This expense will include all operating costs that the railroads incurs in a given year. Using variables from the database, this variable will be defined as total railway operating expenses minus freight car expense plus a calculated freight car rental rate. Freight car expenses are subtracted from total expenses since a rental rate was calculated for this variable instead of using the freight car expense data from the database. Many short lines in the database had a zero freight car expense since they were most likely able to use Class I railroads' freight cars for free. However, in such cases the rental rate for rail cars is reflected in lower revenues received from the Class I railroads. Therefore, using a rental rate will more accurately reflect freight car expense for the short line.

Within the translog function are variables called factor prices. Factor prices are known as the prices of the inputs that the short line uses in its production function. A short line's major variable costs in the short run are fuel, labor, equipment, and material expense. The track and structures are fixed in the short run. However, in the long run, the railroad can attempt to optimize them to their most cost effective structure. Therefore, the major factor prices for the short line are fuel, labor, equipment, and materials. These four

variables will be measured in dollars per unit. Fuel price is used in the model by determining the average price per gallon.

Labor price is used by determining the average price of labor per man hour. Labor is determined by calculating total expenses the line pays in labor, which includes salaries and benefits. Then the total money spent on labor is divided by man hours worked. Equipment costs are a little more difficult to determine. A rental rate for freight car expense is used in this model to accurately reflect the true cost of the railroad. This calculation will be explained more fully in Chapter 5. Even though a railroad may not pay for some of its freight cars, there is the foregone expense of the optimal earnings it could earn if it did operate its own cars. Therefore, this rental rate and the locomotive expense are calculated to find a weighted average between locomotives and freight cars so that the factor price may be determined. Using the variables in the database, the factor price of equipment will be defined as the ratio of freight car rental expense to total equipment expense multiplied by the freight car expense per car. This value will be added to the ratio of locomotive expense to total equipment expense multiplied by locomotive expense per locomotive. By doing this, we will get a value that is the factor price for locomotives and railcars. The material factor price is found by using the value represented by the AAR Materials and Supply Price Index.

Quality of track is used in this model as a proxy for the value of way and structures. This is measured in the percentage of track that is greater than 90-pound rail. Higher quality track will not require as many repairs and the railroad can operate at higher speeds. It also is logically assumed that railroads with higher quality track will have lower variable costs. Track is considered a fixed cost in the short run. Since quality of track is used as a

proxy for the value of way and structures, it may be assumed that short lines with higher quality track have lower variable costs.

Average length of haul is used as a technology variable and an index for output. Railroads that can spread their costs over longer hauls typically are more cost effective. Average length of haul basically has been used in every recent study of railroad costs. It is used to demonstrate that as the length of haul increases, average costs decrease. If average length of haul is found to be significant and highly influential in the cost function, it can be said that railroads with shorter hauls may be inefficient while railroads with longer hauls are more cost effective. Average length of haul will be measured in the average miles from origin to destination for a shipment.

Revenue ton-miles may demonstrate that density or the amount of output the short line carries significantly affects cost structure of the industry. The revenue ton-miles factor is an output variable used for the short-line industry. The miles of road factor is used as a size variable in the model. The factor miles of road is different from the factor miles of track, since the factor miles of road does not double count track miles if the railroad owns a set of parallel track. If miles of road are found to be significant and influential in the model, it can be shown that miles of road can play a major role in cost structure of the industry.

The dummy variable in the model is used to explain differences between switching and terminal railroads and local line hauls and regional railroads. In the data set, the switching and terminal railroads were set equal to one and all other railroads equaled zero. Switching and terminal railroads are considered to offer different services than those of the other railroads. If the dummy variable is significant, it demonstrates that there are

statistical differences between the switching and terminal railroads, and local line hauls and regional railroads.

With all these variables there also are the interaction variables. The interaction variables explain the interaction between two variables. These nine variables with the interaction variables will amount to 53 variables in the model. These variables have been shown through past studies to be the most pertinent variables that affect the variable cost structure of the short-line industry. They will accurately demonstrate cost structure of the rail industry and show where improvements in short line operations could take place.

Empirical Model

By using the theoretical model developed in Chapter 3 and the variables previously mentioned, we can develop an empirical model which will be used to study the cost structure of the short-line rail industry. The model developed on the following page will be the one used to study the short-line rail industry, and will provide us with a better understanding of economies of size and density.

Friendler and Spady (1981) demonstrated that the translog function is obtained from a Taylor series approximation to an unknown function. When performing the Taylor series function, each variable is divided by its sample mean. One advantage of dividing variables by their sample means is that the first order coefficients will show elasticity of variable cost with respect to that particular variable (Bitzan).

$$\ln C = \alpha_0 + \alpha_1 \ln(f/\bar{f}) + \alpha_2 \ln(l/\bar{l}) + \alpha_3 \ln(e/\bar{e}) + \alpha_4 \ln(t/\bar{t}) + \alpha_5 \ln(a/\bar{a})$$
$$+ \alpha_6 \ln(r/\bar{r}) + \alpha_7 \ln(q/\bar{q}) + \alpha_8 \ln(m/\bar{m}) + \alpha_9 (D) + \alpha_{10} \frac{1}{2}\left[\ln(f/\bar{f})\right]^2 + \alpha_{11} \frac{1}{2}\left[\ln(l/\bar{l})\right]^2$$
$$+ \alpha_{12} \frac{1}{2}\left[\ln(e/\bar{e})\right]^2 + \alpha_{13} \frac{1}{2}\left[\ln(t/\bar{t})\right] + \alpha_{14} \frac{1}{2}\left[\ln(a/\bar{a})\right]^2 + \alpha_{15} \frac{1}{2}\left[\ln(r/\bar{r})\right]^2$$
$$+ \alpha_{16} \frac{1}{2}\left[\ln(q/\bar{q})\right]^2 + \alpha_{17} \frac{1}{2}\left[\ln(m/\bar{m})\right]^2 + \alpha_{18} \ln(f/\bar{f}) \ln(l/\bar{l}) + \alpha_{19} \ln(f/\bar{f}) \ln(e/\bar{e})$$
$$+ \alpha_{20} \ln(f/\bar{f}) \ln(t/\bar{t}) + \alpha_{21} \ln(f/\bar{f}) \ln(a/\bar{a}) + \alpha_{22} \ln(f/\bar{f}) \ln(r/\bar{r}) + \alpha_{23} \ln(f/\bar{f}) \ln(q/\bar{q})$$
$$+ \alpha_{24} \ln(f/\bar{f}) \ln(m/\bar{m}) + \alpha_{25} \ln(f/\bar{f})(D) + \alpha_{26} \ln(l/\bar{l}) \ln(e/\bar{e}) + \alpha_{27} \ln(l/\bar{l}) \ln(t/\bar{t})$$
$$+ \alpha_{28} \ln(l/\bar{l}) \ln(a/\bar{a}) + \alpha_{29} \ln(l/\bar{l}) \ln(r/\bar{r}) + \alpha_{30} \ln(l/\bar{l}) \ln(q/\bar{q}) + \alpha_{31} \ln(l/\bar{l}) \ln(m/\bar{m}) + \alpha_{32} \ln(l/\bar{l})(D)$$
$$+ \alpha_{33} \ln(e/\bar{e}) \ln(t/\bar{t}) + \alpha_{34} \ln(e/\bar{e}) \ln(a/\bar{a}) + \alpha_{35} \ln(e/\bar{e}) \ln(r/\bar{r}) + \alpha_{36} \ln(e/\bar{e}) \ln(q/\bar{q})$$
$$+ \alpha_{37} \ln(e/\bar{e}) \ln(m/\bar{m}) + \alpha_{38} \ln(e/\bar{e})(D) + \alpha_{39} \ln(t/\bar{t}) \ln(a/\bar{a}) + \alpha_{40} \ln(t/\bar{t}) \ln(r/\bar{r}) + \alpha_{40} \ln(t/\bar{t}) \ln(q/\bar{q})$$
$$+ \alpha_{41} \ln(t/\bar{t}) \ln(m/\bar{m}) + \alpha_{42} \ln(t/\bar{t})(D) + \alpha_{43} \ln(a/\bar{a}) \ln(r/\bar{r}) + \alpha_{44} \ln(a/\bar{a}) \ln(q/\bar{q})$$
$$+ \alpha_{45} \ln(a/\bar{a}) \ln(m/\bar{m}) + \alpha_{46} \ln(a/\bar{a})(D) + \alpha_{47} \ln(r/\bar{r}) \ln(q/\bar{q}) + \alpha_{48} \ln(r/\bar{r}) \ln(m/\bar{m}) + \alpha_{49} \ln(r/\bar{r})(D)$$
$$+ \alpha_{50} \ln(q/\bar{q}) \ln(m/\bar{m}) + \alpha_{51} \ln(q/\bar{q})(D) + \alpha_{51} \ln(m/\bar{m})(D) + \epsilon$$

$$s_1 = \alpha_1 + \alpha_{10} \ln(f/\bar{f}) + \alpha_{18} \ln(l/\bar{l}) + \alpha_{19} \ln(e/\bar{e}) + \alpha_{20} \ln(t/\bar{t}) + \alpha_{21} \ln(a/\bar{a}) + \alpha_{22} \ln(r/\bar{r})$$
$$+ \alpha_{23} \ln(q/\bar{q}) + \alpha_{24} \ln(m/\bar{m}) + \alpha_{25}(D)$$

$$s_2 = \alpha_2 + \alpha_{11} \ln(l/\bar{l}) + \alpha_{18} \ln(f/\bar{f}) + \alpha_{26} \ln(e/\bar{e}) + \alpha_{27} \ln(t/\bar{t}) + \alpha_{28} \ln(a/\bar{a}) + \alpha_{29} \ln(r/\bar{r})$$
$$+ \alpha_{30} \ln(q/\bar{q}) + \alpha_{31} \ln(m/\bar{m}) + \alpha_{32}(D)$$

$$s_3 = \alpha_3 + \alpha_{12} \ln(e/\bar{e}) + \alpha_{19} \ln(f/\bar{f}) + \alpha_{26} \ln(l/\bar{l}) + \alpha_{33} \ln(t/\bar{t}) + \alpha_{34} \ln(a/\bar{a}) + \alpha_{35} \ln(r/\bar{r})$$
$$+ \alpha_{36} \ln(q/\bar{q}) + \alpha_{37} \ln(m/\bar{m}) + \alpha_{38}(D)$$

f=Factor Price of Fuel
l=Factor Price of Labor
e=Factor Price of Equipment
t=Factor Price of Materials
a=Average Length of Haul
r=Return Ton Miles
q=Quality of Track(percent of track above ninety-pound rail)
m=Miles of Road
D=Dummy(1=Switching &Terminal)
s_1 =Share of Fuel
s_2 =Share of Labor
s_3 =Share of Equipment

By examining the empirical model, we can see the full dual system of equations. With the full dual system, the cost share equation for materials is not included in the model because the cost shares add up to one, and including it would result in the matrix not being full rank (Nganje).

By using the coefficients of revenue ton-miles, miles of road, and average length of haul, we can determine the elasticities of density and size. These variables will explain how total costs of the short line are affected if the short line is able to increase its output or size. Many studies have expressed the importance of density; however, the economies of size factor has had mixed results. These studies did not utilize the translog cost function and the findings of this function may provide a clearer understanding of cost structure of the industry.

Tests and Techniques

The translog cost function is a logarithmic regressional model. Therefore, a seemingly unrelated system of equations is an effective technique to determine coefficients. Many of the standard regression techniques will be used to determine the fit of the model. F-tests and t-tests will be used to determine significance of the model and coefficients. The R-squared value will describe how well the model explains the true cost function. Also, the Durbin-Watson statistic will be used to explain if the model has a problem with serial correlation. These tests and values will verify the effectiveness of the model and the model's ability to explain cost structure of the industry.

DATA

This chapter will explain in detail the data set that will be used in the empirical model. This section will clarify how some variables were calculated for use in the model. Some variables in this model were modified to get an accurate representation of costs for the short lines. This section also describes the data set characteristics. The model was tested using the full range of observations, including switching and terminals, regionals, and local line haul railroads. This chapter also will explain the reasoning of why a dummy variable was used to illustrate the differences between classifications of railroads.

Variable Procedures

Some of the variables in the short line database had to be supplemented with information or data from outside the database, and some of the variables had to be calculated. One of the variables that exhibited this problem was revenue ton miles. Revenue ton miles exhibited many observations where the value was zero or seemed inaccurate given corresponding data. Therefore, revenue ton miles were calculated.

Revenue ton miles were derived by first getting information on the number of cars a short line hauled by Surface Transportation Commodity Code. To go along with the number of cars a short line hauled per commodity code, the study needed data on the average tons per railcar per commodity. Average tons per railcar was calculated by using Carloads Originated by Commodity Code and Tons Originated by Commodity Code found in Railroad Facts published by the Association of American Railroads. Average tons per carload is found by dividing tons originated by the number of carloads originated. After the average weight per railcar per STCC is found, it is then multiplied by the number of railcars

a particular short line hauled for that commodity code. Then the total calculated tons per commodity code is added up to equal the total weight a particular short line hauled for a given year. With this information, revenue ton miles is found by multiplying the calculated total weight hauled per short line by the average length of haul.

Also, freight car expense needed to be calculated for this model. Freight car expense was calculated for two reasons: 1) some data observations were absent from the database, and 2) many short lines might receive the cars for free or at discount rates for filling the cars and bringing them to Class I carriers in a certain time period. This would give a misrepresentation of cost in relation to the rail carriers that do not receive the rail cars at this rate. This calculation also allows for a uniform calculation of the freight car expense for all observations.

The first step in calculating a freight car expense is to determine a rental rate expense for each of the different types of railcars. To get a rental rate, e-tables were taken out of the Uniform Railroad Costing System Worktable E. The e-tables give a cost for each type of railcar that a railroad would use. These costs are associated with the Class I carriers' costs of railcar operation and ownership. Each short line was linked to the corresponding connecting Class I carriers using The Official Railway Guide. Eastern or western regional averages were used to determine rental rates for the short lines where the Class I carriers were non-existent or unable to be found. Short lines with more than one connecting carrier had the rental rates from all the corresponding connecting Class I carriers averaged. These Class I rail car expenses provide an accurate approximation to the freight car expenses incurred by short lines. The costs per day associated with these e-tables were car day operating costs, car day depreciation costs, and car day return on investment. Also

included with freight car expense are the car mile operating costs, car mile depreciation costs, and car mile return on investment. The e-tables provide the total car mile and car day expenses assessed to each type of railcar.

The short line database provided information on the number of railcars by commodity group that a particular railroad hauled. The e-table's car mile costs were added to determine a total car mile cost for each railcar type for each Class I carrier. The total rental rate per mile for a particular type of railcar was then multiplied by the number of railcars that the particular short line hauled for that type of railcar. This value was then multiplied by the average length of haul. Then all the different types of railcars were added to calculate the total car mile freight car expense for all the types of railcars that an individual short line may haul. This provides the total car mile freight car expense for each individual short line.

Next, the car day expense was determined. To determine a car day total expense, the three car day expenses for each particular railcar type were summed up for each Class I carrier. This total car day expense for a particular railcar type was then multiplied by the number of railcars that a particular short line used of that type of railcar. This value is then multipled by the average car days on the branch. Using a frequency of service (days per weeks) of five, Monday through Friday service, the average car days a rail car would spend on the branch rail line would be 5.63 (United States Railway Association).

This total car expense is then divided by the total number of railcars. This is then multiplied by the weighted percentage of how much railcars account for total equipment expenses. This value is added with the weighted average of locomotive expense, which will then provide the factor price of equipment. With this calculated equipment factor

price, the factor price of labor, the factor price of materials, and the factor price of fuel, all the factor prices are determined.

With these variables determined, the variable of quality of track had to be modified to accommodate the fact that there were zero values. The translog function, using natural logarithms, will not accommodate a value of zero. To accommodate this problem, the Box-Cox transformation was used. Caves, Christensen, and Tretheway described how this method can be used to accommodate a value of zero. The Box Cox Transformation is illustrated by the following.

$$(Y_i^{\lambda} - 1) / \lambda = \ln Y_i$$

This Box Cox Transformation demonstrated by Caves, Christensen, and Tretheway shows that with observations not equal to zero, the natural log is approximated by $(Y_i^{\lambda} - 1) / \lambda$. With values of zero, the Box Cox Transformation simply will be equal to $-1/\lambda$. λ is often estimated using non-linear estimation techniques, in this model the λ is set equal to 0.0001. With this transformation, observations of zero will have a value and can be used in the translog function.

Descriptive Statistics

In the database, a railroad is defined as either a regional railroad, local line haul, or a switching and terminal railroad. The local line haul short lines make up the majority of the railroad observations used in this model. For this study, the examination of the local line haul railroads are of the utmost importance. Local line hauls represent the railroads that provide service to the main lines for many smaller communities. For many smaller

communities, this loss of service can cause various economic hardships. Therefore, the understanding of the cost structure of these lines is the most beneficial to these communities not directly connected to the mail lines.

Regional railroads represent railroads that are the most similar to the service the local line hauls provide. The main difference between these two classifications is size. The regional railroads are much larger than the local line hauls. However, the service that switching and terminal railroads provide is significantly different than that of the regional and local line haul railroads. Switching and terminal railroads do not originate or terminate shipments. Switching and terminal railroads provide a service of switching railcars from one rail carrier to another, known as bridge traffic. For the most part, these shipments are quite short and, therefore, switching and terminal railroads could be significantly different than regional and local line haul rails. A dummy variable is used in this model to demonstrate the difference between classifications of railroads.

Table 1 lists data characteristics, including switching and terminals, local line hauls, and regional short-lines. In the next chapter, the data will be analyzed to determine cost structure and technology of the short-line rail industry. These data will give us a better understanding of the extent of economies of density and size in the short-line industry. It also will show how short lines have different cost characteristics between classifications of railroads. This information could be used in conjunction with the studies of Class I railroads to see how the cost structure differs between smaller network lines and that of larger network lines.

Table 1. Descriptive Statistics

63 Observations

Total Operating Expenses:		
Min: 91335.99	Max: 160210135.20	Mean: 11051901.38
Factor Price of Labor:		
Min: 8.01	Max: 32.90	Mean: 18.61
Factor Price of Equipment:		
Min: 103.58	Max: 43022.72	Mean: 6688.09
Factor Price of Fuel:		
Min: 0.52	Max: 1.19	Mean: 0.78
Revenue Ton Miles:		
Min: 12043.57	Max: 2796059709.00	Mean: 154764852.53
Miles of Road:		
Min: 2.00	Max: 682.00	Mean: 123.59
Average Length of Haul:		
Min: 0.50	Max: 251.00	Mean: 40.53
Total Labor Expense:		
Min: 47680.00	Max: 44934000.00	Mean: 3291896.61
Total Equipment Expense:		
Min: 2921.99	Max: 94387079.22	Mean: 4702944.55
Total Fuel Expense:		
Min: 905.52	Max: 5274392.00	Mean: 423547.47
Year Established:		
Earliest: 1891	Latest: 1995	Mean: 1961

EMPIRICAL RESULTS

In this chapter, we will examine the results of the empirical model. First, an evaluation of the model and the coefficients will demonstrate the fit of the model. Next, economies of density will be examined to see how short lines are affected by increases in traffic density. Afterwards, an evaluation of size will show the effects of increases in size for a short line. Also included will be a brief explanation of differences between switching and terminal railroads, and regional and local line hauls.

Empirical Model Results

The results of the model are illustrated in Table 2. The first order terms all have their expected signs. Also, all are significant except quality of track. The factor share coefficients demonstrate the percentage of variable costs that each factor price accounts for in the total variable cost function. It shows that labor accounts for approximately 26 percent of cost. The cost factor that accounts for the largest share of variable cost is the cost of equipment, around 36 percent. Fuel amounts to a fairly small percentage of the short line's variable costs, about 4 percent, and the material and supplies amount to roughly 34 percent of variable costs. Also, average length of haul is negative and significant, indicating that longer hauls reduce average costs. The quality of track variable, a proxy for capital, was negative; however, it was insignificant. The dummy variable for switching and terminal is negative and significant, indicating a difference in the cost structure for switching and terminal railroads.

Table 2. Seemingly Unrelated Regression for Translog and Share Equations-Results

First Order Terms	
Intercept	16.822509* (0.0001)
ln Labor Price	0.261456* (0.0001)
ln Equipment Price	0.359895* (0.0001)
ln Fuel Price	0.039582* (0.0001)
ln Material & Supply Price	0.339067* (0.0001)
ln Revenue Ton Miles	0.731361* (0.0001)
ln Miles of Road	0.255815* (0.0168)
ln Average Length of Haul	-0.843338* (0.0001)
Quality of Track (Box Cox Transformation)	-0.052200 (0.3629)
Dummy(1=Switching & Terminal)	-1.191069* (0.0076)
Second Order Terms	
½(ln Labor Price)^2	0.130581* (0.0319)
½(ln Equipment Price)^2	-0.034011* (0.0061)
½(ln Fuel Price)^2	0.010625 (0.2500)

Table 2. (Continued)

½(ln Materials and Supply Price)^2	0.108635** (0.0725)
½(ln Revenue Ton Miles)^2	0.027312 (0.4828)
½(ln Miles of Road)^2	-0.343877* (0.0148)
½(ln Average Length of Haul)^2	0.426838* (0.0078)
½(Quality of Track)^2	-0.000010451 (0.3624)
ln Price of Labor * ln Price of Equipment	0.010872 (0.3165)
ln Price of Labor * ln Price of Fuel	-0.012301 (0.1117)
ln Price of Labor * ln Price of Materials and Supplies	-0.129151* (0.0318)
ln Price of Labor * ln Revenue Ton Miles	-0.017799 (0.1397)
ln Price of Labor * ln Miles of Road	-0.003503 (0.8609)
ln Price of Labor * ln Average Length of Haul	-0.004629 (0.8287)
ln Price of Labor * Quality of Track	0.000006205 (0.3003)
ln Price of Labor*Dummy	0.047730 (0.2524)
ln Price of Labor*Dummy	0.047730 (0.2524)

Table 2. (Continued)

ln Price of Equipment * ln Price of Material & Supplies	0.020989 (0.1195)
ln Price of Equipment * ln Revenue Ton Miles	0.031331* (0.0083)
ln Price of Equipment * ln Miles of Road	0.034316** (0.0773)
ln Price of Equipment * ln Average Length of Haul	-0.047690* (0.0246)
ln Price of Equipment * Quality of Track	-0.000009414** (0.0868)
ln Price of Equipment * Dummy	-0.050169 (0.1943)
ln Price of Fuel * ln Price of Material & Supplies	-0.000473 (0.9620)
ln Price of Fuel * ln Revenue Ton Miles	-0.000159 (0.9216)
ln Price of Fuel * ln Miles of Road	0.003525 (0.2000)
ln Price of Fuel * ln Average Length of Haul	0.005939** (0.0645)
ln Price of Fuel * Quality of Track	0.000001061 (0.1855)
ln Price of Fuel * Dummy	0.003327 (0.5348)
ln Price of Material & Supplies * ln Revenue Ton Miles	-0.013373 (0.3294)
ln Price of Material & Supplies * ln Miles of Road	-0.034338 (0.1743)
ln Price of Material & Supplies * ln Average Length of Haul	0.046381** (0.0910)

Table 2. (Continued)

ln Price of Material & Supplies * Quality of Track	0.000002149 (0.7565)
ln Price of Material & Supplies * Dummy	-0.000888 (0.9854)
ln Revenue Ton Miles * ln Miles of Road	0.049131 (0.2893)
ln Revenue Ton Miles * ln Average Length of Haul	-0.175389* (0.0140)
ln Revenue Ton Miles * Quality of Track	-0.000003496 (0.8433)
ln Revenue Ton Miles * Dummy	-0.344976* (0.0168)
ln Miles of Road * ln Average Length of Haul	0.117289 (0.1931)
ln Miles of Road * Quality of Track	-0.000032773 (0.5112)
ln Miles of Road * Dummy	-0.205917 (.3082)
ln Average Length of Haul * Quality of Track	0.000114** (0.0803)
ln Average Length of Haul * Dummy	0.539755* (0.0227)
ln Quality of Track *Dummy	0.000048826 (0.3446)

System Weighted R-Squared =0.8761
System Weighted MSE=1.9528
Degrees of Freedom=208
* Significant at the 5 percent level
** Significant at the 10 percent level
Standard Errors in Parentheses

The dummy variable also interacts with other variables and therefore changes the slopes of coefficients for switching and terminal railroads. It is important to test the appropriateness of this relationship between independent variables and costs to make sure that switching and terminals are different than that of local line hauls. An F test like the one on the following page tests to evaluate the robustness of the model.

$$= \frac{(ESS_R - ESS_{UR}) / q}{ESS_{UR} / (N - k)}$$

ESS_R =Error Sum of Squares Restricted
ESS_{UR} =Error Sum of Squares Unrestricted
q=Number of Restrictions
N-*k*=Degree of Freedom Unrestricted Model

Using this formula, we find the F value is equal to 3.45 and is significant at the 5 percent level. Therefore, it is important to include the dummy variables in the model to indicate the difference between switching and terminals, and local line hauls and regionals.

Economies of Density

Density is a key variable that can influence cost structure for many short lines. If economies of density exist for the short line, then as an increase occurs in revenue ton miles, cost for the railroad will increase by a lesser percentage. In the model we find the value of the first order term for revenue ton miles is 0.7314. This shows that as revenue ton miles increases by 1 percent, cost will increase by a rate of 0.7314 at the point of means. This elasticity shows increasing returns to scale.

Caves, Christensen, and Swanson (1980) demonstrated how returns to scale (RTS) can be calculated with a variable cost function to give a more accurate representation as to what it would be for a total cost function. The formula is as follows:

$$RTS = \frac{1 - \sum (\partial \ln CV / \partial \ln Z_i)}{\sum (\partial \ln CV / \partial \ln Y_i)}$$

CV=Total variable costs

Y=Output

Z=Represent the fixed factors

An RTS value equal to one indicates constant returns to size, greater than one equals economies of size, and less than one equals diseconomies of size.

In the case of this model, the fixed factor is the quality of track. Track quality can not be adjusted in this model and represents a proxy for capital. Using the criteria for returns to density, it can be seen that the value for returns to density increases slightly with this inclusion of the capital proxy. Without using the capital proxy, the RTS is equal to 1.3673 at the point of means. However, with the use of the above formula, the RTS is equal to 1.4387 at the point of means. This demonstrates that when increasing density, capital expenses can be spread out over more revenue ton-miles. Density can be a key factor for a short line to be cost effective. The values above were listed for the elasticity of density at the point of means. However, if we allow revenue ton miles to vary while holding all other variables constant, we see that the degree of economies of density decreases as revenue ton miles increase. This is demonstrated in Table 3 where all variables are set at their mean levels except for revenue ton miles, which is allowed to vary.

Table 3. Economies of Density for Local Line Hauls and Regional Allowing RTM to Vary

Revenue Ton Miles	Returns to Density
42,411	2.072193
100,000	1.980804
250,000	1.891684
500,000	1.829419
1,000,000	1.771122
2,500,000	1.699530
5,000,000	1.649104
10,000,000	1.601584
25,000,000	1.542814
50,000,000	1.501145
100,000,000	1.461667
500,000,000	1.377550
1,000,000,000	1.344233
2,000,000,000	1.312490
2,796,059,709	1.297677

Using this chart, it easily is seen how the degree of economies of density decreases as revenue ton miles increases. In this chart, the smallest and largest observations of revenue ton miles were used as a range with various other values in between to demonstrate how the degree of economies of density changes as revenue ton miles increase. The chart indicates that all short lines can increase revenue ton miles and costs will not increase at the same proportional level. This chart also shows that the smallest railroads have the most to gain by increasing revenue ton miles. Density in this manner is important for short lines to be more cost effective.

Economies of Size

Economies of size also are very important when examining cost structure of the short line rail industry. Braeutigam (1984) illustrates that output and miles of road should be used when determining economies of size for the railroad industry. Caves, Christensen, and Swanson (1980) also pointed out that it is important to examine average length of haul

as an output index. This is particularly true for the short line industry. It can be assumed that if a short line increases miles of road by a certain percentage, then average length of haul will increase by the same or a similar percentage. Most short lines do not have a sizeable network structure with rail lines branching off of their main line. Most short lines offer service from one end of their track to the other, and an increase in track size will result in a similar increase in average length of haul. Therefore, size is an increase in revenue ton miles, miles of road, and average length of haul. Using a procedure similar to the one mentioned earlier, the calculation of economies of size (ES) is defined as follows. This formula demonstrates that returns to size is the result of an increase in output reflected by an increase in miles of road and a equal proportional increase in average length haul.

$$ES = \frac{1 - \sum(\partial \ln CV / \partial \ln Z_i)}{\sum(\partial \ln CV / \partial \ln Y_i) + \sum(\partial \ln CV / \partial \ln MR_i) + \sum(\partial \ln CV / \partial \ln ALH_i)}$$

CV=Total variable costs

Y=Output

Z=Represent the factors that are difficult to adjust(fixed factors)

MR=Miles of Road

ALH=Average Length of Haul

Again the inclusion of the capital proxy provides a better approximation to the degree of economies of size for the short-line rail industry. Including the capital proxy, the degree of economies of size at the means is 7.3152. This demonstrates that there are substantial economies when increasing size and average length of haul for the railroad. On the following page the degree of economies of size is demonstrated by holding revenue ton

miles at a specific value and allowing miles of road and average length of haul to vary by the same percentage increases. As miles of road increase by 1 percent, costs increase by 0.2558 percent. Average length of haul also plays a key role in making a short line more cost effective. The first order term for average length of haul is -0.8433 and is highly significant. This indicates that as average length of haul increases by 1 percent, average costs decrease by 0.8433 percent. This is important since it demonstrates that as the railroad increases it average length of haul, the costs are spread out over this greater distance. This corresponds with the common belief that is it more costly to set up or disassemble the train than it is to keep the train in motion. Also, administration expenses associated with each train haul can be distributed over a greater distance. Therefore, in general, as the average length of haul increases, railroads are being more cost effective than with shorter hauls. As Table 4 shows, railroads that use their lines less effectively have more to gain than railroads that are utilizing their track more fully.

Table 4 demonstrates that size does make a substantial impact on the cost structure of the short line rail industry. This impact is largely felt by the benefits associated with average length of haul increases due to expansion in miles of road. Short lines, by their nature, usually have limited miles of road and any increase in miles of road will result in an increase in their average length of haul. This increase in average length of haul helps to spread the cost over a greater distance traveled. As Table 4 illustrates, the shortest railroads have the most to gain by increasing miles of road and average length of haul; however, even larger short lines have much to gain by increasing their size.

Table 4. Economies of Size Allowing Miles of Road and Average Length of Haul to Vary

Revenue Ton Miles=152,346,651.7
Average Length of Haul Utilizing 85% of Miles of Road

Average Length of Haul	Miles of Road	Returns to size
8.5	10.00	74.768215
21.25	25.00	5.5571449
42.5	50.00	3.2684356
105	123.59	2.1263181
170	200.00	1.7922005
255	300.00	1.5830715
425	500.00	1.3801725

Revenue Ton Miles=40,000,000
Average Length of Haul Utilizing 85% of Miles of Road

Average Length of Haul	Miles of Road	Returns to size
8.5	10.00	7.1875885
21.25	25.00	3.2711534
42.5	50.00	2.3163653
105	123.59	1.6777100
170	200.00	1.4625713
255	300.00	1.3202410
425	500.00	1.1760539

Revenue Ton Miles =40,000,000
Average Length of Haul Utilizing 60% of Miles of Road

Average Length of Haul	Miles of Road	Returns to size
6	10.00	58.594469
15	25.00	5.4454275
30	50.00	3.2294676
74.15	123.59	2.1090761
120	200.00	1.7804205
180	300.00	1.5738733
300	500.00	1.3731757

Difference for Switching and Terminal Lines

Switching and terminal railroads offer different services than that of the local line hauls and regional railroads. Therefore, their characteristics are different than other railroads. The degree of economies of density for the local and regional railroads was 1.4387 at the point of means. However, when using the dummy interaction terms for

revenue ton miles and quality of track, the degree of economies of density is 2.7231 at the point of means for switching and terminals. Switching and terminal railroads can increase traffic by 2.7231 percent, however, their cost will only increase by 1 percent. This demonstrates that switching and terminal railroads can achieve substantial average cost savings by increasing density on their existing line, more than the regional or local line hauls.

Improvements in size also are beneficial for switching and terminal railroads. Using the same procedure as used for the local line hauls and regionals, we find that the degree of economies of size is 7.9288 at the point of means. This demonstrates that increasing the size of the railroad has substantial benefits for the switching and terminal railroads. Switching and terminals can become more cost effective by increasing their density and size. Tables 5 and 6 are set up in a similar manner to the tables used with the regional and local line hauls. Tables 5 and 6 demonstrate the degree of economies of density and size for switching and terminals, and have similar characteristics to those of the tables for the regional and local line hauls. The degrees of economies of density and size demonstrate that switching and terminals have more to benefit by increasing density and size than local line hauls and regionals. Again, it can be seen that size does make a substantial difference and the use of track helps switching and terminals to be more cost effective.

Table 5. Economies of Density for Switching and Terminal Allowing Revenue Ton Miles to Vary

Revenue Ton Mile	Density value
42,411	6.463038
100,000	5.649972
250,000	4.980642
500,000	4.571006
1,000,000	4.223631
2,500,000	3.838059
5,000,000	3.590132
10,000,000	3.372293
25,000,000	3.121883
50,000,000	2.955848
100,000,000	2.806582
500,000,000	2.512036
1,000,000,000	2.403405
2,000,000,000	2.303780
2,796,059,709	2.258525

Table 6. Economies of Size for Switching and Terminal Railroads Allowing Revenue Ton Miles and Miles of Road to Vary

Revenue Ton Miles =10,000,000
Average Length of Haul Utilizing 60 Percent of Miles of Road

Average Length of Haul	Miles of Road	Returns to size
3	5	92.28002
6	10	6.78289
12	20	3.65714
24	40	2.50347
30	50	2.27267
60	100	1.76672

Revenue Ton Miles =10,000,000
Average Length of Haul Utilizing 80 Percent of Miles of Road

4	5	8.18075
8	10	4.02826
16	20	2.67198
32	40	1.99895
40	50	1.84901
80	100	1.49962

SUMMARY AND CONCLUSIONS

Rural communities can be greatly affected by the loss of rail service to their area. This loss of service takes away one of the shipping options available to shippers. Railroads abandon track for several reasons, most notably because the section of track just is not profitable. Short line railroads offer an alternative to the abandonment of a section of track. Short lines often provide service to communities where service would otherwise be non-existent. If short lines are an alternative to abandonment and can be cost effective, they will allow shippers in many communities more options when transporting products.

Many authors have studied cost structure of the short-line railroad industry. Most agreed there were economies of density in the short-line rail industry, but these economies varied in degree. Economies of size varied widely among the authors. Some authors found economies of size, while others did not. The data used in these models also varied. Some authors used financial data, some used actual data, and others used hypothetical data. This study improves upon previous methods by using a database of actual observations from the short lines themselves. This database is compiled by the American Short Line Railroad Association and the Upper Great Plains Transportation Institute. These observations possibly could be the best database for the use of studying the short-line rail industry.

The translog regression function also improved on results of the previous studies. As many authors have pointed out, the translog regression function offers superior results when compared to conventional linear or simple non-linear regression. It gives an accurate representation of variable costs with a fairly high degree of confidence. Prior to this study, the translog function had not been used to study cost structure of the short lines, and may offer improvements on understanding of cost structure of the industry.

The results indicate that short lines have much to gain by increasing density on their railroads. Economies of density were present for the short-line industry and were present for various increases in output. This shows that short lines currently are not at constant or diseconomies of scale. As the railroad increases traffic, there still are economies to be exploited. Increases in density can assist short lines in decreasing average costs.

Economies of size also were significant. For most short lines it can be reasonably assumed that an increase in miles of road will result in an equal or similar increase in average length of haul. Average length of haul is a key output index for the short line industry. By increasing average length of haul, a short line can spread its costs over a greater distance. Therefore, assuming that increases in miles of road cause similar increases in average length of haul, there is much for the short lines to gain by increasing miles of road. Also in this manner, short lines have much to gain by utilizing their track more fully.

The economies of size and density show that there are improvements short lines can make to improve cost structure. This information helps us to realize that short lines can be more cost effective if their densities are improved. If short lines are better able to draw more traffic, their cost structure will improve, thus making them more viable. Size also plays a key role. If short lines increase their network size, they will most likely see substantial benefits.

From the results of the model, there are strong indications that short lines can make substantial improvements to their performance. The tables in Chapter 6 illustrated that as railroads increase in size and density, they are getting closer to constant returns to scale. This demonstrates that the smallest railroads will see a more substantial cost savings than

those of the larger railroads. This can be explained because of the quasi-fixed investments such as track and structures, overhead, and small train size. The costs associated with these factors must be assumed by the railroad no matter how large or small the railroad is. However, there still are substantial savings for the larger railroads.

In many cases, an increase in miles of road may be difficult for a short line to accomplish. Many short lines are using a section of track formally owned by a Class I railroad. Short lines for the most part are utilizing this track from one end to the other, and the only feasible increases could be accomplished by laying down new rail themselves. Building new rail operations from scratch is an investment that most short lines would find difficult to afford. Therefore, even though it would be difficult to increase density on the existing railroad, this might be easier to accomplish than attempting to increase the size of the rail network. However, it should be noted that the results from this study indicated that future sales should be configured so that longer short lines are formed.

REFERENCES

American Short Line Railroad Association and the Upper Great Plains Transportation Institute. 1995 Annual Data Profile of the American Short Line & Regional Railroad Industry. North Dakota State University, 1995.

Association of American Railroads, Economics and Finance Department. Railroad Ten-Year Trends, 1999-1997. Washington, D.C., 1998.

Babcock, Michael W., Marvin Prater, John Morrill, and Eugene R. Russell. "Short-Line Railroads Performance." Transportation Quarterly, 49. 2, (1995): 73-86.

Babcock, Michael W., Marvin Prater, and Eugene Russell. "Long-Term Profitability of Grain Dependent Short Line Railroads in the Midwest." Kansas Department of Transportation Report No. KSU-96-9, August 1997.

Bitzan, John D. "The Structure of Railroad Costs and the Benefits/Costs of Mergers." Research in Transportation Economics, 5 (1999): 1-52.

Borts, George H. "The Estimation of Rail Cost Functions" Econometerica: Journal of the Econometric. 28 (1960): 108-131.

Braeutigam, RR, AF Daughety, and MA Turniquist. "A Firm Specific Analysis of Economies of Density in the U.S. Railroad Industry." The Journal of Industrial Economics. 32. 1, (1984): 3-20.

Cave, Douglas W., Laurits R. Christensen, and Michael W. Trethway. "Flexible Cost Functions for Multiproduct Firms." Review of Economics and Statistics. 62. 3, (1980): 477-81.

Dooley, Frank J. "Economies of Size and Density for Short Line Railroads." MPC Report No. 91-2, Upper Great Plains Transportation Institute. North Dakota State University, April 1991.

Due, John F., and Carrie Meyer. "Success and Failure of Newly Formed Railroad Companies." Prepared for the United States Department of Transportation. Washington, D.C., 1988.

Friendlaender, Ann, and Richard Spady. Freight Transport Regulation: Equity, Efficiency, and Competition in the Rail and Trucking Industries. Cambridge, MA: MIT Press, 1981.

Grimm, C.M. and H.J. Sapienza. "Determinants of Shortline Railroad Performance." _ Transportation Journal 32 (1993): 5-13.

Harris, RG. "Economies of Traffic Density in the Rail Freight Industry." Bell Journal of Economics 8. 2, (1977): 556-564.

Harris, R.G., and T.E. Keeler, "Determinants of Railroad Profitability: An Econometric Study." Economic Regulation: Essays in Honor of James R Nelson. East Lansing, MI: Michigan State University, 1981. 37-53.

Hirschey, M.J. "Service Estimation of Cost Elasticities for Light Density Railroad Freight." Land Economics 55. 3, (1979): 366-378.

Jehle, Geoffrey A. Advanced Microeconomic Theory. Englewood Cliffs, NJ: Prentice Hall, 1991.

Keaton, MH. "Economies of Density and Service Levels on U.S. Railroads: An Experimental Analysis." Logistics and Transportation Review. 26. 3, (1990): 211-227.

Keeler, Theodore. "Railroad Costs, Returns to Scale, and Excess Capacity." Review of Economics and Statistics 56. (1974): 201-208.

Nganje, William and Michael Mazzocco. "Economic Efficiency Analysis of HACCP in the U.S. Red Meat Industry." The Economics fo HACCP: Costs and Benefits. Ed. Laurian J Unnevehr. St. Paul, MN: Eagan Press, 2000. 241-265.

Ray, S.C. "A Translog Cost Function Analysis of U.S. Agriculture, 1939-77." American Journal Agricultural Economics. 64 (1982): 490-498.

Resor, RR, and ME Smith. "Track Maintenance Costs and Economies of Density: An Analysis of the Speed Factored Gross Tonnage Model." Journal of the Transportation Research Forum, 33. 1, (1993): 24-41.

Sidhu, Nancy D., Alberta H. Charney, and John F. Due. "Cost Functions of Class II Railroads and the Viability of Light Traffic Density Railway Lines." Quarterly Review of Economics and Business. 17. 3, (1977): 7-24.

United States Railway Association. Viability of Light-Density Rail Lines: The United States Railway Association's Analytic Policies and Procedures. Washington: 1976.

Varian, Hal R. Microeconomic Analysis. New York: W.W. Norton & Company, 1984.

Wilson, W.W., and E.W.Tyrchniewicz. "A Conceptual Framework for Financing Rail Branch Line Operation and Rehabilitation." World Conference on Transport Research. Vol. 2. (1980): 743-756.

Wolfe, K. Eric. "Long-Run Financial and Demographic Differences Between Failed and Successful Local and Regional Railroads." Journal of the Transportation Research Forum. 28. 3, (1989): 13-23.

Wolfe, K. Eric. "The Downside Risk: An Analysis of Local and Regional Railroad Service Failures." Journal of the Transportation Research Forum, 29. 1, (1988): 124-137.

Wolfe, K. Eric. "Financial and Demographic Conditions Associated With Local and Regional Railroad Service Failures." Transportation Quarterly 43. 1, (1989): 3-28.