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ECONOMIES OF SIZE AND DENSITY FOR SHORT LINE RAILROADS

by

Dr. Frank J. Dooley

Upper Great Plains Transportation Institute
North Dakota State University
P.O. Box 5074
Fargo, North Dakota 58105

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16. Abstract

The overall objective was to determine the extent that economies of size and density are available to short line railroads. Size economies are limited for short line railroads. For example, doubling the size of the network (from 56 to 129 miles) decreases costs by only 6.9 percent. The elasticity of total cost with respect to size was between 0.60 and 0.80. This is consistent with the findings for Class I carriers.

Increasing traffic density offers significant opportunities for lowering costs. An increase in the traffic density from 20 to 30 cars per mile lowers average total costs by 30 percent. The elasticity of total cost with respect to density was 0.16. Thus, the concern with new short lines should be with the traffic density, not the size of the network.

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Preface

This report describes a study completed at Upper Great Plains Transportation Institute, North Dakota State University that analyzes the extent that economies of size and density are available to short line railroads. The objectives of this study were to:

1. To provide additional information about the reasons for and the nature of the evolution of the short line railroad industry;
2. To examine and further develop the theoretical framework of cost for the short line railroad industry;
3. To develop theoretically consistent estimates of short line costs using a short line simulation costing model; and
4. To provide guidelines to assist the rail industry, rail labor, and state and federal policy-makers adjust to the changing structure of the rail industry.

Size economies are limited for short line railroads. For example, doubling the size of the network (from 56 to 129 miles) decreases costs by only 6.9 percent. The elasticity of total cost with respect to size was between 0.60 and 0.80. This is consistent with the findings for Class I carriers.

However, increasing traffic density offers significant opportunities for lowering costs. Increasing the traffic density from 20 to 30 cars per mile lowers average total costs by 30 percent. The elasticity of total cost with respect to density was 0.16. Thus, the concern with new short lines should be with the traffic density, not the size of the network.

Dr. Frank J. Dooley
Upper Great Plains Transportation Institute
North Dakota State University

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INTRODUCTION

by

Dr. Frank J. Dooley*

PROBLEM STATEMENT

Short line railroads have increasingly become an important component of the U.S. transportation system. "By acquiring and operating light density lines that no longer fit the economics of the large carriers, small railroads have preserved service on lines which would likely have been abandoned and torn from the ground a decade ago" (U.S. Department of Transportation 1989a, hereafter cited as U.S. DOT).

A fundamental understanding of the short line rail industry is a prerequisite to the development of both sound business decisions and public policies. A considerable literature about short lines has developed over the past decade in the trade and academic journals. Most of this work focuses upon management strategies for successful short lines or describes characteristics of short lines.

Much of the available information about short lines was first developed by Professor John Due. In a broad work, he summarized "the experiences and attempts to ascertain the primary determinants of success" for short line railroads (Due). Due identified seven factors associated with a successful short line railroad. They are: 1) competent management, 2) shipper support, 3) adequate quality of track, 4) adequate traffic, 5) access to more than one connecting carrier, 6) adequate capital, and 7) state or

*Dooley is a Research Assistant at the Upper Great Plains Transportation Institute, North Dakota State University, P.O. Box 5074, Fargo, ND, 58105, (701) 237-7767, fax (701) 241-1945.

local government assistance. More recently, in a report to Congress, the Federal Railroad Administration (FRA) of the U.S. Department of Transportation (U.S. DOT) attributed the success of short lines to two factors.

> First, by offering service and rates tailored to the needs of these identified local shippers, small railroads are able to compete for local traffic more effectively than major carriers managing thousands of miles of line. Second, small railroads by their nature have a more flexible cost structure than their larger predecessors (U.S. DOT 1989a).

Due also provided information about many other aspects of short line operations, including ownership patterns, traffic patterns, carloads per mile of track, and productivity. Rockey, the FRA report to Congress, and Dooley (1990) provided similar, more recent information.

Due suggested six reasons that short lines might fail. Counterpart to the reasons for success, they are: 1) inadequate traffic, 2) physical problems with bridges, tunnels, or track, 3) management problems, 4) lack of shipper support, 5) lack of capital, and 6) poor rate divisions. Wolfe addressed the reasons for failure in greater detail (1988). Wolfe first noted that the success rate for the short line industry was comparable to that for all businesses. His analysis determined that failures are "due to a variety and combination of managerial, economic and financial reasons -- none of which dominates the list" (Wolfe 1988).[1]

As noted by the U.S. DOT, a more flexible cost structure is an important reason for the success of short lines. The three major sources of cost savings are labor, equipment, and maintenance of way (MOW).[2] Short line labor costs are lower because of more

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[1]Other work by Wolfe details a method for accessing the viability of short lines. See Wolfe, *Transportation Quarterly,* 42(1):3-28, (1989) and Wolfe, *Transportation Journal* 28(3):13-24 (1989).

[2]The sources of cost savings are addressed in greater detail in Chapter 2.

flexible work rules, smaller crew consists, and lower wage and benefit rates. Power costs are lower because short lines operate smaller locomotives. In addition, the short lines almost exclusively rely on less expensive used locomotives. Finally, short lines maintenance of way cost is 20 percent less than the former Class I railroads.

The information base on particular elements of short line costs is developing. However, there is little information available about the relationship between costs and outputs for short lines. Information on economies of size and density of railroads is used by both the public and private sectors. Rail management and shippers use such information to make management decisions regarding expansion, pricing, location, rail operations, etc. Public sector parties use such information to formulate public policy on issues such as rail mergers and maximum price policies.

There is general agreement about the extent of economies of density and size for Class I railroads. The lack of comparable information for short line railroads has hindered both the private and public sector's ability to make informed judgments and decisions regarding the relatively new economic phenomena of short line railroads.

RESEARCH OBJECTIVES

The general purpose of this study is to determine the extent that economies of size and density are available to short line railroads. To achieve this purpose, the specific objectives of this study are:

1. To expand upon the work of Due and others, providing additional information about the reasons for and the nature of the evolution of the short line railroad industry;

2. To examine and further develop the theoretical framework of cost for the short line railroad industry;

3. To develop theoretically consistent estimates of short line costs using a short line simulation costing model;

4. To provide guidelines to assist the rail industry, rail labor, and state and federal policy-makers adjust to the changing structure of the rail industry.

RESEARCH METHOD

Information required to evaluate economies of density and size in the short line industry was developed from various secondary sources. The exploratory phase of the research included informal discussions with individuals from short line and Class I railroads and a cursory literature review. Once the study objectives were defined, a comprehensive literature review of the short line railroad industry and economic costing theory was conducted. From this information, modifications to the North Dakota Short Line costing model were made. The simulation costing model was then used to analyze the short line railroad cost structure.

Class II and Class III railroads have not been required to file financial or operating reports with the Interstate Commerce Commission (ICC) since 1980. Thus, the rich data available for Class I carriers are not available for short lines.

An important secondary source of data is a data base complied by the Association of American Railroads (AAR). Entitled *Profiles of U.S. Railroads* (or *Profiles*), it includes basic operating data for short line railroads. Data contained in *Profiles* are year of creation, miles of road, number of employees, revenue range, type of railroad, ownership, carloads, and major commodities hauled. The 1988 edition of *Profiles*, containing information on 484 short lines, was employed in this analysis.

DEFINITIONS

"There is no clear definition of a new short line railroad. It can consist of as little as 1 mile of track to as much as several hundred." (Evans). Before proceedings, key terms and definitions are provided. The AAR segments short lines into regional, local, and switching and terminal railroads. A regional railroad is defined to be a non-Class I, line-haul, freight railroad which operates at least 350 miles of road and/or earns at least 40 million dollars in revenue. A local railroad is defined to be a freight railroad which operates less than 350 miles of road and earns less than 40 million dollars. A switching and terminal railroad is a railroad that is not a linehaul carrier. In this paper, the term "short line" is broadly defined to include regional, local, and switching and terminal railroads. A linehaul short line excludes switching and terminal railroads.

Many associate the creation of new short lines (and rail deregulation in general) with the passage of the Staggers Rail Act in 1980. However, 1970 is selected as the demarcation point for comparisons because events during the early 1970s led to the first spinoffs of short lines by Class I carriers.

REPORT ORGANIZATION

The remainder of this report is organized in five chapters. Background information about the short line industry is presented in Chapter 2. A review of the literature on economic costing theory is found in the following chapter. In Chapter 4, the simulation costing model is detailed. The empirical results of the analysis are presented in Chapter 5. The report concludes with a summary and conclusions in Chapter 6.

CHAPTER 2

THE SHORT LINE RAIL INDUSTRY

Short line railroads have increasingly become an important component of the U.S. transportation system. A fundamental understanding of the growth of the short line rail industry is a prerequisite to the development of an economic model. The focus of this chapter is upon three aspects of the short line industry. First, factors underlying the development of short lines are reviewed. Second, characteristics of short lines are presented. Finally, important differences in the cost structure of Class I and short line railroads are identified.

DEVELOPMENT OF SHORT LINES

The Transportation Act of 1920 called upon the ICC to create a plan for consolidation of the nation's railroads into nineteen systems (Thoms, Dooley, and Tolliver). However, the ICC feared the effect on rail employment of closing switching yards. In addition, profitable railroads opposed the consolidation plans because of proposals that they be consolidated with unprofitable railroads (Keeler 1983). Although the Commission gradually backed away from the Transportation Act's consolidation mandate, the period between 1920 and 1970 is characterized as a period of decline for short line railroads. The number of short lines fell from 1009 in 1916 to 238 in 1979 (Levine et al., 1982).

The role of short lines shifted during the 1970s. "New small railroad companies were formed to take over many light density rail lines that until that time had been operated as parts of Class I rail systems" (U.S. DOT 1989a). Three events are tied to this change. First, legislation establishing Conrail in 1973 "provided the initial stimulus for the formation of new railroads" (U.S. DOT 1989a). Second, the reorganization of the Milwaukee Road and the liquidation of the Rock Island created additional opportunities for short line creation. Finally, federal railroad deregulation legislation led to new opportunities for short lines creation. The 3-R Act of 1973, the 4-R Act of 1976, and the Local Rail Service Assistance Act of 1978 all included provisions that provided operational subsidies and rehabilitation funds for light density branch lines (Levine et al., 1982). The Staggers Rail Act of 1980 created new options for communities and shippers to purchase or support rail lines identified as candidates for abandonment by Class I carriers (Keeler 1983).

Most present large Class I carriers evolved through Interstate Commerce Commission (ICC) approved mergers since the late 1950s (Keeler 1983). For example, mergers led to the present Burlington Northern, CSX, Norfolk Southern, Union Pacific, Southern Pacific, and Santa Fe. The railroad merger movement since the late 1950s left the country with the largest Class I railroad systems in history. During the past decade, however, the systems of Class I railroads as an industry have been contracting.

With deregulation in the late 1970s, Class I railroads aggressively reduced their systems. In 1978, Class I railroads owned 177,710 miles of road (Assn. of American Railroads or AAR). By 1987, the miles of road owned by Class I carriers had fallen by 25.6 percent to 132,220 miles (AAR). The downsizing of Class I railroads has been accomplished primarily via abandonment and short line sales.

Abandonment

Lines being considered for abandonment tend to be either unprofitable or only marginally profitable for their owners (Mielke). Historically, shippers and states have vigorously resisted rail line abandonment. The 4-R Act and the Staggers Act eased the abandonment process, imposing stringent time deadlines on the ICC for the disposition of abandonment cases (Keeler 1983). For example, unopposed abandonment applications must be approved by the ICC within 30 days. From 1970 to 1988, the ICC granted certificates of abandonment for 39,993 miles of road (Table 2.1).

Almost 20,000 miles of track were abandoned during the 1970s. Since 1980, 20,222 miles of track have been abandoned. During the 1970s, six percent of the track filed for abandonment was restored via short line sales or rehabilitation (Wolfe 1988b). According to Wolfe, 74 percent of the track filed for abandonment during the 1980s remains in service because of rehabilitation programs and short line sales. Thus, while the level of abandonment has remained high, short line sales have lessened the effect of abandonment.

A few lines were taken over by states, which then proceeded to find a designated operator to run them. Twenty-six states have set up rail authorities to purchase otherwise abandoned railroads (Levine et al.). Most states have found designated operators for the service, although New York and West Virginia have also operated railroads (Dempsey and Thoms).

Short Line Sales

Abandonment has been the traditional means of disposing of excess lines. More recently, Class I railroads have also been downsizing by selling or leasing lines to short line operators. During the 1970s, 2,526 miles of road were sold to 44 short line operators (Table 2.1). Over 18,000 miles of road were sold to 196 short lines in the 1980s. Compared with the 1970s, there was a 630 percent increase in miles of track sold and a 346 percent increase in the number of short lines created from 1980 to 1988.

TABLE 2.1. Miles of Road Abandoned and Miles of Short Line Created, 1970-1988

Year	Miles of Road Abandoned	Short Lines Created	
		Miles of Road	Number
1970	1,782	2	1
1971	1,287	53	2
1972	3,458	66	3
1973	2,428	414	4
1974	529	14	1
1975	708	242	1
1976	1,789	183	8
1977	2,500	900	8
1978	2,417	368	8
1979	2,873	284	8
1980	2,321	1,578	12
1981	1,342	587	10
1982	5,151	1,470	24
1983	2,454	341	15
1984	3,083	1,506	26
1985	2,343	2,620	27
1986	1,417	3,551	31
1987	818[a]	6,674	46
1988	1,293[a]	104	5
1970's TOTAL	19,771	2,526	44
1980's TOTAL	20,222	18,431	196
1970-88 TOTAL	39,993	20,987	240

SOURCE: Levine et al., *Statistics of Regional and Local Railroads*, Assn. of American Railroads, pp. 49, 51 (1988).

[a]Interstate Commerce Commission, *ICC88 - Interstate Commerce Commission 1988 Annual Report*, Washington, D.C., 1989.

Two different strategies motivate the sale or leasing of rail lines (Mielke). Some sales involve the divestment of rail interests. In particular, these companies divest or pare down their systems by selling light density branch lines. Other railroads use short line sales to establish low-cost feeder systems. In part, Class I's prefer the short line alternative because the property can be sold in its entirety. By doing so, the seller avoids the associated salvage costs and expense of selling land parcel by parcel (Mielke).

Divestiture may be either forced or voluntary. The liquidation sales of the Rock Island and the Milwaukee Road are examples of forced divestitures. Although these carriers were bankrupt, certain line segments within their systems remained profitable. The Rock Island and Milwaukee Road sold 2,028 and 848 miles of road, respectively, to short line operators (Mielke).

The Illinois Central Gulf (ICG) is perhaps the most active carrier voluntarily divesting lines (Rockey). After having absorbed the parallel Gulf, Mobile & Ohio, the ICG then either abandoned lines or turned them over to twenty short lines (Table 2.2). The ICG line sales involved high density and presumably profitable track. These sales were not motivated by abandonment or bankruptcy. The ICG's goal was to streamline its system, creating a core system of lines between Chicago and New Orleans, thereby making the system an attractive acquisition (Mielke).[1]

Most railroads sell off lines for reasons other than divesture. These railroads are attempting to establish low-cost feeder lines. Feeder line sales are motivated by three reasons:

1. a desire to eliminate the burdens of ownership (high operating and maintenance costs, etc.);

2. an expectation to recover some economic value from the line (sales price); and

3. a desire to preserve the benefits associated with ownership (access to traffic originated or terminated on the lines) (Mielke).

[1]Apparently, the divestment strategy has been successful. In March 1989, ICG was sold to Prospect Group, Inc., and its name changed to Illinois Central Transportation Co. (Abbott, 1989).

TABLE 2.2. Miles of Road and Number of Short Lines Spunoff by Class I Railroads, 1971 to 1988

Class I Carrier	Number of Short Line Sales	Miles of Track Sold	Average Sale Size (in miles)
Atchison, Topeka, and Sante Fe	2	153	76.5
Burlington Northern	14	3,919	279.9
Chicago & North Western	4	1,155	288.8
ConRail	53	2,689	50.7
CSX Transportation	42	2,033	48.4
Grand Trunk Western	3	239	79.7
Guilford Transportation Co.	8	725	90.6
Illinois Central Gulf	20	3,995	200.0
Missouri-Kansas-Texas	1	2	2.0
Norfolk Southern	5	366	73.2
Pittsburgh & Lake Erie	1	32	32.0
Soo Line	13	3,469	266.8
Southern Pacific	6	560	93.3
Union Pacific	6	231	38.5
TOTAL	166	17,345	104.5

NOTE: Summing the column values for the number of short lines created and the miles of track do not equal the total because some of the new short lines were created from lines owned by more than one Class I railroad.

SOURCE: Levine et al., *Statistics of Regional and Local Railroads*, Association of American Railroads, pp. 53-57 (1988).

Similar to divestiture related sales, feeder arrangement sales and leasing arrangements are motivated by the seller's goal to maximize the economic return from the property. However, feeder line sales seek to maximize the economic return on a long-term basis rather than strictly through a one-time influx of cash as with divestiture. Thus, with feeder line sales, the seller usually will be more concerned with the short line's ability to generate and interchange traffic than it is with the selling price.

Besides the ICG, the most active railroads in short line spinoffs are the Burlington Northern, Soo Line, Conrail, and CSX (Table 2.2). Between 1986 and 1988, BN sold 2,844 miles of track to eight different entities. "All these sales were designed to feed and enhance BN's remaining rail operation." (Mielke). Over 56 percent of the track sold by the Soo Line (1,969 miles) was spunoff in one sale. The sale by the Soo Line creating the Wisconsin Central is the largest short line sale to date. All of the Soo Line sales involved former Milwaukee Road property. Conrail and CSX have spunoff the most short lines, 53 and 42, respectively. The average size of short lines spunoff by the Eastern carriers are much smaller than those sold by Western carriers (Table 2.2). The average size of short lines sold by Conrail or the CSX is approximately 50 miles. In contrast, the typical short line sale by the BN, Soo Line, and C&NW are all over 200 miles.

The number of short lines created and miles of track sold steadily increased from 1970 to 1987 (Table 2.1). In late 1987, short line sales activity almost ceased as a result of successful legal challenges raised by rail labor unions. The unions argued that a railroad had a duty to bargain the effect of a short line sale with its employees. The issue eventually reached the Supreme Court. In *Pittsburgh and Lake Erie Railroad v. Railway Labor Executives' Association,* the Supreme Court reversed, holding that labor protection is not required in short line sales.[2]

While uncertainty remains over labor protection and short line sales, sales activity has resumed. To overcome concerns with short line sales, more railroads are leasing lines to short line operators. Unverified data published in *The Short Line* stated there were a

[2]For greater detail, see Thoms, Dooley, and Tolliver.

total of 26 new short lines created in 1988 and 45 created in 1989 (McDonald). Of the 45 new short lines in 1989, 34 are new railroads. The other 11 railroads are existing short lines adding more lines. Fourteen of the new short lines were leased by the Norfolk Southern and 10 were spunoff by the CSX. Seven other Class I carriers, including the Union Pacific, Santa Fe, CNW, ConRail, B&M, and the CN, spunoff a total of a total of 15 lines. Six short lines were taken over by other short lines.

In 1989, ten major Class I railroads were surveyed to determine how many additional miles of track they plan to transfer to new short line operators over the next five years (U.S. DOT 1989a). Seven of the ten responded, reporting plans to transfer 17,265 miles of track to new short lines (Table 2.3). This would increase the total short line mileage by approximately 60 percent. If the carriers follow their plans, the number of short lines in western United States would sharply increase. Through mid-1988, the Sante Fe and Union Pacific had sold only 484 miles of track to eight short lines (Table 2.2). In the next five years, they plan to spinoff over 9,700 miles of track (Table 2.3).

A spinoff not only preserves rail service, but may actually improve it. The new owners are local or regional entrepreneurs who are more responsive to on-line shippers. They can provide a level of service which the former Class I carrier could not match. A survey by the ICC and Federal Railroad Administration found "a clear pattern of shipper satisfaction with both service and rates offered by the shortlines and regional railroads created after the enactment of the Staggers Act" (U.S. DOT 1989b). Ninety-four percent of the shippers reported that service levels had been maintained or improved. Eighty-eight percent of the shippers reported that rate levels had improved or been maintained. Similar results were reported in a survey of grain shippers (see Dooley and Rodriguez). Spinoff railroads can also be important mechanisms for local and regional economic development (Bruce).

TABLE 2.3. Miles of Potential New Short Line Spinoffs by Class I Railroads

Class I Railroad	Miles of Track	Percent
Atchison, Topeka and Santa Fe	4,000	23.2
Burlington Northern	2,244	13.0
Chicago and North Western	1,797	10.4
Conrail	No Response	-
CSX Transportation Co.	2,115	12.3
Grand Trunk Western	142	0.8
Kansas City Southern	No Response	-
Norfolk Southern	1,251	7.2
Soo Line	No Response	-
Union Pacific	5,716	33.1
TOTAL	17,265	100.0

NOTE: Conrail advised that it has no plans to sell or abandon significant mileage other than the miles already shown on their System Diagram Map. The future of the Soo Line is uncertain, but short line spinoffs appear to be a likely part of a restructuring.

SOURCE: U.S. Department of Transportation, Federal Railroad Administration, *Deferred Maintenance and Delayed Capital Improvements on Class II and Class III Railroads: A Report to Congress*, p. 94, Washington, D.C., 1989.

CHARACTERISTICS OF SHORT LINE RAILROADS

In this section, various characteristics of short line railroads are presented. Because of differences by type of short line, results are reported for local, regional, and/or switching/terminal railroads.[3] To reflect changes in rail policy since 1970, results are reported for railroads created before and after 1970. Characteristics analyzed include typical firm attributes, traffic, and operating statistics. Firm attributes include number of short lines, ownership, and revenue. Traffic characteristics include principal

[3]As defined in Chapter 1, a regional railroad is one with 350 miles of track and/or revenues greater than 40 million dollars. Switching and terminal railroads identified themselves as such. All other short lines are local railroads.

commodities hauled and density. Operating statistics are provided for miles of track, employees, employees per mile, number of interchanges, length of haul, and average speed.

Typical Short Line Firm Attributes

In 1988, there were 484 short line railroads (Table 2.4). Local railroads accounted for 58.9 percent of the total short lines. Over 35 percent were switching/terminal railroads, while the other 5.6 percent were regional railroads. The number of short lines created before and after 1970 are almost identical. Of the 484 shortlines, 244 were formed before 1970 and 240 were formed in 1970 and after.

TABLE 2.4. Number of Short Line Railroads, by Period and Type of Short Line

Type of Short Line	Before 1970	1970 & After	Overall
Regional	12	15	27
Local	144	141	185
Switching/Terminal	88	84	172
All Short Lines	244	240	484

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, AAR (1988).

Most regional and local railroads (or linehaul short lines), 59.9 percent, are operated by private owners (Table 2.5). Other major owners of linehaul short lines are shippers (19.6 percent) and Class I railroads (10.3 percent). The percentage of privately owned linehaul short lines rose sharply between the two periods, rising from 47.4 to 72.4 percent (Table 2.5). The number of regional and local railroads owned by shipper groups and Class I railroads fell between the two periods. The percentage of regional and local railroads owned by shipper and Class I railroad fell 14.7 and 19.3 percentage points,

TABLE 2.5. Type of Ownership Distribution for Regional and Local Railroads, by Period

Type of Owner	Before 1970	1970 & After	Overall
	Percent		
Private	47.4	72.4	59.9
Shipper	26.9	12.2	19.9
Class I Railroad	19.9	0.6	10.3
Local/State Government	2.6	7.1	4.8
Other Shortline Railroad	0.0	5.1	2.6
Car Lessor	2.6	0.6	1.6
Other	0.6	1.9	1.3
TOTAL	100.0	99.9	100.1
Number of Railroads	156	156	312

NOTE: Total does not equal 100 percent due to rounding.

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, AAR (1988).

respectively (Table 2.5). Since 1970, there has been an increase in ownership by state and local governments and other short line railroads.

Most regional and local railroads (79.7 percent) have annual revenues under five million dollars (Table 2.6). The revenue distribution has shifted slightly between periods. Regional and local railroads created since 1970 have somewhat lower annual revenues than those created before 1970. Over 15 percent of the linehaul short lines created before 1970 have annual revenues over 10 million dollars (Table 2.6). In contrast, only 5.9 percent of the linehaul short lines created since 1970 have annual revenues over 10 million dollars.

TABLE 2.6. Annual Revenue Distribution for Regional and Local Railroads, by Period

Revenue Range	Before 1970	1970 & After	Overall
	Percent		
Under $5 million	74.2	85.3	79.7
$ 5 to 9.9 million	10.6	8.7	9.6
$10 to 19.9 million	6.0	1.3	3.7
$20 to 39.9 million	5.3	3.3	4.3
Over $ 40 million	4.0	1.3	2.7
TOTAL	100.1	99.9	99.9

NOTE: Total does not equal 100 percent due to rounding.

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, AAR (1988).

Traffic Characteristics

The AAR Profiles database includes the top three commodities hauled by short lines. By two digit Standard Transportation Commodity Code (STCC), the percentage of total carloads hauled was reported for the top three STCC groups. Most regional and local railroads are extremely dependent on three or fewer commodity groups. A single STCC group accounts for more than 80 percent of the total annual carloads for 40.5 percent of the regional and local railroads (Table 2.7). Over 78 percent of the regional and local railroads report that the top three STCC groups account for more than 80 percent of total carloads. On average, the top STCC group accounts for 66.4 percent of a linehaul short line's annual carloads (Table 2.7) The top three STCC groups are 89.1 percent of a typical linehaul short line's annual carloads.

The six major commodities hauled in 1988 were lumber/wood products, chemicals, farm products, pulp/paper products, coal, and nonmetallic minerals (Table 2.8). Over 42 percent of the linehaul short lines reported that lumber/wood products was one of their

TABLE 2.7. Percentage Distribution of Top Three STCC Groups Hauled by Local and Regional Railroads, 1988

Percent of Total Carloads Hauled	Top Ranked STCC Group	Top Two STCC Groups	Top Three STCC Groups
	Percent		
Under 20 Percent	1.4	0.0	0.0
20.1 - 40 Percent	16.5	2.7	1.0
40.1 - 60 Percent	25.7	11.8	5.1
60.1 - 80 Percent	15.9	20.6	15.5
Over 80 Percent	40.5	64.9	78.4
Mean	66.4	82.7	89.1

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, AAR (1988).

principal products (Table 2.8). Over 30 percent of the local and regional railroads reported that chemicals and farm products are one of their principal hauls. The principal commodities hauled were quite similar for linehaul short lines created before and after 1970.

Density of traffic is calculated by dividing the total carloads handled by the miles of track. Densities were calculated for regional and local railroads created before and after 1970. Densities for switching and terminal railroads are not directly comparable with linehaul railroads. "While switching and terminal railroads often handle fairly high volumes of traffic, they generally have large amounts of yard and siding as opposed to main and branch line track" (U.S. DOT 1989a). Thus, densities are not calculated for switching/terminal short lines.

"In comparison to the Class I railroads' core rail lines, the lines that are candidates for sale or transfer generally have lighter traffic density, and they have often experienced a long-term decline in traffic." (U.S. DOT 1989a). Regional and local railroads created

TABLE 2.8. Principal Commodities Hauled By Local and Regional Railroads, by Period

Commodity	Before 1970	1970 & After	Overall
	------ Percent of Linehaul Short Lines Hauling ------		
Lumber/Wood Products	42.9	37.2	40.1
Chemicals	24.4	37.8	31.1
Farm Products	17.3	42.9	30.1
Pulp/Paper Products	28.2	24.4	26.3
Coal	26.9	17.3	22.1
Nonmetallic Minerals	17.9	21.8	19.9
Food/Kindred Products	14.1	17.3	15.7
Clay/Glass/Stone	10.9	12.2	11.5
Primary Metal Products	9.6	6.4	8.0
Hazardous Materials	6.4	6.4	6.4
Waste/Scrap	5.8	5.1	5.4
Metallic Ores	6.4	3.2	4.8
Petroleum/Coal Products	5.8	3.8	4.8
Transportation Equipment	2.6	4.5	3.5
Fabricated Metal Products	1.3	1.3	1.3
Textile Mill Products	0.6	0.6	0.6
Machinery, Except Electric	0.6	0.6	0.6
Miscellaneous Mixed Shipment	0.6	0.6	0.6
Ordnance	0.6	0.0	0.3
Rubber/Miscellaneous Plastics	0.6	0.0	0.3
Furniture/Fixtures	0.0	0.6	0.3
Number of Railroads	156	156	312

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, AAR (1988).

before 1970 have higher average densities than those created since 1970. The average density for regional railroads fell 76.9 percent, from 499.9 cars per mile to 115.4 miles per car (Table 2.9). The average density for local railroads fell 75.6 percent, from 446.9 cars

TABLE 2.9. Mean Traffic Density for Regional and Local Railroads, by Period

Type of Railroad	Before 1970	1970 & After	All Short Lines	Paired T-Test
	Mean Density			
Regional	499.9	115.4	286.3	-2.25*
Local	446.9	108.9	276.0	-5.65*
Regional and Local	451.3	109.6	277.0	-6.06*

NOTE: The * denotes a statistical difference between the pre- and post 1970 means at the 95 percent level of significance.

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, AAR, (1988).

per mile to 108.9 cars per mile. A paired T-test of the means found a significant difference at the 95 percent level of confidence for linehaul short line railroads.[4]

Average density varies widely, depending upon the commodity hauled by the railroad. Pre- and post-1970 densities were calculated for the nine principal commodities hauled by linehaul short lines (Table 2.10). The density is not a commodity specific density. Rather it is the firm density for railroads hauling at least 10 percent of a specific commodity. The mean traffic density declined for all nine of the principal commodities (Table 2.10). The differences in the mean densities between linehaul short lines created pre- and post-1970 were statistically significant for all of the commodities except chemicals and clay/glass/stone.

The largest decline in absolute terms was for primary metal products. For linehaul short lines formed before 1970, the mean density for those hauling at least 10 percent primary metal products was 722.5 cars per mile (Table 2.10). For linehaul short lines created since 1970, the mean density for primary metal products fell over 602 cars

[4]See Appendix A for a description of the statistical tests employed.

TABLE 2.10. Mean Density and Percentage Change in Density for Local and Regional Railroads, by STCC, by Period

Commodity	Mean Density Before 1970	Mean Density 1970 & After	Percentage Decrease	Paired T-Test
	-------- Carloads per mile --------		-percent-	
Lumber	313.43	146.46	53.6	-1.83*
Chemicals	293.14	157.60	46.2	-1.10
Farm Products	261.69	50.87	80.6	-2.31**
Pulp and Paper	446.23	162.48	63.6	-2.28**
Coal	589.05	218.53	62.9	-3.01**
Nonmetallic	226.82	79.45	65.0	-1.96*
Food & kindred	168.10	67.79	59.7	-2.59**
Clay, glass, & stone	398.43	69.55	82.5	-1.25
Primary metal prod.	722.51	120.44	83.3	-2.97**

NOTE: The * and ** denote a statistical difference between the pre- and post 1970 means at the 90 and 95 percent level of significance, respectively.

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, AAR, (1988).

per mile, to 120.4 cars per mile. The lowest absolute density, 50.87 cars per mile, was for farm products hauled by linehaul short lines created since 1970. In relative terms, the mean density for the nine principal commodities fell by an average of 66.4 percent. The percentage decline ranged from 46.2 for chemicals to 83.3 percent for primary metal products.

Operating Statistics

Linehaul short lines created since 1970 are longer than those formed before 1970. The difference in means for miles of road is statistically significant at the 95 percent level of confidence for regional, local, and all short lines (Table 2.11). The mean miles of road increased 77.2 percent for regional railroads, from 391.3 miles to 693.6 miles. For local railroads, the mean miles of track rose from 41.6 miles to 60.6 miles, an increase of 45.8 percent. The difference in mean miles of road is not statistically different for switching/terminal railroads.

All types of short lines created since 1970 employ fewer people on average than are employed by short lines formed before 1970. The difference in means for the number of employees is statistically different at the 95 percent level of confidence level for all but regional railroads, which is significant at the 90 percent level (Table 2.11). The mean number of employees fell by 42.7 percent for regionals, 60.9 percent for local, and 92.5 percent for switching/terminal railroads. For railroads created since 1970, the typical regional and local employed 304 and 13.5 persons, respectively.

The average number of employees per mile has fallen for all types of short lines. The difference in the mean number of employees per mile for pre- and post 1970 short lines is statistically significant at the 95 percent level of confidence for all types of short lines (Table 2.11). The mean number of employees per mile fell by 78.6 percent for regional, 63.2 percent for local, and 85.2 percent for switching/terminal railroads. The mean number of employees per mile for railroads created since 1970 is 0.45, 0.39, and 0.85 for regional, local, and switching/terminal railroads,respectively. In contrast to pre-1970, the number of employees per mile for regional and local railroads is almost the same. Before 1970, the typical regional railroad employed almost twice as many employees per mile as the typical local railroad.

The change in the number of interchanges has varied by type of short line. The difference in the mean number of interchanges is only statistically significant for switching/terminal railroads (Table 2.11). The mean number of interchanges for switching/terminal railroads fell from 3.82 to 1.76. The mean number of interchanges

TABLE 2.11. Typical Characteristics of Short Line Railroads, by Period

Item/Years	Regional	Local	Switching/ Terminal	All Short Lines
Miles of Road				
Before 1970	391.33	41.57	22.80	52.00
1970 & after	693.60	60.62	23.87	87.32
Overall	559.26	51.00	23.32	69.51
Paired T-Test	2.58**	2.82**	0.22	2.54**
Employees				
Before 1970	530.58	34.54	108.21	86.50
1970 & after	304.00	13.51	8.12	31.63
Overall	404.70	24.03	61.86	59.55
Paired T-Test	-2.05*	-4.40**	-4.83**	-4.10**
Men per mile				
Before 1970	2.10	1.06	5.77	2.77
1970 & after	0.45	0.39	0.85	0.54
Overall	1.18	0.73	3.49	1.67
Paired T-Test	-2.37**	-4.48**	-5.50**	-6.22**
Interchanges				
Before 1970	7.42	2.16	3.82	3.02
1970 & after	13.07	1.87	1.76	2.53
Overall	10.56	2.01	2.81	2.77
Paired T-Test	1.57	-1.62	-4.57**	-1.41

NOTE: The * and ** denote a statistical difference between the pre- and post 1970 means at the 90 and 95 percent level of significance, respectively.

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, Assn. of American Railroads, (1988).

increased from 7.42 to 13.07 for regional railroads. There was little difference in the mean number of interchanges for local railroads.

While the mean number of interchanges has not varied significantly for pre- and post 1970 short lines, more short lines created since 1970 have only one interchange. Almost 38 percent of the short lines created before 1970 had only one interchange (Table

2.12). For short lines formed since 1970, 55.0 percent have only one interchange. Over 40 percent of the switching/terminal railroads have only one connection, suggesting that many terminal railroads have been created since 1970.

TABLE 2.12. Frequency Distribution of Number of Interchanges, by Type of Short Line, by Period

Number of Interchanges	Regional	Local	Switching/ Terminal	All Short Lines
	Percent			
Created Before 1970				
1	0.0	48.6	25.0	37.7
2-5	50.0	45.1	54.5	48.8
> 5	50.0	6.3	20.5	13.5
Number of Railroads	12	144	88	244
Created 1970 & After				
1	0.0	58.9	58.3	55.0
2-5	33.3	36.9	39.3	37.5
> 5	66.7	4.2	2.4	7.5
Number of Railroads	15	141	84	240
All Short Lines				
1	0.0	53.7	41.3	46.3
2-5	40.7	41.0	47.1	43.2
> 5	59.3	5.3	11.6	10.5
Number of Railroads	27	285	172	484

ADAPTED FROM: Levine et al., *Statistics of Regional and Local Railroads*, AAR, (1988).

The average length of haul is less than 150 miles for 44 percent of all short lines (U.S. DOT 1989a). This includes mileage traveled on other railroads as part of a joint movement. The average length of haul is 150 to 500 miles for 26 percent of the short lines, 500 to 1000 miles for 16 percent, and over 1000 miles for the remaining 8 percent. The distribution is similar for all three types of short lines.

Timetable speeds on main and branch line trackage are relatively slow for over half of the short lines surveyed by U.S. DOT (Table 2.13). The distribution of timetable speeds varies by size of short line. Over 95 percent of the short lines with less than 25 miles of track operated at speeds less than 25 miles per hour. In contrast, almost 54 percent of the short lines with more than 100 miles of track operated at speeds over 25 miles per hour.

TABLE 2.13. Distribution of Timetable Speeds for Short Line Railroads

Timetable Speed	Short Line's Total Main and Branch Line Track Milage			
	< 25 miles	25-100 miles	> 100 miles	All Short Lines
	Percent			
< 10 MPH	53.3	35.3	16.5	23.3
11-25 MPH	42.3	42.8	29.8	33.7
26-40 MPH	2.8	18.0	37.2	30.4
> 40 MPH	1.6	3.9	16.6	12.6
TOTAL	100.0	100.0	100.1	100.0
No. Railroads	139	125	55	319

ADAPTED FROM: U.S. Department of Transportation, Federal Railroad Administration, *Deferred Maintenance and Delayed Capital Improvements on Class II and Class III Railroads: A Report to Congress*, p. 30, Washington, D.C., 1989.

Slow timetable speeds are more of a potential problem for longer short lines. Shorter short lines can complete service over their lines even when they move at speeds under 25 miles per hour. However, limited timetable speeds on longer short lines implies "that the current condition of track and structures may hamper economical operations on those carriers." (U.S. DOT 1989a).

SOURCES OF COST SAVINGS

By their very nature, short lines have a more flexible cost structure than Class I railroads. In this section, information highlighting the differences between Class I and short line labor costs is provided. The three major sources of cost savings are labor, equipment, and maintenance of way.

Labor

High rail labor costs are a major reason underlying the recent growth of short lines in the United States. As a result of lower labor costs, short lines may be able to continue operating profitably over light-density rail lines when Class I's can no longer afford to. Labor costs are especially critical for light-density branch lines. In 1982, Class I rail labor costs for train crews, locomotive, freight cars, and maintenance of way were estimated to equal 49.2 percent of total operating costs on light-density lines (Tolliver and Dooley). Short line rail labor costs may be appreciably lower than Class I rail labor costs as a result of less restrictive work rules, smaller crew consists, and lower wage rates (Tolliver and Dooley).

The labor characteristics of short lines are compared to those of the Burlington Northern (BN). The BN is a good reference carrier for short line comparisons because it still operates a considerable amount of branch lines. In addition, BN is one of the carriers aggressively attempting to sell portions of its light-density lines.

Tolliver and Dooley collected primary data from 48 short line railroads. In addition to various railroad characteristics, information was obtained about employment levels, job classifications, wage rates, and benefit packages. Similar information for the Burlington Northern was obtained from R-1 annual reports.

Job Classifications and Work Rules

There are four major differences between short lines and Class I carriers in the areas of rail labor work rules and job classifications. The first difference is the scale of the work force. Second, is the number of job classifications. Third, is the distribution of employees among the classifications. Fourth, is the utilization of job classifications, particularly regarding train and engine crews.

First, the size of the labor force differs between Class I's and the typical short line. In 1987, total employment for Class I railroads (excluding Amtrak and Auto-Train) was 248,526 persons or 1.88 employees per mile of track (AAR). In comparison, the typical short line formed since 1970 had 31.6 full time workers, or 0.54 employees per mile of track (Table 2.11). Thus, when controlling for size, the typical short line railroad's per mile work force is only 29 percent of a Class I railroads.[5]

The second major difference between short line and Class I railroads is the number of job classifications. Class I railroads may have contracts with up to 19 different unions. Work rules generally segregate work duties by union, preventing employees from performing duties outside their classification (Dooley and Tolliver).

The number of job classifications for short lines is difficult to determine. Most short lines do not distinguish between job classifications. As a result, a direct comparison between job classifications for short line railroads and Class I railroads cannot be made. However, short line operators reported that they group their employees among eight general job classifications (Dooley and Tolliver).

Class I railroads obviously have employees from all job classifications. None of the short lines, however, had employees in all the job classifications. The three most common

[5]In addition to size, the scale of the work force is related to the density of traffic, the presence of powerful labor organizations, and other variables.

job classifications reported by short line railroads were train crews (95.0 percent), administration (82.5 percent), and maintenance of way (57.5 percent) (Table 2.14). No other job classification was reported by more than 40 percent of the short lines.

TABLE 2.14. Short Line Employment by Job Classifications, 1987

Employee Classification	Percent of Short Lines Reporting	Mean Number of Employees on a Short Line
Train Crew	95.0	4.4
Administration	82.5	2.2
Maintenance of Way	57.5	6.6
Mechanical	40.0	3.4
Clerks & Freight Handlers	35.0	2.6
Communications & Signals	27.5	1.2
Yard Crew	15.0	4.0
Shop Crafts	10.0	2.0

SOURCE: Dooley, F.J. and D.D. Tolliver, *A Comparison of Short Line and Class I Labor Costs in North Dakota*, UGPTI Report No. 73, p. 10, Upper Great Plains Transp. Inst., North Dakota State Univ., Fargo, 1989.

The third major difference between short line and Class I rail labor is the distribution of employees among job classifications. While short line and BN job classifications are not directly comparable, several broad categories do match-up. The major difference in the distribution of employees concerns the category of train and engine crews. At the close of 1986, Burlington Northern's train and engine crew work force comprised 34.0 percent of all BN workers (Table 2.15). In comparison, the typical short line classified almost 53 percent of its workers as train and engine crew employees.

Utilization of job classifications is the final difference between short line and Class I railroads. Short lines can succeed with fewer job classifications for three reasons. First,

TABLE 2.15. Distribution of Employees in Major Rail Job Classifications, in Percent

Job Classification	Burlington Northern	Typical Short Line
	Percent	
Train & Engine Crews[1]	34.0	52.6
Maintenance of Way	22.5	20.9
Executive/Professional/Administrative	20.3	15.8
Maintenance of Equipment	17.8	5.4
All Other	5.4	5.3
TOTAL	100.0	100.0

[1]Includes both road train and yard crews.

SOURCE: Dooley, F.J. and D.D. Tolliver, *A Comparison of Short Line and Class I Labor Costs in North Dakota*, UGPTI Report No. 73, p. 11, Upper Great Plains Transp. Inst., North Dakota State Univ., Fargo, 1989.

employees perform more than one type of duty. Second, short lines contract out some of the less routine work. Finally, strict Class I work rules are relaxed on short lines.

First, short line job classifications are somewhat misleading because employees typically do several types of work. For example, it is not unusual for a short line employee to operate a train, repair track, and make sales calls. Owners and employees may both benefit from the less structured system of job classifications. Many short line owners feel that the lack of strict job classifications led to operational flexibility and large cost savings (Dooley and Tolliver). According to the owners, the employees also benefitted by being encouraged to perform a variety of tasks. The owners feel that employees are more satisfied with their work because their jobs are less tedious and more interesting. This observation has not been corroborated by short line employees.

Second, short lines are able to decrease the number of job classifications by contracting some types of work out to other firms. The types of work most frequently contracted are track maintenance (60.4 percent), car and engine repairs (52.4 percent), and equipment repairs (35.4 percent) (Dooley and Tolliver). This is consistent with the low percentage of short lines reporting employees for these types of job classifications. Contracting out may also allow the short line to avoid the associated fixed costs for items such as track maintenance and repair equipment or car and locomotive shops. Approximately eight percent of the short lines contracted administrative/clerical services and 6.3 percent contracted communications (Dooley and Tolliver).

Finally, most Class I railroads feel that antiquated work rules restrict their operations (Gohmann). Although progress has been made in recent months, many trains continue to operate with four or even five man crews. Train crews continue to include firemen and brakemen although trains are diesel powered and often do not pull cabooses. In contrast, the average crew consist on a short line is only 2.13 workers.

Wages and Benefits

Three major differences exist between the wages and benefits for short line and Class I employees. First, the absolute wage scale is much lower for short line than BN employees. Second, the method of payment for the two types of employees differs. Finally, benefit packages are less attractive for short line employees.

First, short line hourly wage scales are much lower than comparable Burlington Northern (BN) wage scales. Average hourly wage rates for short line labor range between 8.85 to 13.01 dollars per hour (Table 2.16). Hourly wage rates for similar job classification on the BN were calculated from ICC Wage Forms A and B. On average, BN labor receives between 17.00 to 25.00 dollars per hour. Expressed as a ratio, the typical BN hourly wage rate is between 152 and 247 percent as much as the typical short line employee (Table 2.16).

TABLE 2.16. Short Line and BN Hourly Wage Rates and Wage Rate Ratio, by Job Classification, 1987

Employee Classification	Burlington Northern[1]	Typical Short Line	Wage Rate Ratio
	---- Average Hourly Wage Rates ----		--- Percent ---
Train Crew[1]	$25.00	$10.10	247.5
Administration	19.77	13.01	152.0
Maintenance of Way	18.00	8.85	203.4
Mechanical	17.00	10.49	162.1
Yard Crew	25.00	12.06	207.3

[1]Calculated from ICC Wage Forms A and B. Wages include straight time actually worked, overtime, time paid but not worked, constructive allowances, vacations, and holidays. Service hours are actual hours worked at straight pay and overtime rates.

SOURCE: Dooley, F.J. and D.D. Tolliver, *A Comparison of Short Line and Class I Labor Costs in North Dakota*, UGPTI Report No. 73, p. 11, Upper Great Plains Transp. Inst., North Dakota State Univ., Fargo, 1989.

Second, perhaps a more important distinction between the two types of rail labor is the difference in the method of payment. Short line employees are paid on an hourly basis. Overtime is paid on the basis used in most industries, time-and-a-half. The typical work day for a short line employee is 8.26 hours (Dooley and Tolliver).

Class I rail labor's total salaries are extremely complex to calculate. Class I train and engine crews are paid on a dual basis of distance traveled and length of time on duty. Their standard work day is eight hours or a run of 108 miles. This sets a minimum flat payment for all runs, even those that require less than eight hours or 108 miles.

The calculation of overtime is also complicated as it is a function of mileage and time. Overtime payments for Class I train and engine crews may vary according to factors which influence train speed such as track condition, traffic, or geography of the area. In general, overmiles (miles run more than 108 miles per day) are paid on a flat rate per mile. Overtime is paid on an hourly basis at time-and-a-half.

The calculation of Class I train and engine crews salaries is also complicated by work rules resulting in additional compensation for several factors not related to work. Payment is received for items such as deadheading, terminal delays, and held-away-from-home terminal. The salary cost for items other than straight pay and overtime is estimated to equal 23 percent of total pay (Dooley and Tolliver).

Fringe benefits are the final major difference between short line and Class I employees. As a percentage of annual salary, the average fringe benefit package of BN employees was over twice that of short line employees. In 1986, BN's employees fringe benefits were estimated to be 35.56 percent of their total salary (Dooley and Tolliver). A comparable figure for short lines was 16.96 percent.

Class I employees have attractive comprehensive benefit plans. The fringe benefits offered to short line employees are much more limited. According to survey results, benefits vary somewhat from short line to short line with larger firms offering more benefits. The most commonly offered benefits were health insurance, railroad retirement, and dental insurance which were offered by 76.2, 57.1, and 35.7 percent of all short lines, respectively. Other fringe benefits offered by fewer short lines (between 10 and 25 percent) included life insurance, paid vacation, profit sharing, pension plans, bonuses, paid holidays, and unemployment insurance.

Equipment and Maintenance of Way

The cost structure of short line railroads is also more flexible because of equipment and maintenance of way.

> "A small railroad can maintain a less costly inventory of freight cars and locomotives, fitting that inventory to its unique traffic needs. In addition,

small operators can more closely control expenditures on each segment of rail line, maintaining the track for the specific volume and nature of local traffic rather than conforming to generalized maintenance standards common to Class I carriers. (U.S. DOT 1989a).

It is difficult to compare locomotive requirements for local and regional railroads versus Class I carriers. Each type of railroad uses different types of locomotives for their linehaul carriage. Locomotives vary in horsepower, axles, tractive effort, and other ways (Table 2.17).

TABLE 2.17. Characteristics of Locomotives Used by Local, Regional, and Class I Railroads

Locomotive	Horsepower	Axles	Weight (pounds)	Fuel Efficiency[1]
GP9	1750	4	258,000	114.6
GP38-2	2000	4	260,000	123.0
GP40-2	3000	4	270,000	163.7
SD40-2	3000	6	385,000	163.7
C40-8	4000	6	400,000	190.0

[1]Gallons per hour, assuming that the locomotive is in Run 8 (top speed)

A second difference is the cost of the power. A direct comparison is difficult to make between used and new equipment. Local and regional railroads almost exclusively purchase used locomotives. Class I railroads are more likely to purchase new or rebuilt locomotives. An additional factor complicating the locomotive cost is the associated fuel and maintenance cost. A locomotive with a higher purchase price may be cheaper to operate.

Among the types of locomotives favored by local railroads are GP7s, CF7s, and GP9s. All of these units have low horsepower, are nonturbocharged, and are simple to operate and maintain. In November 1989, a typical 'operating' GP7 or CF7 ranges in price from 65,000 to 80,000 dollars. The GP9s, which have more power, cost around 90,000 dollars for an operating unit to 150,000 dollars for a rebuilt unit.

Class I carriers have sold many of the smaller locomotives from their fleets. However, recent changes in Class I locomotive demand and purchasing practices have led Class I carriers to purchase used equipment. This has driven locomotive prices up and reduced the availability of certain units. Thus, new local railroads may find it more difficult to find power in the future.

With larger traffic levels, larger networks, and perhaps larger budgets, regional carriers have a wider range of suitable locomotives to choose from, including 6-axle units. In addition to the smaller units mentioned above, regional railroads use GP35s, GP38s, GP40s, and SD40s. Regional railroads' costs for used locomotives ranges from 85,000 to 115,000 dollars for a GP30 to 400,000 to 500,000 dollars for a GP40. A used SD40, the Class I industry standard for many years, ranges from 100,000 to 250,000 dollars. The price for a recently rebuilt SD40 is between 500,000 and 800,000 dollars. There is also a growing shortage of medium sized locomotives. A lack of medium horsepower units has caused Class I's to keep older units. In addition, Class I carriers are increasingly purchasing used medium locomotives to be remanufactured.

The Class I railroads use a variety of locomotives. For linehaul purposes, the most recent purchases by Class I's have been of high power and high tractive effort locomotives. The typical price of a SD60s, C40-8s, GP60s or B40-8s ranges from 1.1 to 1.5 million dollars.

Maintenance of way costs are also difficult to standardize, being subject to several variables. Maintenance of way costs are influenced by the type and weight of rail, average speed, track curvature, traffic density, roadbed and soil characteristics, bridges and structures, and other factors. Thus, estimates of annual normalized maintenance of way costs vary widely.

According to the U.S. DOT, the average annual maintenance of way (MOW) expense for a short line railroad is 10,236 dollars per mile (1989a). The average annual MOW expense ranged from 3,368 to 29,068 dollars per mile. The wide range in MOW cost is explained in part by the variation in traffic density and timetable speeds for short lines. In addition, the U.S. DOT estimate may include deferred maintenance cost.

Normalized maintenance of way costs were estimated using a comprehensive economic-engineering model at the Upper Great Plains Transportation Institute (UGPTI).

> "Normalized maintenance of way (NMOW) is an idealized concept or standard. It denotes the annualized sum necessary to maintain a track at some predefined level. NMOW cost may never agree with actual track expenditures during a given year. Actual expenditures are subject to budgetary constraints and management priorities. In the short-run, carriers can (and do) defer normalized maintenance. However, over a longer period of time, the cumulative effects of deferred maintenance will require rehabilitation of the line, or will lead to its abandonment. (Tolliver 1989a).

The UGPTI model considers the physical requirements and costs of ties, ballast, rail, bridges, crossings, switches, inspection, signals, spot maintenance, snow removal, vegetation removal, signing, and miscellaneous costs.

The average annual NMOW cost per mile on light density branch lines is 8,880 dollars per mile under Class I ownership (Tolliver 1989a). Under short line ownership, the NMOW cost for the same lines is 7,100 dollars per mile (Tolliver 1989a). The short line MOW cost is 20 percent less than the Class I carrier cost. The primary reason for lower short line MOW costs are lower tie installation and ballast costs as a result of lower labor costs. Short line NMOW cost savings are offset by lower rail and materials costs for Class I carriers. In addition, Class I labor is more productive as Class I carriers use more specialized, high-cost equipment.

SUMMARY AND CONCLUSIONS

Since the mid-1970s, Class I railroads have been attempting to rationalize their rail networks by either abandoning or selling their light-density branch lines. Since 1970, almost 40,000 miles of road has been abandoned. During the same time, 240 new short lines operating almost 21,000 miles of track have been created.

Short lines created since 1970 are much different from short lines created before 1970. The typical short line created since 1970 is longer, but employs fewer people than short lines formed before 1970. On average, a short line formed since 1970 is 87.3 miles long and employs 31.6 people. In contrast, the average short line formed before 1970 is only 52 miles long, but has 86.5 employees. Thus, the average number of employees per mile of track has fallen from 2.77 to 0.54, or 80.5 percent.

Compared with Class I trunk lines, most short lines operate over light density lines. In addition, short lines formed since 1970 have a much lower average traffic density than those created before 1970. The pre-1970 average density for local and regional railroads was 451.3 cars per mile. Since 1970, the average density for local and regional railroads has fallen by 75.7 percent to 109.6 cars per mile.

In conclusion, the spinoff of short lines by Class I carriers has created a short line industry with two distinct segments. As a whole, pre-1970 short lines are viable small railroads. In contrast, many of the short lines created since 1970 operate over lines that were at best marginally profitable for their former Class I owners. As such, the economic success of the new short lines is closely related to their ability to control costs, especially labor, and provide improved service.

Class I railroads reported that they may sell an additional 17,265 miles of track in the next five years. The characteristics of these potential short lines are most likely similar to those of short lines created since 1970. Given the lower traffic densities on these lines, public policies and private decision-making must recognize that the new short lines will require a more flexible cost structure to operate economically.

CHAPTER 3

THEORETICAL FRAMEWORK

The sources of institutional change identified in the previous chapter are causing changes in the structure of the rail industry. Such changes may alter the efficiency and competitiveness of the rail industry, thereby affecting all participants. This includes the railroads, rail labor, shippers, competing modes, and various government agencies. A knowledge of the theoretical economic reasons underlying this change is important to understanding these changes. Thus, economic theory is reviewed in this chapter, providing a framework for the empirical analysis in later chapters.

The relationship between cost and scale in the railroad industry, especially the Class I railroads, has been extensively studied. This implies the existence of a consistent underlying theory to explain and evaluate economies of scale or size. However, this is not the case and the term "economies of scale" is fraught with peril. A major source of this confusion is the failure by many economic writers to distinguish clearly among the concepts of economies of size, economies of scale, and returns to scale.

As such, in this work an attempt is made to try to avoid this common pitfall by first reviewing the nature, definition, and sources of economies of size and related topics. The terms "economies of size" and "economies of density" are then defined. Finally, empirical evidence of economies of size and density for Class I and short line railroad industries are reviewed.

ECONOMIC CONCEPTUAL DEFINITIONS

Returns to Scale

Assume that a firm operates with a production function. The firm produces output from various combinations of inputs. The term 'production' is broader than the literal physical transformation of raw materials by manufacturing concerns. As denoted here, production may also consist of producing or offering marketing functions or services such as transportation or storage. "To an economist, all of these may be equally productive acts" (Baumol).

A production function shows the maximum output attainable from any specified set of inputs, with a given level of technology (Ferguson 1972). The production function may be expressed as a mathematical relationship, stating the quantity of output (Q) as a function of the quantities of variable inputs ($x_1, x_2, \ldots, x_n$) employed or

$$Q = f(x_1, x_2, \ldots, x_n; k) \tag{3.1}$$

A fixed input (k) is a parameter whose quantity cannot be readily changed in response to a changing output level. The quantity of the variable inputs employed is directly related to the level of output produced. The distinction between fixed and variable inputs is temporal. In the long run all inputs are variable.

The technological nature of the production function is classified according to its returns to scale. "'Returns to scale' describes the output response to a proportionate increase of all inputs" (Henderson and Quandt). A production function may exhibit constant returns to scale, increasing returns to scale, or decreasing returns to scale. A single production function may possess all three of these characteristics.

Constant returns to scale exist if there is a proportionate increase in output for a proportionate increase in all inputs. The case of constant returns to scale holds that it is possible to scale output up by some amount by simply replicating the existing production process. The replication argument is used to support the idea "that constant returns to scale is often a reasonable assumption to make about technological structures" (Varian). However, input usage usually does not vary in exact proportion with output.

The second case, increasing returns to scale, means that output increases more than proportionately for a scale increase in all inputs. Increasing returns to scale may arise for either real economic or pecuniary reasons. With real economies, the quantity of inputs employed is reduced as output increases per unit of input.

> Pecuniary economies are achieved when the firm is able, by exerting some kind of market power, to obtain a given set of inputs at lower monetary cost without any essential change in the physical processes of production (Scherer et al.)

However, pecuniary economies can also act as a real source of increasing returns to scale.

There are four sources of real economies. They are: (1) division of labor and specialization, (2) factor indivisibility, (3) geometric relationships, and (4) massed reserves.

Adam Smith identified specialization and division of labor as the first real economic source for increasing returns to scale. If a firm operates a small plant and employs a few people, it is likely that each worker will perform several job tasks in the production process. A larger plant with a larger work force may attain labor cost savings through the division of the production process into various jobs with workers specializing at each particular job. Specialization allows workers to become more proficient at their jobs, increasing their skill and speed of operation. Division of labor saves time and costs in a large plant by eliminating the set-up time that small plants incur as workers shift from task to task.

Factor indivisibilities are the second real economic source of increasing returns to scale. "Some inputs just do not come in small units. We cannot install half a blast furnace or half a locomotive (a small locomotive is not the same as a fraction of a large locomotive)" (Baumol). Thus, although a firm could double its output through replication by building two small factories, this may be inefficient. Instead, one larger factory may be more efficient because it is large enough to use certain technologies that are infeasible at the smaller-scale plant.

Geometric properties of containers and pipes are a third real economic source of increasing returns to scale. A classic example is Baumol's warehouse construction case.

> Suppose the work in building a cubical warehouse is in proportion to the number of bricks used in its construction and that, within limits, the number of bricks depends strictly on the wall area of the building. It is a matter of elementary geometry that the wall and floor areas will increase as the square of the perimeter of the warehouse but the volume of the building (the storage area) will increase as the cube of the perimeter. In other words, double the land, bricks, and the bricklaying labor and one more than doubles warehouse capacity (Baumol).

Thus, the cost of construction of a container increases with surface area, whereas capacity increases with volume. In engineering design work, it is assumed that on average a 100 percent increase in capacity will lead to only a 60 percent increase in construction cost, at least up to the point where size does not require additional structural reinforcement (Hay and Morris). Similar relationships, though less mathematically exact, have been observed for energy usage and various types of processing equipment (Scherer).

The final real economic source of increasing returns to scale arises from "economies of massed reserves." Following the law of large numbers, the concept is that inputs held in anticipation of random variations in output, such as backup machinery or maintenance staff, vary less than proportionately with the size of output. For example, a small plant with only one specialized machine may find it necessary to have a backup machine to protect against random breakdowns.

> For a larger plant with numerous machines, a single extra machine may provide almost the same degree of protection . . . because the event of random machine failures rises less than proportionately with the number of machines in service (Scherer).

Similarly,

> The law of large numbers makes the number of breakdowns more predictable in a plant using a large number of machines, so that the number of stand-by maintenance staff need not be increased in proportion to size (Hay and Morris).

In addition to the real economic forces, there are also pecuniary or financial reasons for increasing returns to scale. Sources of pecuniary economies include purchase quantity discounts, capital-raising, and sales promotion. There is some question among economists whether pecuniary economies are a real source of increasing returns to scale or a market-power characteristic arising from the existence of increasing returns to scale. Most likely, pecuniary economies are both a source and a result of increasing returns to scale.

For example, purchase quantity discounts may allow a supplier to decrease unit production costs for large quantity orders by increasing the length of its production run. In addition, a shipper may decrease outbound transportation costs per unit shipped for large quantity orders by shipping such orders via rail rather than truck. Increasing returns to scale arising from capital-raising are partially associated with real resource savings. "Negotiating a loan or new stock issue or obtaining the necessary regulatory agency clearance entails transaction costs that are nearly fixed, whether the amount of funds raised is small or large" (Scherer). Thus, the larger the issue or loan, the lower the costs per dollar of capital raised. Furthermore, there is less risk associated with capital-raising by large corporations in the sense "that earnings tend to be more stable and defaults or bankruptcy are rarer" (Scherer). Researchers have had great difficulty in establishing the existence of real economic increasing returns to scale for sales promotion.

Economists distinguish between real and pecuniary economies on the basis of their social desirability. Real economies are considered to be desirable because they result in a more efficient use of inputs, freeing resources for use in satisfying other unfilled wants.

> The social desirability of a purely pecuniary economy is more ambiguous, since such economies characteristically reflect income redistributions benefiting their recipients but reducing the welfare of agents whose supply price has been beaten down (Scherer et al.).

Thus, there is a strong belief that pecuniary economies arise because of a firm's size and market power, rather than acting as a real economic source of increasing returns to scale.

The final case, decreasing returns to scale, means there is a less-than-proportionate increase in output for a scale increase in all inputs. The existence of decreasing returns to scale is usually attributed to increased problems and complexities of large-scale management. When the scale of operation reaches some point, it becomes necessary to delegate authority and responsibility to lower echelon management. This may result in decisions being made by persons lacking experience and knowledge of the firm's overall business policy. Moreover, as authority is delegated, top management is removed from the day-to-day operations. Being forced to rely upon information generated from within the firm, top management may eventually lose an appreciation for the firm's actual operations.

The function coefficient (ε) is used to measure returns to scale of a particular production function and input mix. "The function coefficient is the elasticity of output with respect to an equi-proportional variation of all inputs" (Ferguson 1979). Thus, it shows the proportional change in output for a scale increase in all inputs.

Consider any particular two-variable input bundle, (x_1, x_2). By equation (3.1), output is,

$$Q^\circ = f(x_1^\circ, x_2^\circ) \tag{3.2}$$

Increase each input by the same proportion, λ. Then,

$$Q = f(\lambda x_1^\circ, \lambda x_2^\circ) = g(\lambda) \tag{3.3}$$

Taking the elasticity of output with respect to λ yields the function coefficient (ε).

$$\varepsilon = \frac{dQ/Q}{d\lambda/\lambda} = \frac{dg(\lambda)}{d\lambda}\frac{\lambda}{g(\lambda)} = \frac{d\ln Q}{d\ln\lambda} \tag{3.4}$$

λ is a scale factor because it represents a proportionate change in all inputs. Thus, the function coefficient is the elasticity of output with respect to scale. In a neighborhood of any input point, the production function exhibits increasing, constant, or decreasing returns to scale as ε is greater than, equal to, or less than 1, respectively (Ferguson 1979).

Economies of Scale or Size

In economic literature, the terms "returns to scale" and "economies of scale" are used interchangeably. A one-to-one relationship exists between the two concepts. Returns to scale refers to the change in output arising from scale increases in inputs, while economies of scale refers to the relationship between cost and output.

Cost curves can be used to analyze graphically the relationship between cost and output (Figure 3.1). The short-run average cost (SRAC) and long-run average cost (LRAC) curves are each typically depicted with a U shape. However, the factors underlying this

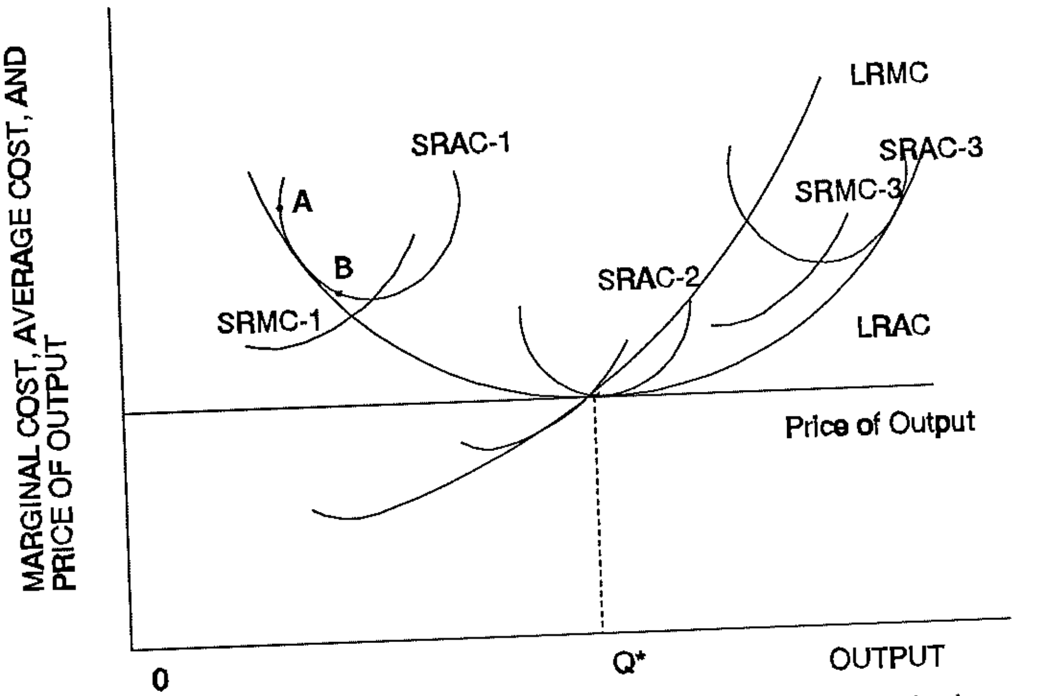

FIGURE 3.1. Graphical Representation Between Cost and Output (NOTE: LRMC = long-run marginal cost, LRAC = long-run average cost, SRMC = short-run marginal cost, and SRAC = short-run average cost.
SOURCE: Dooley, F.J. *The Theory and Economics of Multiplant Firms.*

shape differ between the two curves. SRAC is U shaped because the decline in average fixed cost is ultimately more than offset by the increase in average variable cost. The latter occurs because the average product of variable inputs reaches a maximum, before declining. However, the law of diminishing marginal returns has nothing to do with the shape of the LRAC. The U shape of the LRAC arises because of economies and diseconomies of scale. In Figure 3.1, the firm has economies of scale from the origin to Q^o, at which point diseconomies of scale set in.

Long-run total cost of production may be expressed as a function of output,

$$C = f(Q) \tag{3.5}$$

Long-run average cost is the cost per unit of output,

$$LRAC = \frac{C}{Q} \tag{3.6}$$

Long-run marginal cost is the first derivative of the long-run total cost with respect to output,

$$LRMC = \frac{dC}{dQ} \tag{3.7}$$

Let κ denote the elasticity of long-run total cost with respect to output.

$$\kappa = \frac{dC}{dQ}\frac{Q}{C} = \frac{LRMC}{LRAC} \tag{3.8}$$

The elasticity of long-run average cost with respect to output, Ω, is

$$\begin{aligned}\Omega &= \frac{d(C/Q)}{dQ}\frac{Q}{C/Q} = \frac{LRMC * Q - C}{Q^2}\frac{Q^2}{C} \\ &= \frac{LRMC}{LRAC} - 1 = \kappa - 1\end{aligned} \tag{3.9}$$

"Specifically, the value of the elasticity of cost may be used, in comparison with unity, to infer the behavior of the average cost function (and thus the nature of returns to scale along the expansion path)" (Ferguson 1979). If κ is less than 1, the slope of the LRAC is negative and the long-run average cost function exhibits economies of scale. If κ equals 1, the slope of the LRAC is zero, and the long-run average cost function is at its minimum. Finally, if κ is greater than 1, the slope of the LRAC is positive, and the long-run average cost function exhibits diseconomies of scale.

In addition to inferring the behavior of the long-run average cost function, Ferguson states that the elasticity of long-run total cost with respect to output is also related to returns to scale. Specifically, Ferguson proves that the elasticity of long-run total cost with respect to output is the reciprocal of the function coefficient, ε (the elasticity of output with respect to scale), or

$$\kappa = \frac{1}{\varepsilon} \tag{3.10}$$

Thus, "long-run average cost decreases or increases accordingly as there are increasing or decreasing returns to scale" (Ferguson 1972). Other authors reach the same conclusion, including Gravelle and Rees and Mansfield. This has led some to define economies of scale as the response of output to a proportional increase in all inputs.

Economies of scale is a useful analytical device for studying the relationship between long-run average cost and output. Confusion apparently exists in the literature as to whether economies of scale arise solely from scale increases in all inputs. There is absolutely no requirement that the change in output arise from a scale increase in all inputs. To avoid this confusion, some argue that the relationship between cost and output should be expressed as "economies of size" rather than "economies of scale."

The difference between economies of size and scale can be graphically represented by using the expansion path. "The expansion path is the locus of input combinations for which the marginal rate of technical substitution equals the input price ratio" (Ferguson 1979). Any ray from the origin is a scale line, i.e., it represents an equiproportional change in all inputs. Thus, if the expansion path is a scale line (Figure 3.2), economies of scale and economies of size are consistent.

However, a firm's input adjustment in response to price changes will not necessarily be proportional. In this case, the expansion path is not a scale line (Figure 3.3). As previously stated, a rational firm will adjust its input usage to remain on its

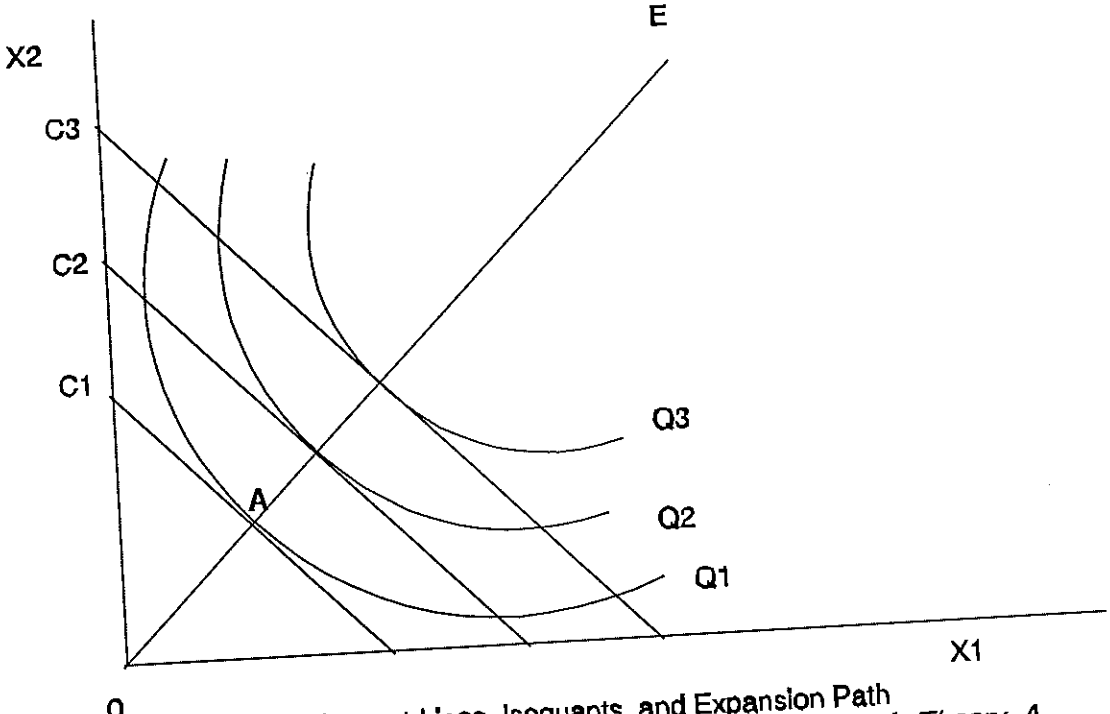

FIGURE 3.2. Isocost Lines, Isoquants, and Expansion Path
ADAPTED FROM: Henderson and Quandt, *Microeconomic Theory, A Mathematical Approach*, 3rd ed., New York, McGraw-Hill, 1980.

expansion path. Thus, as output is increased, x_2 is increased relatively more than x_1 to produce efficiently. Within the context of Figure 3.3, equation (3.10) means that if a firm is producing with an input mix on its expansion path (hence, on its LRTC curve), the point elasticity of LRTC with respect to output is equal to the reciprocal of the point elasticity of output with respect to a scale increase in inputs. This is true of every point on the expansion path. This does not imply that the expansion path must be a scale line. It may or may not be, depending on the technology of production. However, in every case, input use corresponding to various points on a LRTC curve will occur along the expansion path.

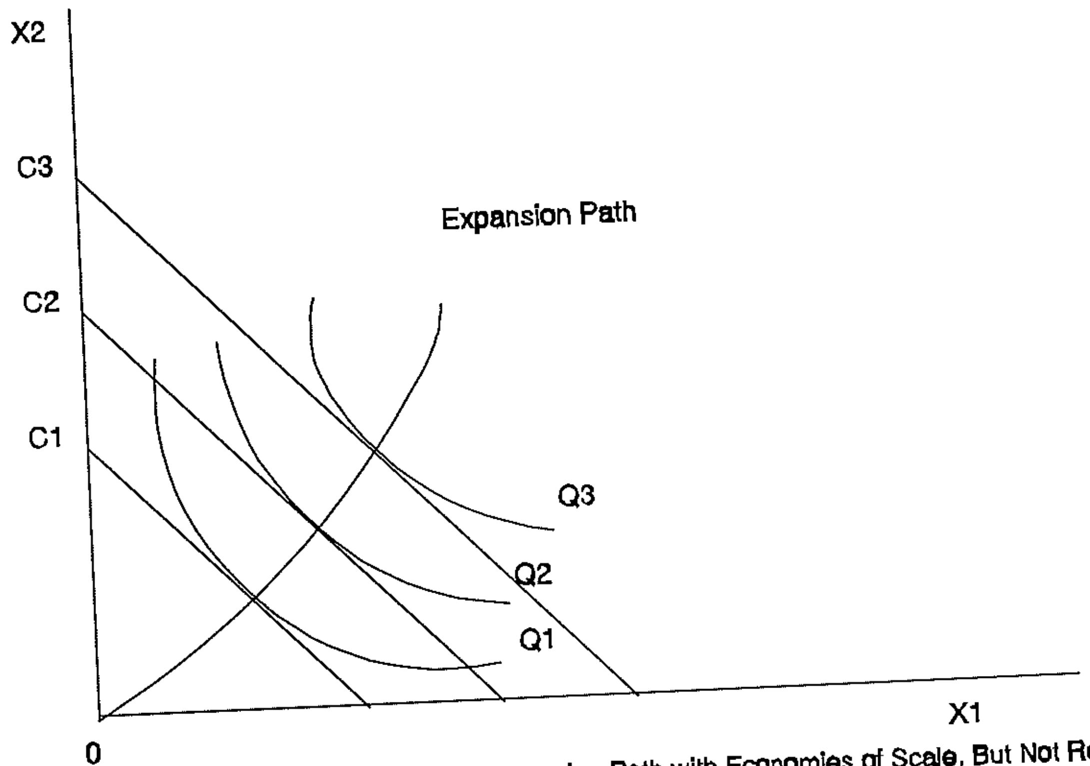

FIGURE 3.3. Graphic Representation of Expansion Path with Economies of Scale, But Not Returns to Scale
SOURCE: Dooley, F. J., *The Theory and Economics of Multiplant Firms.*

Close inspection of the real economic sources of increasing returns to scale indicates that scale increases in all inputs probably do not occur. "There appears to be almost universal agreement among economists that in real life firms do not expand all resources and products in exactly equal proportions as the level of the firm's activity is increased" (Madden). Thus, it is doubtful whether any of the four real economic sources of increasing returns to scale actually represent a scale increase in all inputs. Rather, the relationship between cost and output appears to be more a function of plant size.

As a firm moves from small plants to larger plants, it may save labor operating costs through specialization and division of labor. However, when increasing plant size, firms do not simply install more of the same type of machines. Instead, firms may install more sophisticated, capital-intensive equipment to allow labor to specialize. Thus, the increase in plant size may be accompanied by a substitution of capital for labor. The argument is similar for factor indivisibilities. As Baumol succinctly stated, "a small locomotive is not the same as a fraction of a large locomotive." By definition, geometric properties are increases in plant size or equipment, not a scale increase in all inputs. "Moreover, the crew required to operate a large processing unit or machine is often little or no larger than what is needed for a unit of smaller capacity" (Scherer). Finally, economies of massed reserve arise not because of scale, but are directly a result of increased plant size (Scherer).

Since long-run average costs apparently are more dependent upon plant size than scale increases in all inputs, it is arguable that the relationship should be expressed as economies of size rather than economies of scale. Economies of size have been defined to "mean reductions in total cost per unit of production resulting from changes in the quantity of resources employed by the firm or in the firm's output" (Madden). To determine whether there are economies or diseconomies of size, analysis must consider the cost function. Long-run total cost is defined to be a function of output and plant size, where k denotes the size of plant,

$$C = j(Q, k) + h(k) \tag{3.11}$$

In the long-run, plant size is assumed to be continuously variable. Thus, in the long run, the firm "is free to vary k and select a plant of optimum size. The shapes of the entrepreneur's production function and cost function depend upon his plant size" (Henderson and Quandt). Ferguson has also noted that size of plant is a determinant of LRAC (1979). Thus, if there are economies associated with operating a large plant, LRAC will be decreasing, while if diseconomies occur, LRAC will be rising.

In conclusion, economies of scale, not returns to scale, is the appropriate theoretical concept to employ in analyzing the shape of the long-run average cost curve. There is no evidence in microeconomic theory literature to suggest that economies of scale arise solely as a result of a scale increase in all inputs. Furthermore, it is doubtful that it is even possible to achieve a scale increase in all inputs. The confusion arising from the term "economies of scale" can be avoided by adopting the term "economies of size" to describe the relationship between total cost of production and the firm's output. Moreover, this may be a more appropriate term because there is theoretical evidence that plant size, not input usage, determines the shape of the long-run average cost curve.

Economies of Density

Economies of traffic density are the economies of scale resulting from increased traffic volume, holding the network constant (Braeutigam, Daughety, and Turnquist, 1984). Thus, economies of density are the "cost savings response to a proportionate increase of traffic level in the short run" (Lee).

Mathematically, economies of density (RTD) are obtained by taking the partial derivative of the cost function with respect to output, or

$$\frac{\partial C(Q,W,N)}{\partial Q} = RTD \qquad (3.12)$$

where Q is output, W is input prices, and N is network characteristics. Graphically, economies of density are illustrated as the shift from point A to point B in Figure 3.1.

There are three reasons for economies of density in the railroad industry. First, average costs are lowered by spreading fixed costs per mile over more output. Second, economies of density are also realized by reducing linehaul operating costs. Finally, improved service may also lead to economies of density.

First, the "railroad industry is characterized by a high level of fixed costs and heavy investments in long-lived specialized assets" (Lee). As such, railroads incur large costs for capital and maintenance of way (MOW) for track and road property. Traffic density on most short lines and Class I light density lines is generally under 1 million gross ton miles per mile of track. Increasing the volume of traffic on the under-utilized network acts to lower average fixed costs.

Second, a significant portion of economies of density arise from sources other than the fixed costs of capital and MOW. Harris found that

> "two-thirds of the economies of density are due to high fixed *operating* costs per mile of road. This should not be surprising, since the provision of rail service entails more than simply installed capacity; it includes minimal (and often indivisible) amounts of crew, engines, maintenance, etc." (1977).

For example, Class I carriers' crew costs for any trip are fixed by contract, regardless the number of cars pulled or stations served. Similarly, a locomotive can pull 20 or more cars before a second unit is required. Both of these costs are semi-variable in nature. Increasing the traffic density per trip creates potential for economies of density.

Third, "economies of density can take the form not only of lower costs, but also of better service at the same cost" (Keeler 1983). According to Healy (1961),

> "it is common knowledge that where lines are in the same territory and parallel, smaller systems have often by their superior service been able to attract traffic away from larger ones. The more intimate contact possible between shippers and the whole railroad organization in the case of smaller systems can lead to better communications, faster response and more mutual understanding and working together. All this can in turn be credited with reinforcing employee morale.

A higher traffic density could allow the railroad to offer more frequent service. An increase in service frequency lowers the branch line car cycle time.[1] Once-a-week service

[1]A branch line car day cycle begins when the car departs the classification yard for a shipper's station. The cycle ends when the car returns to the classification yard for off-branch shipment to the final destination.

results in an eleven day car cycle time. With three-day-a-week service, the car cycle is lowered to 6.38 days, which leads to a correspondingly lower car-hire cost.

Conclusion

In theory, the concepts of economies of size and density are clearly distinguishable. Economies of traffic density are the cost savings resulting from increased traffic volume, holding the network constant. Economies of size mean that costs decrease as firms become larger, ceterus parabis.

As a practical matter, however, it is impossible to determine whether cost savings arise from economies of size or density. The cost structure of a railroad is an interaction of size and density, as well as other factors such as average length of haul and labor agreements. Thus, "a small firm with high traffic density may very well have lower average costs than a large firm with low density" (Harris 1977). The next section considers the empirical evidence of economies of size and density in the railroad industry.

EMPIRICAL EVIDENCE OF ECONOMIES OF SIZE

The methods used to measure and the empirical evidence of economies of size and density in the railroad industry are presented in this section. While not exhaustive, the following review of empirical evidence is certainly representative of the work. The approach taken is to provide a general summary of findings and methodologies over time. Most of the work was done analyzing the cost structure of Class I railroads. Studies focusing on short lines are reviewed in detail after the chronological review of Class I studies.

Class I Railroads

According to Keeler (1983), the first statistical rail cost analysis was made by the Interstate Commerce Commission (ICC) in the late 1920s. The ICC sought to determine the relationship between total and variable costs. The first modern rail cost function was specified by Meyer and his colleagues in a number of articles and a book published between 1957 and 1961. They specified total cost (TC) to be a function of freight and passenger traffic (Q_f and Q_p) and a measure of size (S). Traffic was typically some measure of gross ton-miles, while size was measured in track miles.

$$TC = \alpha_0 + \alpha_1 Q_f + \alpha_2 Q_p + \alpha_3 S \tag{3.13}$$

Borts (1958) criticized Meyer's specification, arguing that a long-run cost function should exclude the size variable. Including a size variable was consistent with a short-run cost function. Meyer and Kraft re-estimated their equation and argued that the specification depended on whether railroads had achieved minimum efficient densities. Since this specification confuses returns to size and traffic density, it does not provide a reliable estimate of either. Thus, their study and others based on this specification, such as Griliches, Hirschey, and Healy (1962), are flawed.

The next study of railroad costs was done by Borts (1960). A statistical analysis of variance of freight costs was employed for a cross section of railroads in the 1950s. Borts measured returns to density using a two-step process. First, the firms in the sample were divided into classes by size. Second, a covariance analysis was performed on the entire sample to estimate within- and between-class cost elasticities. The within- and between-class elasticities were interpreted to be the short-run and long-run cost elasticities, respectively. The short-run elasticity is estimated holding firm size, measured by route miles, constant. "If the cost elasticity holding firm size constant was below the elasticity allowing firm size to vary, that would be evidence of economies of density" (Keeler 1983).

Bort's results were invalid because he used the ICC method for allocating traffic between freight and passenger costs. The ICC cost allocation method overstated freight costs and understates passenger costs. Thus, there was an upward bias the more intensive the passenger operations. Correcting for this flaw, Friedlaender found increasing returns to traffic density on most U.S. railroads.

Next, a study by Healy (1962) explicitly considered economies of traffic density. He found substantial economies of density up to 3 million revenue ton-miles per mile of road. Using system wide data, Healy concluded that all eastern railroads and two western roads had reached this level. However, system wide data are misleading, and Healy points out there are meaningful economies of traffic density on many line segments. Healy's work was also biased because of problems in cost allocation.

In a related work, Healy (1961) used number of employees as an index of scale. He felt that number of employees "reflects more than any other the magnitude of the problem of controlling labor costs which are the biggest single input involved in producing railroad service" (Healy 1961). Healy found if density was already high, a scale increase to more than 10,000 employees was most likely accompanied by real diseconomies. In addition, railroads with low traffic densities could increase density by merging with a second carrier. However, this strategy depended upon the carrier's ability to abandon redundant lines before the ICC.

Keeler (1974) used a Cobb-Douglas technology to derive cost functions. The determinants of cost were:

$$TC = f(Q_f, Q_p, T) \tag{3.14}$$

where TC is total costs, Q_f is gross-ton miles of freight, Q_p is gross ton-miles of passenger service, and T is track-mileage. The minimum efficient density (MED) is estimated by differentiating equation (3.14) by T and setting the derivative equal to zero. Solving for T yields the optimal relationship between trackage and output. By substituting the optimal density back into the short-run cost function, a long-run cost function is generated.

In the above studies, the choice of output measures and size were flawed (Keeler 1983). Rather than gross-ton miles per track-mile (GTM/T), density should be measured by net ton-miles per route-mile (NTM/MR). The use of NTM/MR is preferred for two reasons. First, it reflects the actual weight of the traffic hauled by excluding the weight of the locomotive and freight cars. Second, track miles is an inappropriate measure of capacity because it includes yard track and sidings.

> "The institutional problem of excess capacity is related to the rail route system, not trackage. The regulatory barriers to abandonment apply to the provision of service to shippers and communities; therefore, it is the cost of this basic indivisibility--the length of the road to connect two points--that we should measure" (Harris 1977).

Three other deficiencies were also present in the early economies of size and density studies (Harris 1977). First, the early studies stratified the data by region, although no theoretical reason was offered for cost differences between regions. Instead, the regional variable most likely captured differences arising from a misallocation of costs between passenger and freight traffic. Second, specification error was present because average length of haul was not included as an explanatory variable. Finally, most of the earlier studies used total operating expenses (TOE) as the measure of costs. However, TOE fails to include a return on capital investment as a cost.

Harris directly incorporated net ton-miles and route-miles into his estimation of rail cost function. He also excluded passenger service and thereby avoided the cost allocation problem. The model estimated by Harris is:

$$TC = \beta_0 RTM + \beta_1 RFT + \beta_2 MR \tag{3.15}$$

where: RTM is revenue ton-miles, RFT is revenue freight miles, and MR is miles of road. Although MED is not generated by this approach, Harris' average cost curve was similar to that of Keeler (1974).[2] Harris found that the differences between average and marginal costs become negligible at a density of 8 million NTM/MR. As significant as the finding of economies of density, was the finding that a significant portion of these economies arise from sources other than declining average capital costs. Harris (1977) found that "two-thirds of the economies of density are due to high fixed *operating* costs per mile of road."

Using a similar model, Miller estimated 46 different regressions for various ICC rail operating expense accounts. The dependent variables are the operating costs for performing various functions. These included cost accounts for train expenses, transportation, labor, fuel, yard, signal and communications, dispatching, maintenance of way, car repairs, maintenance of equipment, and general expenses. Depending upon the regression, the independent variable was some measure of revenue ton-miles or carloads of traffic. To make the data more homoscedastic, all of the regressions were deflated by miles of road. Although the paper title and usage suggest that he was testing for economies of scale, Miller was actually testing for economies of density in the various cost accounts. For most of the cost accounts, he found significant economies of density.

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[2]After making adjustments, Keeler estimated the MED to be 15 million NTM/MR.

Although the work of Harris (1977), Keeler (1974), and Miller was generally consistent, they also shared some common weaknesses. First, Harris (1977) and Miller used a synthetic approach that did not allow for cross sectional variation in prices or technology. Keeler's work also did not allow for cross sectional variation in factor prices. However, Keeler (1974) found there was not wide variation across firms for wages. Second, Keeler's production function assumed the relatively restrictive technology of the Cobb-Douglas production function. Third, the specification of Miller's model fails to account for interactions between cost accounts.

All of the above works analyze economies of size and density for a railroad system. However, system wide data are misleading because there are meaningful economies of traffic density on many lines (Healy 1962). Tolliver (1984) developed a framework to adjust raw ICC costs to estimate economies of density on a particular line segment basis. His results were comparable to Harris' econometric estimation.

Sammons presents a contrarian viewpoint, arguing that traditional analyses of economies of size and density have focused on the wrong dimensions of rail costs. Using a graphical analysis, he first concludes that returns to firm size are generally constant. Sammons then argues that returns to density are limited to the very light to medium density line segments. Operating costs are high on light density lines because there are minimal labor and equipment requirements that must be met regardless of traffic levels. An increase in density lowers per unit operating costs because of specialization. However, higher density levels also require increased investment costs. "As rail traffic increases, the investment costs for greater speeds, signal system sophistication, passing siding density, and number of main tracks also increase" (Sammons).

Sammons argues that the relevant measure should be returns to traffic flow concentration. Returns to traffic flow concentration "arise when origin-destination traffic within a market lane is concentrated on fewer rail routes." Concentrating traffic onto fewer routes lowers yard switching costs, rail car ownership costs, and line haul operating costs. In addition, lower transit times improve service quality.

In essence, Sammons argues that returns to density are limited to gains over the lighter density lines. Increased investment requirements for higher density lines negate further density savings. However, his returns to traffic flow concentration should not be considered to be a new measure. It measures returns to density to the extent that it shifts traffic from one line to another. If it involves abandonment of redundant lines, it becomes a returns to size question.

The basic model used to study economies of size and density was varied by Dion and Dorin. They specified

$$OR = f(MR, LOH, DEN, LOH/MR) \qquad (3.16)$$

where OR is the operating ratio, MR is miles of road, LOH is average length of haul, DEN is freight density, and LOH/MR is the ratio of length of haul to miles of road. Instead of some measure of cost, OR was chosen as the dependent variable for three reasons. First, the operating ratio is more stable across time and railroads because it is calculated in accordance with ICC regulations. Second, as a ratio, the OR automatically adjusts for inflationary increases in costs and revenue. Finally, the OR includes both transportation and maintenance expenses.

OR was regressed on the independent variables "in order to establish the individual impact of these variables on the operating ratio when the other factors were held statistically constant" (Dion and Dorin). DEN was the only variable statistically significant in the regression equation, accounting for 25 percent of the variation in OR.

Dion and Dorin concluded that freight density, not size as measured by miles of road, is a significant influence on railroad performance as measured by OR. As such, their results are similar to the other size and density studies. They also suggest that the divestitures of track by Class I's to short lines makes economic sense. Divestiture of low density lines is a way to improve the operating ratio of Class I railroads (Grimm, Phillips, and Selzer).

The rail costing methodology used to analyze returns to density and scale became much more sophisticated in the late 1970s. Work by Harmatuck; Caves, Christensen, and Swanson; and Friedlaender and Spady; attempted to remedy the earlier problems by using a more general form of technology. Each of these studies was based on a translog cost function. The translog cost function sets the logarithms of costs quadratic in the logarithms of outputs and factor prices. A general form of the translog model is:

$$C = C(Y, X, W, T) \tag{3.17}$$

where: C is cost,

Y = a vector of outputs,

X = a vector of fixed factors,

W = a vector of prices of the variable factors, and

T = a vector of technological variables.

The translog model is superior to the earlier rail cost specifications for at least four reasons. First, it permits multiple output and quantity levels. Second, hypotheses about the underlying structure of production can be tested because the functional form is flexible. Third, general technological factors are incorporated. Finally, it can be used to measure either short-run or long-run costs.

For sake of comparison, returns to density and size were calculated for seven of the rail cost studies (Table 3.1). Regardless of the study, there is a consistent finding of constant returns to scale. The conclusion as to returns to density have varied over time, depending upon the model specification, methodology, and perhaps data.

TABLE 3.1. Returns to Density and Size for Various Studies

Study (Year)	Returns to Density	Returns to Size	Data Base Years
Keeler (1974)	1.79	1.01	1968-70
Harris (1977)	1.72	1.03	1972-73
Harmatuck (1979)	1.92	0.93	1968-70
Friedlaender and Spady (1981)	1.16	1.02	1968-70
Caves, Christensen, and Swanson (1981)	1.00	1.01	1955-74
Caves, Christensen, Tretheway, and Windle (1985)	1.76	0.98	1951-74
Lee and Baumel (1987)	1.24	0.99	1983-84
Barbera, Grimm, Phillips, and Selzer (1987)	1.59	0.98	1979-83

ADAPTED FROM: Barbera, A., C.M. Grimm, K.A. Phillips, and L.J. Selzer. "Railroad Cost Structure--Revisited." *Journal of the Transportation Research Forum,* 28(1):237-244, 1987.

Analyzing five studies[3], Keeler (1983) concluded "they all give strong evidence of increasing returns, up to a rather high traffic density relative to tonnages moving over most route-mileage in the United States." He also found that increasing returns to density were greatest over light density lines.

Caves, Christensen, Tretheway, and Windle (CCTW) questioned Keeler's conclusions. They agreed that the three earliest studies all pointed to substantial returns

[3]The five studies were Keeler (1974), Harris (1977), Harmatuck, Friedlaender and Spady, and Caves, Christensen, and Swanson.

to density. However, they argued that Friedlaender and Spady and Caves, Christensen, and Swanson did not find strong returns to density. Moreover, the results of the latter studies should be more valid because they were based on the superior translog cost model, were more advanced specifications, and used more thorough cost accounting data. Modifying the earlier translog specifications to include unobserved network effects, CCTW found strong evidence of returns to density, consistent with the findings of Harmatuck, Keeler (1974), and Harris (1977). "However, in contrast to these studies we find no tendency for returns to density to diminish at higher levels of density" (CCTW).

The two most recent studies - Lee and Baumel, and Barbera, Grimm, Phillips, and Selzer - also use the more advanced translog model. They are notable for two reasons. First, both rely on more recent data. All of the previous studies were based on data no more recent than 1974. Because of changes in data reporting requirements, the newer data are measurably better. In addition, more recent data are required to analyze the effects of structural change caused by rail deregulation. Second, the ICC changed the reporting requirements for capital in 1983. Previously, maintenance expenses were treated as current expenses rather than as additions to capital stock. As such, the costs reflected accounting rather than economic costs.

The results of Lee and Baumel, and Barbera, Grimm, Phillips, and Selzer are consistent with the findings from the six earlier studies. This implies that rail deregulation did not alter the railroad cost structure. Further, "deregulation and the massive structural changes from 1950 to 1980 have not exhausted the economies of density" (Lee and Baumel). Returns to density may have been lower for Lee and Baumel than Barbera, Grimm, Phillips, and Selzer because the former study is based on fewer observations. With additional data, the degrees of freedom necessary to analyze unobserved network effects in a post-deregulation environment will be available.

Short Line Railroads

In this section, economies of density and size are analyzed for light density lines and short line railroads. For this section, a light density line is defined to be a branch line of a Class I railroad. A short line is a Class II or III railroad. Light density lines are the lines most likely to be spun-off by Class I carriers as new short lines. Thus, the first study reviewed considers the cost structure of light density lines. The other three studies specifically address economies of density and size for short line railroads.

The objective of Harris (1980) was to estimate the level of excess branch line capacity and the potential cost savings associated with its abandonment. A simulation model was used to estimate branch line viability.

The Federal Railroad Administration (FRA) Network Model and data were used to analyze the viability of 3024 light density line segments with densities less than 1 million gross ton miles per mile of road. Waybill data was used to route traffic over the network. For each line segment, there were observations on carloads, car-miles, revenues, and traffic density.

The simulation model required several cost parameters. Rather than estimate his own costs, Harris (1980) relied on six other light-density line cost studies.[4] Simulations were run using the low, mean, and high values from the six studies. Cost categories

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[4]Banks, R.L. and Associates, Inc., *Development and Evaluation Abstraction of Light Density Rail Line Operations*, Federal Railroad Administration, Washington, D.C., 1973; United State Railway Association, *Viability of Light Density Lines,* Washington, D.C., 1976; Johnson, M.A., "Market and Social Investment and Disinvestment in Railroad Branch Lines: Evaluation Procedures and Decision Criteria," Unpublished Ph.D. dissertation, Michigan State Univ., East Lansing, 1975; Baumel, C.P., J.J. Miller, and T.R. Drinka, *A Summary of An Economic Analysis of Upgrading Branch Rail Lines: A Study of 71 Lines in Iowa,* Iowa State University, Ames, 1976; and Sidhu, N.D., A.H. Charney, and J.F. Due, "Cost Functions of Class II Railroads and the Viability of Light Traffic Density Railway Lines," *Quarterly Review of Economics and Business*, 17(Fall 1977):7-24. The remaining cost data was provided by the Southern Pacific Railway.

included total fixed cost per mile, rehabilitation cost per mile, cost per car of origination/termination, cost per on-branch car-mile, and cost per off-branch car-mile. Harris (1980) determined that the most critical variable in assessing the viability of line density lines is fixed costs per mile. The second most important variable is line rehabilitation costs.

Harris (1980) used the results from the sensitivity analysis to estimate the worst and best cases for branch line viability. For the best case, he assumed that fixed cost per mile was low (3353 dollars per mile), rehabilitation costs were zero (deferred maintenance), and revenues are maximized. Even under the best cases, he found that 15,000 to 24,000 thousand miles, or 25 to 40 percent, of light density lines were not viable. This would result in an annualized cost savings of 75 to 89 million dollars.

He then ran the worst case scenarios, assuming high fixed costs (5543 dollars per mile), high rehabilitation costs (3585 dollars per mile), and low revenues. In the worst case, 55,125 miles of light density line, or 92 percent of the total, are not viable. In this case, the annualized savings were 872 million dollars.

Harris' (1980) best estimate was that 35,000 to 42,000 miles of light density line should be abandoned. The actual level of track abandoned or sold from 1980 to 1988 was 38,653 miles of road (Table 2.1). The estimated annual cost savings was approximately 300 million dollars.

The findings of Harris (1980) raise issues whether a policy of rail line abandonment should be encouraged to improve rail earnings and avoid economic waste. One of the difficulties in addressing this issue is the nature of short line or light density branch line costs were not well understood relative to Class I carrier costs. Harris' analysis was based on the cost estimates of several studies.

Due, Sidhu, and Charney published two related articles on costs for Class II railroads. The first study (Sidhu, Charney, and Due or SCD) estimated long-run economies of density and length of haul. The companion study (Charney, Sidhu, and Due or CSD) estimated short-run cost elasticities.

The specific objectives of SCD was to: "(1) to determine the influence of volume on traffic and length of haul on cost; and (2) to determine the economic viability of light density lines." Assuming that long-run adjustments had been made, SCD estimated a long-run cost function. It was derived by cross-section analysis.

Their analysis was based on two samples. The first sample was ICC published data for 209 Class II railroads for 1968. To focus on short lines, they excluded railroads that were primarily switching/terminal operations, railroads with substantial passenger traffic, and roads operated as components of a Class I carrier. In the second sample, they had 1973 data for 44 Class II roads submitted to the ICC. The 1973 data were much more complete. No attempt was made to merge the samples.

Their model was similar to that used by Harris (1977) and Miller.

$$C = \alpha + \beta_1 \frac{1}{V} + \beta_2 \frac{1}{D} \qquad (3.18)$$

where C is cost per thousand net-ton miles, V is volume, and D is distance or average length of haul. The specification of the model implies that average cost falls as volume or distance increases.

Similar to Miller, they used the basic model for many regressions. They ran regressions for 11 cost accounts for the 1968 data and 22 cost accounts for the 1973 data. General cost accounts included total operating costs, maintenance of way, maintenance of equipment, transportation-rail line expenses, general expenses, and fixed costs.

SCD concluded that the two major cost components of operating cost, maintenance of way and transportation expense, vary much more with volume than distance. "In other words, these components, in total, cannot be adjusted closely to changes in the volume of traffic even over a long-run period" (SCD). They conclude that volume or traffic density is the most important determinant of average cost. Short lines are able to better utilize fuel, equipment, and manpower with larger traffic volumes.

They also calculated average operating cost per ton mile for each railroad in the 1973 sample. They found substantial economies of scale, which are largely exhausted. The data was arrayed by density. All but one short line with density less than 55,000 NTM/MR had costs over 25 cents per ton mile. On the other hand, no carrier with density greater than 200,000 NTM/MR had costs over 7 cents per ton mile. SCD felt that most economies of density were exhausted at 200,000 NTM/MR. According to calculations by Keeler (1983), SCD's long-run cost elasticity for a median sized Class II railroad was 0.67, confirming the finding of substantial economies of density. SCD's findings were consistent with Harris (1977).

Sidhu, Charney, and Due conclude "there is strong evidence of substantial economies relative to traffic density reflecting indivisibilities and economies of scale for light traffic rail lines, relatively far greater than those for heavy density main lines." Compared to Class I railroads, the economies of density are exhausted at low volumes. SCD also argue that although marginal cost is below average cost, this does not indicate that short lines operate with excess capacity. Rather they argue that short lines adjust their plant capacity by lowering maintenance costs.

The same team of researchers also estimated short-run cost elasticities and returns to density for Class II railroads (Charney, Sidhu, and Due). The data was obtained from annual reports filed with the ICC for ten Class II railroads from 1963 to 1973. They collected data and calculated values for total tons, ton-miles, average length of haul, and 18 cost items. All ten railroads were primarily bulk carriers, with no passenger traffic. The model was the same specification as used for the long-run study (equation 3.18).

The short-run cost elasticities were much lower than the long-run cost elasticities. Six of the ten railroads (Group 1) had cost elasticities below 0.30. Transportation-rail line expenses and track maintenance cost had the lowest elasticities for these six short lines. For the former, the most important cost sub-category was train crew compensation, indicating average labor costs fall substantially with an increase in volume.

The average elasticity for the other four carriers (Group 2) was 0.61. The main differences between the two groups were "in the categories of roadway maintenance, locomotive repairs, compensation of train crews and traffic costs." CSD speculated that the cost elasticity for maintenance of way was higher for Group 2 because these carriers were catching up on deferred maintenance.

Elasticity of cost was not dependent upon density levels. Contrary to *a priori* expectations, elasticities were not larger for the carriers with higher density. They hypothesized that might occur because of "indivisibilities in track maintenance and train operation" (CSD).

A highly sophisticated study by Braeutigam, Daughety, and Turnquist (BDT 1982) confirmed Charney, Sidhu, and Due's findings about short-run costs for short lines. Braeutigam, Daughety, and Turnquist (1982) estimated a flexible forms short-run cost function for a single short line.

There were three important aspects to their approach. First, by using firm cost and production data, they avoided cost allocation problems associated with data reported to the ICC. Second, output was characterized by volume and a measure of quality of service. Average speed of shipment was used as a proxy for quality. Finally, they used information about the rail network and technology to relate speed of service to the technology of the railroad.

Braeutigam, Daughety, and Turnquist (1982) estimated

$$C = c(Y, S, P_F, P_L, P_E; K) \tag{3.19}$$

where C is short-run costs, Y is a measure of volume flow, S is speed of service, P_F, P_L, and P_E are the respective prices for fuel, labor, and equipment, and K is a measure of the fixed factors of production. The cost model was estimated as a translog function. Data were obtained on a monthly basis from a single railroad from 1969 to 1977.

The estimated cost elasticity by Braeutigam, Daughety, and Turnquist (1982) was only 0.17. The finding of substantial economies of density may have resulted because the data was for a bridge rail line, i.e., one connecting two major carriers. This type of short line probably has higher terminal costs than other short lines.

SUMMARY

The theoretical framework presented in this chapter provides a basis upon which to evaluate the cost structure of short line railroads. A general description of the research method and mathematical model used to analyze economies of density and size is presented in Chapter 4.

CHAPTER 4

EMPIRICAL MODEL

INTRODUCTION

The empirical model analyzes the effect of alternative size and density for short line railroads. The empirical model is based on a costing methodology originally developed as part of the North Dakota Rail Services Planning study.[1] The model includes a set of procedures for calculating Class I carrier line-segment unit costs and applying them to light-density lines or networks (Tolliver 1989a).

The cost analysis for most of the studies referenced in the Literature Review was based on econometric analysis. Further opportunities for econometric analysis of short lines are constrained by data limitations. Data for short line railroads are very limited. Most short lines do not have the extensive and detailed accounting systems employed by Class I carriers. Further, the Interstate Commerce Commission (ICC) relaxed data reporting requirements for Class II and III railroads in the early 1980s. Thus, the data available to Sidhu, Charney, and Due are no longer maintained.

In addition to data limitations, the nature of cost analysis for short lines is much different from Class I carriers. Allocation of common and joint costs is a serious problem for the analysis of Class I carriers. Common and joint costs are less of a concern with cost analysis of short lines. This is especially true for an analysis of a single branch line with a limited commodity mix. Allocation of common costs is more likely to be an issue for larger regional carriers that typically have a more diverse traffic mix.

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[1]See two reports prepared by Denver Tolliver. They are *The Benefits and Costs of Local and Regional Railroads*, UGPTI Pub. No. 80, 1989a and *Class I Carrier Light Density Costing Methodology*. UGPTI Rep. No. 76, 1989b.

> Because common and joint costs are theoretically less of a problem in smaller railways (which handle only freight traffic), synthesized costing procedures are generally more applicable. Cost accounting and economic-engineering methods, which are largely unworkable for large carriers, are more relevant to the scope and size of short line carriers (Wilson, Heads, and Tolliver).

Thus, a synthetic costing model, based on economic-engineering and cost accounting is adopted for this research. There are two objectives in this chapter. First, the costing methodology will be overviewed. Second, the principal parameters required for the costing analysis are described.

SHORT LINE COSTING MODEL

The short line costing model[2] is summarized in four parts. First, assumptions underlying the analysis are stated. Second, definitions are provided for allocated, fixed capacity, variable, off-line, and on-line costs. Third, a cost estimation process is introduced, featuring unit cost calculations and operations model. Finally, some basic cost-output relationships are formulated.

Basic Assumptions

Many transportation analysts are familiar with the ICC's costing formulas which compute shipment costs. Line-segment costing is much different from shipment costing. For the latter, costs are estimated for a typical movement, normally between a single origin and destination. For the former, costs are estimated for all classes of traffic originating and/or terminating on a line segment. Thus, the traffic base for line-segment analysis typically includes an array of origins and destinations.

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[2]Much of the material in this section is adapted from Tolliver, *The Benefits and Costs of Local and Regional Railroads*, pp. 46-54.

From a systems perspective, a line segment may be envisioned as a subsystem of a carrier's overall network. As a subsystem, a line segment possesses (on a smaller scale) many of the same attributes or characteristics of the carrier's overall network. Each line or network of lines may differ, however, in its traffic mix, density, track quality, condition, and other physical or geographic characteristics.

Some basic assumptions regarding line segments are set forth below. The propositions underscore many of the assumptions and definitions found in the theoretical model.

1. A line has certain physical assets associated with its operation and existence (such as land, track, other roadway materials, roadway buildings and structures, etc.) which can be directly assigned to the segment.

2. A line-segment has a production function that is somewhat similar to that of the entire rail network in that the same factor inputs (i.e., track, equipment, labor, materials, and supplies) are needed to generate output.

3. The production functions of the various subsystems utilize the same factors of production. Thus, the variable inputs such as locomotives, freight cars, containers, engineers, firemen, brakemen, and conductors can usually be used on another subsystem of the carrier's network.

4. A line segment, as a subsystem of a carrier's network, is subject to short run economies of utilization or density.

5. A line segment is not a self-contained subsystem of a carrier's network. Rather, it interacts with other subsystems, interchanging freight cars, locomotives, and crews.

Cost Classifications and Definitions

Costs are frequently defined or classified in more than one manner, or according to several criteria. Four categories of cost are especially useful in developing a theory of light-density line analysis. In the following discussion, railroad costs are classified according to: (1) subsystem or function, (2) traceability, (3) behavior with output, and (4) accountability.

On-Line Versus Off-Line Costs

Cost may be defined according to subsystem function into two broad categories. They are (1) on-line or on-network costs, and (2) off-line or off-network costs.[3]

On-line costs comprise the operating, capital, and opportunity costs associated with serving and maintaining a set of light-density lines. Off-line costs represent the variable expense associated with moving the traffic to and from the light density network over other subsystems of a Class I carrier's network.

Line-Specific Versus Allocated Costs

As assumption 1 states, a line or network of lines has certain clearly assignable physical assets associated with its existence. Items such as land, track, structures, roadway materials, and buildings are "line-related" or "line-specific" costs. The annual expense for each item can be directly assigned to a particular line or network.

Other factors of production such as equipment or train and engine crew labor may be used on several different networks or lines. The annual expenses for these items cannot be directly and solely attributed to any given line segment. Instead, they must be allocated among the various lines or networks in the carriers' system. The basis of allocation is typically on some level of activity or output on each segment.

Fixed Capacity Versus Variable Costs

On-line costs may also be classified according to behavior with output. Certain line-related costs are fixed in nature and do not vary with traffic. For example, a large proportion of maintenance of way (MOW) expenditures on light-density lines are constant per mile of track. Items such as superintendence, vegetation control, and time-related

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[3]These costs are frequently referred to as "on-branch" and "off-branch", particularly within the context of branch-line analysis.

deterioration of track and roadway assets are largely independent of the level of traffic. Similarly, the opportunity cost of roadway investment is incurred regardless of whether 100 or 5,000 carloads are handled.

Other on-line costs such as locomotive ownership, fuel, and train crew labor vary directly with the level of activity on a line. If no traffic is generated or handled during the year, then no locomotive or freight car costs are incurred. Instead, the equipment may be utilized on other subsystems.

Accounting Classifications

On-line expenses are normally classified according to four broad functional categories found in railroad accounting systems. These are:

1. Maintenance of Way
2. Maintenance of Equipment
   a) Locomotives
   b) Freight Cars
3. Transportation
   a) Train Operations
   b) Yard Operations
   c) Common Operations
   d) Specialized Service Operations
   e) Administrative Support Operations
4. General and Administrative

Each classification contains a set of individual cost items. For example, locomotive fuel, train and engine crew, train inspection, and dispatching costs are individual line items under the general heading of train operations.

Cost Estimation Process

Estimating costs for a network of lines is a three step process. First, a series of on-branch and off-branch unit costs are calculated. The unit costs reflect the variable expense per unit of output (e.g., fuel cost per locomotive hour) or the fixed capacity cost per mile of track (e.g., opportunity cost on net liquidation value). Second, output measures are calculated. This includes the number of annual output units (service units) consumed in serving the branch lines and the miles of track in the network. Third, the level of annual expenses attributable to the line or sub-system is computed by multiplying the service units by the related unit costs.

Sources of the Unit Costs

Fixed capacity on-branch unit costs are derived primarily from economic-engineering models or direct data sources. There are three primary unit costs in this group. They are: (1) normalized maintenance of way, (2) opportunity cost on net liquidation value (NLV), and (3) property taxes. All are line-specific items that can be directly computed for a set of lines.

Normalized MOW per mile is estimated from asset deterioration models and railroad productivity factors.[4] NLV per mile is computed from resale or scrap value of track materials, alternative land-use values, and engineering estimates of recovery cost.[5]

Variable and/or untraceable cost elements are estimated from accounting expenses and operating data contained in R-1 reports.[6] The R-1 unit costs are allocated unit costs. They represent the cost per unit of output for items that cannot be directly assigned to a

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[4]For a description of the deterioration models see: Tolliver and Lindamood, *An Analysis of the Benefits of Rehabilitating the Wahpeton-to-Independence Rail Line*, Staff Paper No. 96, Upper Great Plains Transportation Institute, North Dakota State University, Fargo, 1989.

[5]*See* Mittleider, Tolliver, and Vreugdenhil, *North Dakota Line Segment Analytical Model (NOLAM) - A Technical Description*, UGPTI Rep. No. 50, Upper Great Plains Transportation Institute, North Dakota State University, Fargo, 1983.

[6]The R-1 report is an annual report filed by Class I railroads with the ICC.

particular line segment. Examples of such costs are locomotive depreciation and return on investment.

Off-line unit costs are derived from R-1 expense and operating data using the ICC's cost finding formula, Rail Form A (RFA). The most current Burlington Northern and Soo Line R-1 reports are used to generate an annual updated file of off-line cost coefficients.[7]

Operating Models

The second step in the cost estimation process is the estimation of annual service units for the line or sub-system. This is accomplished with a set of operating models. The models predict the service units accumulated in consolidation and gathering activities on light-density lines. The models also predict the number of service units generated by the traffic as it moves to and from the junction points of the line.

Three concepts are of importance in operations modeling: (1) train class or service, (2) shipment service level, and (3) the scheduled frequency of service. There are three levels of train service, way or local train service, through train service, and unit train service. Way service reflects typical train operations on light-density networks. Way trains operate between classification yards and stations, spotting empty cars and pulling loaded ones. Through trains operate primarily between classification yards. They normally do not switch cars at individual stations. Through trains on light-density networks usually are bridge or overhead traffic which neither originates nor terminates on the lines. Unit trains provide direct service between stations and do not require yard classification.

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[7]For a more detailed explanation of the off-branch methods, *see* Tolliver, *The Benefits and Costs of Local and Regional Railroads*, pp. 67-95.

Shipment service level is a composite variable. It reflects the type and extent of activities that occur at individual stations, as well as the degree of classification off-line. There are four basic service levels: (1) single car, (2) multiple-car, (3) trainload, and (4) unit train.

Way trains typically operate between a classification yard and outlying stations along a designated route, according to a general timetable and schedule. Single-car, three-car, and other small multiple-car shipments are typically handled in scheduled way train service. The frequency of service is determined by the demand for cars along the route and by the operating condition of the lines. Light-density lines, because of low demand and poor operating conditions, typically receive service once or twice a week.

Multiple-car shipments are treated in one of two ways, depending on the service frequency. If large multiple-car shippers are located on a line, the scheduled frequency of way train service may be inadequate. If the frequency of service is less than three times per week, the detention/waiting time at stations will exceed tariff free time significantly. In such instances, large multiple-car shipments may be handled in direct or shuttle way trains. Shuttle way trains operate between classification yards and large multiple-car shippers, providing expedited service where the frequency of scheduled way train service is low.[8] If the service frequency is twice a week or less, large multiple-car shipments are assumed to be handled in direct way train service.

A true unit train is a direct, cyclical, continuous movement between an origin and destination, normally involving a dedicated locomotive and freight car set. A trainload shipment also involves direct origin-destination service. However, a trainload shipment is

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[8]Direct way trains may also handle other traffic that is ready for the pickup on the day of the service.

not a cyclical, continuous movement. Rather, trainload shipments may be sporadic and spread out during the year.

There are few, if any, unit train shipments originating or terminating on light-density networks. However, there may be trainload shippers. From a modeling perspective, a trainload shipment is treated as a separate, solid train.

Cost-Output Relationships

In calculating R-1 unit costs, accounts or groups of accounts are linked with closely related output measures. Cost-output relationships may be derived through statistical analysis, engineering analysis, or operational knowledge. The relationships adopted in this study mostly reflect the ICC's cost-output relationships that are used in abandonment or light-density surcharge analysis. The four most important ones are: (1) locomotive operations and ownership, (2) transportation expenses, (3) other equipment costs, and (4) general and administrative costs.

Locomotive Operations and Ownership

Road locomotive repairs and maintenance are a function of the weight of the units and the distance traveled. This relationship is most appropriately represented by the output variable road locomotive gross ton-miles. Unlike repairs, the servicing of road locomotives is not related to the weight of the unit. Rather it is a function of distance. Thus, servicing expenses are correlated with road locomotive unit miles.

Locomotive depreciation, rentals, leases, and opportunity costs are more closely related to time than to distance or use. The logical output measure for these expenses is hours of road locomotive operation. Locomotive fuel is primarily use-related. On light-density networks, locomotives operate much of the time at low speeds, idling, or switching cars at stations. These are fuel-intensive activities. Thus, hours of operation is a better measure of branch-line fuel consumption than miles or gross ton-miles.

Yard locomotive activities involve the switching of cars over short distances. The principal measure of activity is yard locomotive hours. Unlike road locomotives which engage in running and switching activities under a variety of conditions, yard locomotive expenses are all directly related to yard hours.

Transportation Expenses

Train operating expenses (other than fuel) are related to both train-hours and train-miles. Crews are paid on a dual basis, reflecting both mileage and time. During light-density operations, crews spend a large proportion of their time running at low speeds, or switching at industry sidings. Thus, the basic day is determined most often on the basis of hours instead of miles. For this reason, on-branch crew wages are computed on a train-hour basis.

Most other train operating expenses are related to train-miles. They include train inspection and lubrication, operating signals and interlockers, operating highway grade crossings, and train dispatching. All yard operating expenses are developed on a yard switching-hour basis.

Other Equipment Costs

Freight car repairs and depreciation are a function of time and usage. The ICC has developed factors for the apportionment of each expense among car-days and car-miles. Freight car opportunity costs are solely time-related, and thus are expressed on a car-day basis.

Trailer and container ownership costs are primarily time-related. While on the rail leg of an intermodal shipment, most of the repairs and maintenance are due to weather, environment, or time instead of use. All TOFC/COFC ownership costs are computed on a trailer- or container-day basis.

General and Administrative Expenses

General and administrative expenses involve items such as marketing, sales, legal and secretarial services, accounting and finance, and research and development. These expenses are primarily related to the level of activity for the entire system. However, they are partially related to the level of activity on individual subsystems. Certain accounting, financial, and other functions are required whenever carloads are originated or terminated, regardless of the size of the load. Thus, these expenses are more closely related to car-miles than gross ton-miles.

MODEL INFORMATION REQUIREMENTS

The economic-engineering costing method identifies the major factor inputs required to provide short line service. Costs are then estimated as the product of the factor input and associated factor price. In this section, the information required to estimate costs using the rail costing model are presented. This includes: (1) size of short line, (2) traffic characteristics, (3) costing procedures.

Size of Short Line

To obtain an estimate of economies of size, costs are estimated for nine model short lines. The miles of road range from 56 miles to 654 miles (Table 4.1). The synthesized short lines were selected at approximate increments of 75 miles in size. The range in miles of road is consistent with the industry data. For example, the mean miles of road for local railroads was 60.6 miles, ranging from 2 to 335 miles (Table 2.11). For regional railroads, the mean miles of road was 693.6 miles, ranging from 309 to 1969 miles. Since

TABLE 4.1. Miles of Road, Annual Carloads, and Traffic Density for Model Short Lines

Short Line System	Miles of Road	Annual Carloads	Traffic Density
SL1	55.8	2,578	46.2
SL2	129.2	6,334	49.0
SL3	208.7	8,022	38.4
SL4	268.5	8,751	32.6
SL5	349.7	9,007	25.8
SL6	429.6	10,477	24.4
SL7	510.8	10,733	21.0
SL8	569.1	11,017	19.4
SL9	654.0	11,263	17.2

the model is not constructed to simulate extensive yard operations, all of the model short lines are linehaul short lines.

Traffic Characteristics

The traffic data base for the model short lines was limited to grain shipments. Data availability was the primary reason for only using grain movements. The Upper Great Plains Transportation Institute maintains an extensive grain movement database, collecting monthly shipment data from all the grain elevators in North Dakota.[9]

Only using grain movements should not jeopardize the analysis. Recall that most short line are dependent upon one to three commodities for the bulk of their traffic. The top STCC group accounts for 66.4 percent of a linehaul short line's annual carloads (Table 2.7) The top three STCC groups are 89.1 percent of a typical linehaul short line's annual

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[9]*See* Olsen and Zink, *ND Grain and Oilseed Transportation Statistics*. UGPTI Rep. No. 83, 1990.

carloads. According to the secondary sources, grain accounts for 67 to 100 percent of the traffic for most line segments in North Dakota.

At 50.9 cars per mile, farm products had the lowest average traffic density for linehaul short lines created since 1970 (Table 2.10). The range of traffic densities for these railroads was from 2 to 174 cars per mile. With a 99 percent confidence level, the confidence interval estimate ranges from 36.9 to 65.8 cars per mile for short lines hauling at least 10 percent farm products. The traffic densities for the model short lines ranged from 17.22 cars per mile to 49.02 cars per mile (Table 4.1). The densities for the larger model short lines are somewhat lower than desired. However, this is not a problem for the cost analysis because the volume of traffic can be simulated to be at higher levels.

Costing Procedures

One of the difficulties of the economic-engineering costing approach is that the actual percent variable costs are unknown.

> "However, cost elements can generally be classified into categories based on operational and economic judgement. Most cost items can be categorized as either fixed or variable, based on their general relationship to traffic. (Wilson, Heads, and Tolliver).

Six cost items, normalized maintenance of way (NMOW), central administrative cost, property taxes, opportunity cost of net liquidation value (NLV), insurance, and interest on working capital are fixed line capacity costs. These items do not vary with traffic given the limited density range of short line carriers.

The other cost elements vary in some relationship to traffic. Some cost elements, such as train crew wages and fuel, vary in almost directly with traffic. Others are semi-variable in nature. However, there is no basis to determine the percent variable of each cost category. Thus, all other cost elements are defined to be variable. There are four general classes of variable cost. They are train crew costs, locomotive costs, car costs, and transportation costs.

The principal factor inputs for the short line costing model are reflected in two ways. Some factor input levels are specified to reflect short line operations. Other input requirements are generated from a series of operations models.

Train Crew Costs

Short line crew costs are the sum of crew wages, fringe benefits, and layovers, or

$$TRNCREW = CREWWAGE + FRINGE + LAYOVER \tag{4.1}$$

Crew wages are calculated as

$$CREWWAGE = CREWSIZE \times TRNHOURS \times WAGERATE \tag{4.2}$$

where: CREWSIZE = the number of persons on the train crew,
TRNHOURS = hours of operation for the train, and
WAGERATE = the hourly wage rate for train crew members.

Train hours are generated from one of the operations models. The crew size or consist and the hourly wage rate are specified parameters. A two-person crew is assumed to operate the train for an hourly wage rate of 10 dollars (Tolliver and Dooley). Fringe benefits are assumed to equal 30 percent of the hourly wages (Tolliver and Dooley).

An operations model is used to calculate the average time per trip. Federal hours of service rules require that a crew layover if train time is greater than 12 hours. The layover cost is the product of the number of layovers and a per diem charge of 30 dollars.

Locomotive Costs

Locomotive costs are the sum of lease payments and fuel expenses. Based on market conditions in 1988, the assumed lease payment was 100 dollars per day. The cost for locomotive fuel is based on an ICC costing formula used in abandonment cases. Fuel cost is the product of locomotive hours and the ICC prescribed rate of 32.89 dollars per hour.[10]

Car Costs

Operations models are used to generate estimates of system car-miles and car-days. Car days consist of four elements, running, loading and unloading, spotting and pulling, and waiting. Car days running depend on the distance from the yard and the average train speed. Car miles are calculated for each station as

$$CARMILES = SW_i \times CS_i \times SPR \tag{4.3}$$

where: SW_i = station way train miles,
CS_i = cars switched at station i, and
SPR = the spotted-to-pull ratio.

SPR indicates the frequency that an empty car must be spotted for every load that is pulled. SPR is 2 for most car types.

Car cost is then determined as the sum of car day cost (CARDAY) and car mile cost (CARMILE). CARDAY is:

$$CARDAY = NETCDAYS \times COST/DAY \times OVERHEAD \tag{4.4}$$

where: NETCDAY = car days for the short line network,
COST/DAY = a per day cost for car rental, and
OVERHEAD = an overhead charge assessed to cars.

OVERHEAD accounts for car repair shops, machinery, administration, and other indirect costs.

Similarly, CARMILE is

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[10]This value value was computed by indexing the 1982 GMA value for a 2,000 horsepower locomotive to current levels.

$$CARMILE = NETMILE \times COST/MI \times OVERHEAD \tag{4.5}$$

where: NETMILE = car miles for the short line network and
COST/MI = a per mile cost for car rental.

The assumed cost for COST/DAY is 10.34 dollars per day. For COST/MI, the assumed cost is 0.03 dollars per mile. The overhead rate for car costs is 11.3 percent.

Transportation Cost

Most transportation costs other than fuel are related to train miles. Transportation cost is the sum of train inspection and lubrication, operating signals and interlockers, operating highway grade crossings, train dispatching, and clearing wrecks.

Maintenance of Way

Normalized MOW per mile is estimated from asset deterioration models and railroad productivity factors. Based on a series of rail and tie life models and factor prices for each input, the assumed normalized MOW cost is 7,100 dollars per mile. Thus, the fixed MOW cost is the product of miles of road and 7,100 dollars per mile.

Administrative and Insurance Cost

Administrative and insurance costs were set for the synthesized short lines on the basis of discussions with insurance providers and short line management. The administrative cost ranges from 87,000 dollars per year for the smallest short line to 282,000 dollars per year for the largest model short line. Insurance cost ranged from 47,000 to 152,000 dollars.

Property Tax, Net Liquidation Value, and Interest on Working Capital

Property tax is the product of miles of road and a per mile tax assessment. The cost per mile for a short line in North Dakota is 111 dollars.

The net liquidation value (NLV) is determined as the product of miles of road, capital rate, and a value per mile. Based on discussions with industry personnel, the assumed value per mile of light density track is 15,000 dollars. Most of the short line's working capital is provided internally or from local banks. The short line pays the prevailing prime rate. The assumed interest rate is 10 percent.

Finally, interest on working capital is calculated as the product of the capital rate and 7.7 percent of annual variable costs. The 7.7 percent reflects the level of working capital required at any particular time. Once again, the interest rate is assumed to be 10 percent.

CHAPTER 5

EMPIRICAL RESULTS

The empirical results for the nine model short lines are presented, analyzed, and discussed in this chapter. The results for each model are presented by briefly describing the situation and reporting cost estimates. The results for the various models are then compared to analyze the effect of economies of size and density for short line railroads.

RESULTS FOR MODEL RAILROADS

The first model, SL1, is a single branch line, 55.8 miles long (Table 5.1). In size, it closely approximates the 60.6 mean miles of road for local railroads created since 1970 (Table 2.2). Seven grain elevators are served on the line. For the crop year 1988, 2,578 carloads of grain were shipped from the line (Table 5.1). Thus, the traffic density is 46.2 cars per mile (CPM). The typical grain dependent short line had a density of 50.9 CPM (Table 2.10).

The cost structure is dominated by fixed costs; only 29.4 percent of the costs is variable (Table 5.1). At 396,180 dollars, maintenance of way (MOW) accounts for 55 percent of total fixed costs. Transportation cost and car cost are the most important components of variable cost, each accounting for about 31 percent of total variable costs. The average total cost per carload is 396 dollars.

SL2 operates 129.2 miles of track (Table 5.1). Fourteen grain elevators shipped 6,334 carloads of grain in 1988. SL2 has the highest density of the nine model railroads, at 49.0 CPM.

The percent variable cost for SL2 increased to 36 percent (Table 5.1). Compared to SL1, car cost is a much more important component of total variable cost. For SL2, car

TABLE 5.1 Output and Costs for Model Short Lines SL1, SL2, and SL3

Railroad	SL1	SL2	SL3
SHORT LINE OUTPUT			
Miles of Road	55.8	129.2	208.7
Carloads	2,578	6,334	8,022
Traffic Density (Cars/mi)	46.2	49.0	38.4
VARIABLE COSTS			
Train Crew Cost	$64,393	$158,179	$273,133
Locomotive Cost	50,700	126,864	208,250
Car Cost	91,452	285,979	396,302
Transportation Cost	92,851	229,384	384,364
TOTAL VARIABLE COST	$299,396	$800,406	$1,262,049
FIXED COSTS			
Maintenance of Way	$396,180	$917,320	$1,481,770
Net Liquidation Value	83,700	193,800	313,050
Central Administration	87,340	127,430	165,880
Insurance	47,030	68,620	89,320
Interest on Working Capital	100,000	100,000	100,000
Property Tax	6,194	14,341	23,166
TOTAL FIXED COST	$720,444	$1,421,511	$2,173,186
TOTAL COSTS	$1,019,840	$2,221,917	$3,435,235
PERCENT VARIABLE COST	29.4%	36.0%	36.7%
COST PER CARLOAD	$396	$351	$428

cost is 285,979 dollars, or 35.7 percent of total variable costs. Compared with SL1, MOW is even a greater proportion of total fixed costs. For SL2, MOW is 64.5 percent of total fixed costs. The cost per carload of 351 dollars is the lowest for the nine model systems.

SL3 operates 208.7 miles of track (Table 5.1). SL3 is typical of a short line spunoff by western Class I railroads since 1970. The 23 grain elevators on the system shipped 8,022 carloads of grain in 1988. The traffic density is 38.4 carloads per mile.

Adjusted for size, the cost structures of SL2 and SL3 are similar. The percent variable cost is almost the same, 36.0 and 36.7 percent for SL2 and SL3, respectively (Table 5.1). As a proportion of total fixed costs, MOW rises to 68.2 percent. Car cost and transportation cost remain the most important items of total variable cost. Corresponding with the fall in density, the average total cost per carload rises to 428 dollars.

Operating 268.5 miles of road, SL4 represents a large local railroad (Table 5.2). Twenty-seven grain shippers are served on the system. In 1988, 8,751 carload of grain were shipped from SL4. The traffic density is 32.6 cars per mile.

With the decline in traffic density from SL3 to SL4, the percent variable cost also falls, to 34.6 percent (Table 5.2). MOW increases slightly, to 69.9 percent of total fixed costs. Transportation cost and car costs shift in importance, both remaining about 31 percent of total variable cost. The average total cost per carload rises to 477 dollars.

SL5 represents the transition point between a large local and a small regional railroad. SL5 has 349.7 miles of track and a traffic density of 25.8 CPM (Table 5.2). Thirty-two grain shippers are served on SL5. In 1988, 9,007 cars of grain were loaded on the system.

With the fall in density, the percent variable cost dropped from 34.6 percent for SL4 to 30.7 percent for SL5 (Table 5.2). MOW climbs to 71.4 percent of total fixed costs. The average total cost per car rises further, to 557 dollars per car.

SL6 operates 429.6 miles of track, serving 40 grain elevators. In 1988, 10,477 cars of grain were shipped from the system. The traffic density for SL6 is 24.4 cars per mile.

The percent variable cost for SL5 and SL6 is about the same. Adjusted for size, there is no appreciable difference in costs for SL5 and SL6. For SL6, transportation cost is relatively more important than car cost. The average total cost per car for SL6 is 600 dollars (Table 5.2).

TABLE 5.2 Output and Costs for Model Short Lines SL4, SL5, and SL6

Railroad	SL4	SL5	SL6
SHORT LINE OUTPUT			
Miles of Road	268.5	349.7	429.6
Carloads	8,751	9,007	10,477
Traffic Density	32.6	25.8	24.4
VARIABLE COSTS			
Train Crew Cost	$313,391	$335,268	$447,151
Locomotive Cost	238,609	255,000	340,601
Car Cost	442,545	468,729	544,570
Transportation Cost	446,547	480,256	653,025
TOTAL VARIABLE COST	$1,441,092	$1,539,253	$1,985,347
FIXED COSTS			
Maintenance of Way	$1,906,350	$2,482,870	$3,050,160
Net Liquidation Value	402,750	524,550	721,728
Central Administration	188,600	215,260	237,990
Insurance	101,550	115,910	128,150
Interest on Working Capital	100,000	100,000	112,000
Property Tax	29,804	38,817	47,686
TOTAL FIXED COST	$2,729,054	$3,477,407	$4,297,714
TOTAL COSTS	$4,170,146	$5,016,660	$6,283,061
PERCENT VARIABLE COSTS	34.6%	30.7%	31.6%
COST PER CARLOAD	$477	$557	$600

Forty-five grain shippers are located on the 510.8 miles of road on SL7 (Table 5.3). In 1988, 10,733 cars were loaded from the system. The traffic density for SL7 is only 21.0 cars per mile.

The percent variable cost for SL7 is 29.2 percent (Table 5.3). Thus, despite being almost seven times the size of SL1, SL7 has almost the same percent variable cost. With

TABLE 5.3 Output and Costs for Model Short Lines SL7, SL8, and SL9

Railroad	SL7	SL8	SL9
SHORT LINE OUTPUT			
Miles of Road	510.8	569.1	654.0
Carloads	10,733	11,017	11,263
Traffic Density	21.0	19.4	17.2
VARIABLE COSTS			
Train Crew Cost	$469,027	$494,174	$548,209
Locomotive Cost	356,992	375,833	408,495
Car Cost	570,754	602,131	629,198
Transportation Cost	686,734	725,249	768,762
TOTAL VARIABLE COST	$2,083,507	$2,197,387	$2,354,664
FIXED COSTS			
Maintenance of Way	$3,626,680	$4,040,610	$4,643,400
Net Liquidation Value	858,144	956,088	1,098,720
Central Administration	256,410	265,290	282,100
Insurance	138,070	142,850	151,900
Interest on Working Capital	112,000	112,000	112,000
Property Tax	56,699	63,170	72,594
TOTAL FIXED COST	$5,048,003	$5,580,008	$6,360,714
TOTAL COSTS	$7,131,510	$7,777,395	$8,715,378
PERCENT VARIABLE COST	29.2%	28.3%	27.0%
COST PER CARLOAD	$664	$706	$774

the decline in traffic density, car costs make up a smaller proportion of total variable costs. The average total cost per car for SL7 is 664 dollars.

SL8 operates 569.1 miles of road, serving 50 grain elevators (Table 5.3). In 1988, 11,017 cars were loaded from SL8. The average density is 19.4 cars per mile.

The percent variable cost for SL8 is 28.3 percent (Table 5.3). Adjusted for size, its cost makeup is similar to SL7's. The cost per mile for SL8 is 706 dollars.

SL9, the largest model regional railroad, operates 654.0 miles of road (Table 5.3). SL9 serves 54 grain shippers who loaded 11,263 cars of grain in 1988. The traffic density for SL9 of 17.2 is the lowest of the nine model railroads.

The percent variable cost is lowest for SL9, at only 27.0 percent (Table 5.3). MOW dominates total fixed costs, accounting for 73.0 percent of total fixed costs. The relationship among variable cost items remains consistent, with transportation costs being the most important component. The average total cost per car on SL9 is 774 dollars.

In summary, the percent variable cost rises from 29.4 percent for SL1 to a maximum of 36.7 percent for SL3, before steadily falling to 27.0 percent for SL9. Thus, fixed costs dominate the cost structure for the nine model short line railroads. The percent variable cost first rises because fixed costs are spread over a larger traffic volume. Eventually percent variable cost declines because the increases in traffic volume for the larger sized short lines are not in proportion to the increase in miles of road.

Fixed cost factors related to the rail network, MOW and net liquidation value, dominate the make-up of fixed costs. As a relative percentage, these items increase in importance as the model railroads become larger. Intuitively, the other fixed costs of the railroad remain relatively constant. Thus, the increase in fixed cost is directly attributable to the additional trackage.

Car cost and transportation cost are the most important components of variable cost. Car costs decrease in importance for the larger systems because the traffic density declines. To incur car costs, the railroad must handle the cars.

In conclusion, the lowest average total cost per car is for SL2 at 351 dollars per car. The highest average total cost per car is for the largest system, SL9, at 774 dollars per car. The average total cost per carload is lower on the smaller model short lines than the larger sized railroads because of traffic density. Density appears to be a much more important factor for costs than miles of road. In the next section, economies of size and density are isolated.

ECONOMIES OF SIZE AND DENSITY

An important advantage of simulation models is that different scenarios can be analyzed by doing additional runs. For each of the nine model short lines, density was simulated at six different levels. Cost estimates were obtained for densities ranging from 20 to 70 cars per mile, at an increment of 10 cars per mile.

The analysis of economies of size and density is presented in three ways. First, two scatterplots are presented. Second, a simple statistical analysis is presented in tabular format. Finally, multiple-regression is used to estimate a short run cost function.

Graphical Analysis

Figure 5.1 is a scatterplot of costs per car and traffic density. For each of the nine model short lines, six cost estimates were obtained. Costs were estimated for traffic densities of 20, 30, 40, 50, 60, and 70 cars per mile. The X-axis in Figure 5.1 is cars per mile. For each density level, there is a point for each of the nine model short lines.

The graphical analysis suggests there are significant economies of density over the range 20 to 70 cars per mile (Figure 5.1). At 20 CPM, the average total cost per car ranges from 852 dollars for SL1 to 676 dollars for SL9 (Table 5.4). At 70 CPM, the average total cost per car ranges from 278 dollars for SL1 to 246 dollars for SL9. Economies of density lessen, but are not exhausted over the range of observations.

In addition to economies of density, it appears that the cost advantage enjoyed by larger short lines diminishes with an increase in density. The range in average total cost per car narrows from 176 dollars at 20 CPM to 32 dollars at 70 CPM. In percentage terms, the range decreases from a difference of 20.7 percent to 11.5 percent.

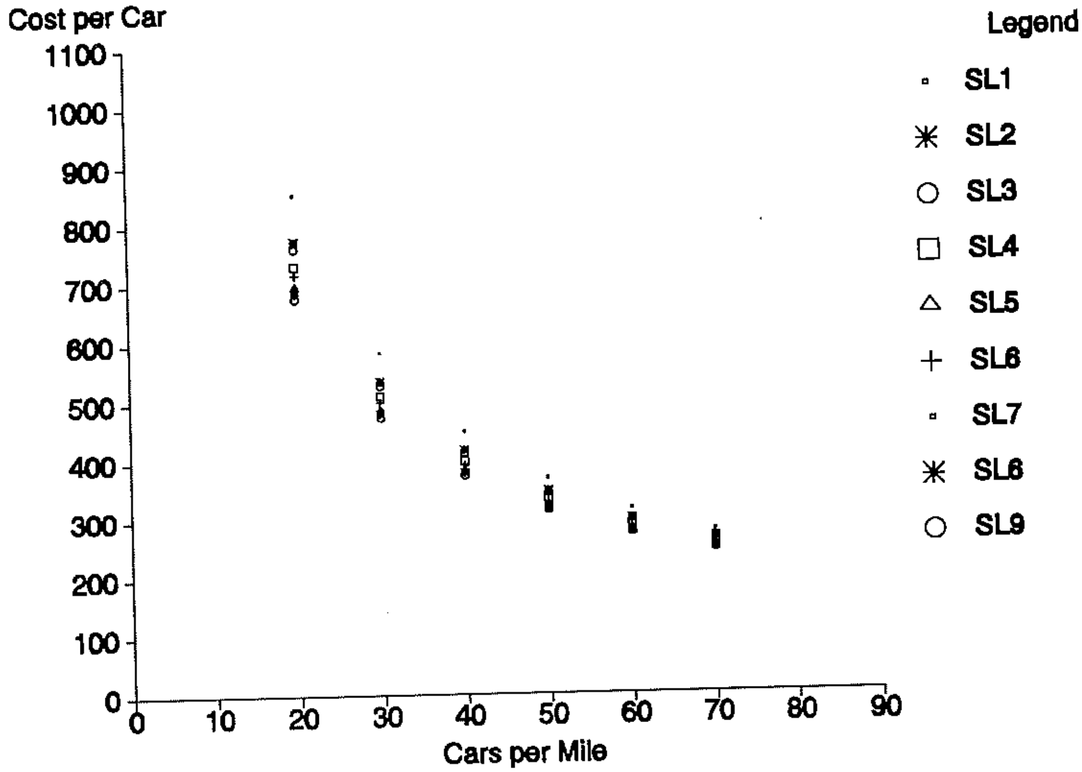

FIGURE 5.1. Density Scatterplot

Figure 5.2 is a scatterplot of costs per car and miles of road. Considering economies of size, it compliments Figure 5.1. The X-axis in Figure 5.2 is miles of road. For each of the nine model short lines, there is a point corresponding to the six density levels.

Economies of size are more prevalent at lower traffic density levels. For example, consider the points for a density level of 20 CPM. The costs fall from 852 dollars per car for SL1, a 56 mile local, to 676 dollars for SL9, a 654 mile regional (Table 5.4). Most of the economies of size are exhausted at 200 miles of road. Economies of size are less important at a traffic density of 70 CPM. At this density level, the average total cost per car falls from 278 dollars for SL1 to 246 dollars for SL9.

TABLE 5.4. Cost per Car for Various Short Line Railroads, Size Cost Ratios, and Density Cost Ratios

DENSITY (Cars per mile)	RAIL NETWORK (size in miles of road)									
	SL1 56.2	SL2 129.2	SL3 208.7	SL4 268.5	SL5 349.7	SL6 429.6	SL7 510.8	SL8 569.1	SL9 654.0	
	Average Total Cost per Car									
20 CPM	$852	$774	$761	$732	$697	$716	$694	$685	$676	
30 CPM	584	535	529	511	488	500	486	481	475	
40 CPM	450	418	413	401	383	392	382	379	375	
50 CPM	369	346	344	334	320	328	320	317	315	
60 CPM	316	298	298	290	279	285	278	277	275	
70 CPM	278	264	265	258	249	254	249	248	246	
	Density Cost Ratio									MEAN
20 CPM	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
30 CPM	68.5	69.1	69.5	69.8	70.0	69.8	70.0	70.2	70.3	69.7
40 CPM	52.8	54.0	54.3	54.8	54.9	54.9	55.0	55.3	55.5	54.6
50 CPM	43.3	44.7	45.2	45.6	45.9	45.8	46.1	46.3	46.6	45.5
60 CPM	37.1	38.5	39.2	39.6	40.0	39.8	40.1	40.4	40.7	39.2
70 CPM	32.6	34.1	34.8	35.2	35.7	35.5	35.9	36.2	36.4	35.2
	Size Cost Ratio									
20 CPM	100.0	90.8%	89.3%	85.9%	81.8%	84.0	81.5%	80.4%	79.3%	
30 CPM	100.0	91.6	90.6	87.5	83.6	85.6	83.2	82.4	81.3	
40 CPM	100.0	92.9	91.8	89.1	85.1	87.3	84.9	84.2	83.3	
50 CPM	100.0	93.8	93.2	90.5	86.7	88.9	86.7	85.9	85.4	
60 CPM	100.0	94.3	94.3	91.8	88.3	90.2	88.0	87.7	87.0	
70 CPM	100.0	95.0	95.3	92.8	89.6	91.4	89.6	89.2	88.5	
MEAN	100.0	93.1	92.4	89.6	85.8	87.9	85.6	85.0	84.1	

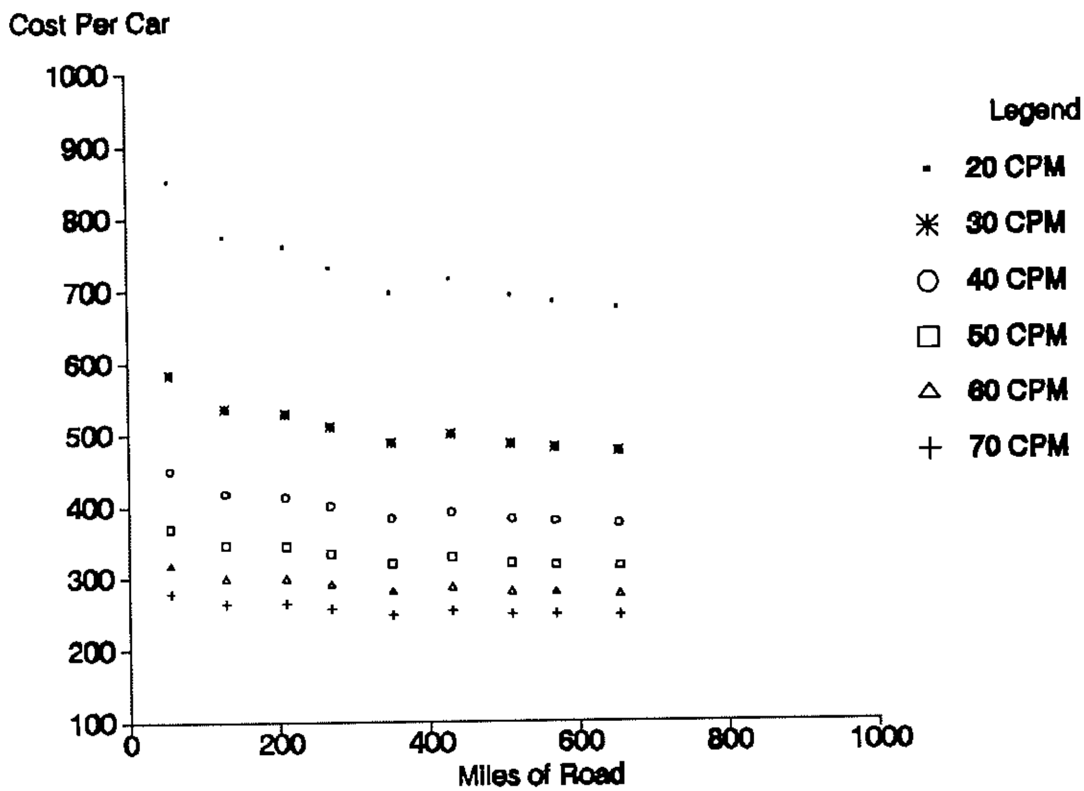

FIGURE 5.2. Size Scatterplot

Tabular Analysis

Further insight into the extent of economies of density and size are gleaned from some simple statistics. Cost ratios are developed to measure the average cost savings associated with an increase in size and density.

The density cost ratio was calculated using 20 CPM as the baseline. For each observation, a cost ratio was calculated. For example, the rail density cost ratio for SL1 at 30 CPM is $584/$852 or 68.5 percent (Table 5.4). For each density level, a mean density cost ratio was calculated (the shaded column in Table 5.4). It is the mean of the densities for the nine model short lines.

On average, an increase in the traffic density from 20 to 30 CPM lowers average total average total cost per car by 30.3 percent (Table 5.4). Average total cost per car continues to decline with further increases in density. The mean cost per car was 54.6 percent of the base at a density of 40 CPM, 45.5 percent at 50 CPM, 39.2 percent at 60 CPM, and 35.2 percent at 70 CPM. Thus, increasing traffic density offers significant opportunities for lowering costs.

The size cost ratio was calculated in a similar manner. For the size cost ratio, SL1 was the baseline railroad. For each short line, a mean size cost ratio was calculated (the shaded row in Table 5.4).

On average, doubling the size of the network from 56 miles to 129 miles decreased average total cost per car by 6.9 percent (Table 5.4). Further increases in size were accompanied with minimal cost savings. Average costs per car for SL9, the largest model short line, were 15.9 percent lower than SL1. However, the size cost savings were largely realized at a size of 350 miles.

Regression Analysis

A total cost function for short line railroads is specified as:

$$TC = \beta_0 CM + \beta_1 MR + \beta_2 CL \tag{5.1}$$

where:
TC = Total Cost,
CM = Car Miles,
MR = Miles of Road, and
CL = Car Loads of traffic.

This specification of total cost is similar to an alternative specification (equation 12) by Harris (1977). In that specification, he included MR, revenue ton miles (RTM), and revenue freight tons (RFT). In equation 5.1, CM is a proxy for RTM and CL is a proxy for RFT.

The ordinary least squares estimation of the parameters is presented as regression 1 in Table 5.5. All the parameters are significant at the 99 percent level of confidence.

TABLE 5.5. Summary of Regression Results

Item	Regression Number 1	2	3	4
Dependent Variable	TC	TC	TC	AC=TC/TM
Independent Variables	Point Estimates for the Independent Variables (T Value)			
MR	12,473.72 (137.61)	12,473.11 (108.14)	9,288.45 (63.02)	
CL	185.15 (10.07)	71.40 (27.69)	63.30 (68.47)	
CM	-0.58 (-6.23)			
TM			7.89 (22.37)	
MR/TM = 1/DENSITY				8,027.99 (14.27)
CL/TM = 1/ALH				56.23 (14.27)
TM/TM = Intercept				11.59 (9.34)
R^2	.9996	.9993	.9999	.8631
F-Value	48,086.8	44,450.2	272,837.9	189.1

The R^2 of .9996 suggests an extremely good fit. However, the sign of CM is incorrect; it should be positive. This problem most likely arises because of multicollinearity between CL and CM.

Two alternative treatments are used for the multicollinearity problem. First, the variable CM is dropped from the model in regression 2. The signs for both parameters are positive, as expected, and significant at the 99 percent confidence level (Table 5.5). However, this treatment of multicollinearity is not preferred because it introduces specification error.

In the second treatment the variable CM is replaced by a similar output variable, train miles (TM). The results for this specification are reported as regression number 3 in Table 5.5. All three variables are significant at the 99 percent level of confidence and have the correct sign. The R^2 is .9999, indicating an extremely good fit. Regression number 3 is judged to be the best estimate of short line total costs.

From the total cost function, an average cost per train mile can be derived as:

$$\begin{aligned} AC &= \frac{TC}{TM} = \beta_0\frac{TM}{TM} + \beta_1\frac{MR}{TM} + \beta_2\frac{CL}{TM} \\ &= \beta_0 + \beta_1\frac{1}{DENSITY} + \beta_2\frac{1}{ALH} \end{aligned} \tag{5.2}$$

where: AC = Average Cost per Train Mile,
DENSITY = Carloads per Mile,
ALH = Average Length of Haul.

This implies that average cost is reciprocally related to length of haul and density. The specification of average cost is similar to that by Harris (1977) and Charney, Sidhu, and Due.

The results for the average cost equation are reported as regression number 4 in Table 5.5. All the variables are significant at the 99 percent level and have the right sign. The positive signs for ALH and DENSITY means that average cost per train mile falls at an decreasing rate as density, average length of haul, or both increase.

All three of the total cost functions were estimated as linear functions. Economic theory suggests that cost functions are curvilinear. The use of a linear function was judged to be appropriate in this application because of the limited range in size of railroads and density. The average cost function, regression number 4, is consistent with theoretical expectations.

To evaluate economies of density, the elasticity of total cost with respect to carloads was calculated. This elasticity was calculated at the mean density value using the estimates from regressions 1, 2, and 3 (Table 5.6). The estimated elasticity of total

TABLE 5.6. Calculated Short Line Cost Elasticities

Regression Number	Elasticity of TC with respect to MR	Elasticity of TC with respect to CL	Elasticity of TC with respect to CM
1	0.80	0.48	-0.28
2	0.80	0.18	no estimate
3	0.60	0.16	0.24

cost with respect to carloads is quite similar in regressions 2 and 3, at 0.18 and 0.16, respectively. These values are almost identical to the 0.17 cost elasticity with respect to density estimated by Braeutigam, Daughety, and Turnquist (1982). The results lie in the range of elasticities of density for short line railroads estimated by Sidhu, Charney, and Due. The higher elasticity for regression 1, 0.48, is suspect because of the multicollinearity between CM and CL.

The low elasticity of total cost with respect to density suggests that marginal cost is very low relative to average cost. Thus, an increase in density should act to substantially lower average cost. The elasticity of total cost with respect to density corroborates the earlier graphical and tabular discussion.

The elasticity of total cost with respect to MR was calculated to analyze economies of size. The range for the size cost elasticities are between 0.60 and 0.80. This suggests that some economies of size advantages are yet available to short line railroads. Recall that most studies have concluded that economies of size are exhausted for Class I carriers (see Table 3.1).

Finally, the elasticity of cost with respect to CM and TM was calculated to analyze economies of average length of haul. The results for regression 1 are not meaningful because of the incorrect sign. The results for regression 3, 0.24, suggest there are substantial economies of length of haul for short lines. However, in application, these economies are probably not available because length of haul is constrained by the size of the short line network. That is, a short line with 50 miles of road cannot have a length of haul longer than 50 miles.

CONCLUSIONS

In summary, fixed costs dominate the cost structure for the nine model short line railroads. The percent variable cost is between 27 and 36 percent. Maintenance of way and net liquidation value, fixed cost factors related to the rail track, account for about 70 percent of the fixed costs. Car cost and transportation cost are the most important components of variable cost.

An increase in traffic density offers substantial opportunities for lowering average costs. On average, an increase in the traffic density from 20 to 30 cars per mile (CPM) lowers average total average total cost per car by 30 percent. Average total cost per car continues to decline with further increases in density. At 70 CPM, The mean cost per car was 35.2 percent of the 20 CPM baseline. The elasticity of cost with respect to carloads was between 0.16 to 0.18.

Economies of size are less significant for short lines. Increasing the size of the network from 56 miles to 129 miles decreased average total cost per car by 7 percent. However, further increases in size were accompanied by only minimal cost savings. Size cost savings are largely realized at a size of 350 miles. The elasticity of cost with respect to miles of road was between 0.60 to 0.80.

Two broad conclusions can be drawn from the empirical analysis. First, potential cost savings from economies of size are limited for short lines. Second, achieving economies of density is a strategy that allow short lines to significantly lower their costs. Further insights are drawn in the next, and final, chapter.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Short line railroads have increasingly become an important component of the U.S. transportation system. The information base on particular elements of short line costs is developing. However, little information is available about the relationship between costs and outputs for the new short lines. Information on economies of size and density of railroads is used by both the public and private sectors. Rail management and shippers use such information in planning expansion, pricing, location, rail operations, etc. Public sector parties use such information to formulate public policy about issues such as rail mergers and maximum price policies.

There is general agreement about the extent of economies of density and size for Class I railroads. The lack of comparable information for short line railroads has hindered both the private and public sector's ability to make informed judgments and decisions regarding the relatively new economic phenomena of short line railroads.

The general purpose of this study was to determine the extent that economies of size and density are available to short line railroads. To achieve this purpose, the specific objectives of this study were:

1. To expand upon the work of Due and others, providing additional information about the reasons for and the nature of the evolution of the short line railroad industry;
2. To examine and further develop the theoretical framework of cost for the short line railroad industry;
3. To develop theoretically consistent estimates of short line costs using a short line simulation costing model;
4. To provide guidelines to assist the rail industry, rail labor, and state and federal policy-makers adjust to the changing structure of the rail industry.

The information required to evaluate economies of density and size in the short line industry was developed from various secondary sources. The exploratory phase of the research included informal discussions with individuals from short line and Class I railroads and a cursory literature review. Once the study objectives were defined, a comprehensive literature review of the short line railroad industry and economic costing theory was conducted. From this information, modifications to the North Dakota Short Line costing model were made. The simulation costing model was then used to analyze the short line railroad cost structure.

SUMMARY

A fundamental understanding of the growth of the short line rail industry was a prerequisite to the development of an economic costing model. A review of the short line rail industry was presented in Chapter 2, focusing upon three factors. First, factors underlying the development of short lines were reviewed. Second, characteristics of short lines were presented. Finally, important differences in the cost structure of Class I and short line railroads were identified.

Since the mid-1970s, Class I railroads have been attempting to rationalize their rail networks by either abandoning or selling their light-density branch lines. Since 1970, almost 40,000 miles of road has been abandoned. During the same time, 240 new short lines operating almost 21,000 miles of track have been created.

Short lines created since 1970 are much different from short lines created before 1970. The typical short line created since 1970 is longer, but employs fewer people than short lines formed before 1970. On average, a short line formed since 1970 is 87.3 miles long and employs 31.6 people. In contrast, the average short line formed before 1970 is only 52 miles long, but has 86.5 employees. Thus, the average number of employees per mile of track has fallen from 2.77 to 0.54, or 80.5 percent.

Compared with Class I trunk lines, most short lines operate over light density lines. In addition, short lines formed since 1970 have a much lower average traffic density than those created before 1970. The pre-1970 average density for local and regional railroads was 451.3 cars per mile. Since 1970, the average density for local and regional railroads has fallen by 75.7 percent to 109.6 cars per mile.

In conclusion, the spinoff of short lines by Class I carriers has created a short line industry with two distinct segments. As a whole, pre-1970 short lines are viable small railroads. In contrast, many of the short lines created since 1970 operate over lines that were at best marginally profitable for their former Class I owners. As such, the economic success of the new short lines is closely related to their ability to control costs, especially labor, and provide improved service.

Class I railroads reported that they may sell an additional 17,265 miles of track in the next five years. The characteristics of these potential short lines are most likely similar to those of short lines created since 1970. Given the lower traffic densities on these lines, public policies and private decision-making must recognize that the new short lines will require a more flexible cost structure to operate economically.

The sources of institutional change identified in Chapter 2 are causing changes in the structure of the rail industry. Such changes may alter the efficiency and competitiveness of the rail industry, thereby affecting all participants. This includes the railroads, rail labor, shippers, competing modes, and various government agencies. To provide an understanding of economies of size and density, neoclassical economic cost theory was reviewed in Chapter 3.

Based on the economic theory developed in Chapter 3, an empirical model was formulated in Chapter 4. A synthetic costing model, based on economic-engineering and cost accounting, was adopted for this research. The model included a set of procedures for calculating Class I carrier line-segment unit costs and applying them to light-density lines or networks.

The results from the empirical analysis were reported and analyzed in Chapter 5. Results about economies of density and size were reported in three ways, a graphical analysis, a tabular statistical analysis, and multiple-regression. The results were compared to analyze the relative importance of economies of size and density.

CONCLUSIONS

In summary, fixed costs dominate the cost structure for the nine model short line railroads. The percent variable cost is between 27 and 36 percent. Maintenance of way and net liquidation value, fixed cost factors related to the rail track, account for about 70 percent of the fixed costs. Car cost and transportation cost are the most important components of variable cost.

An increase in traffic density offers substantial opportunities for lowering average costs. On average, an increase in the traffic density from 20 to 30 cars per mile (CPM) lowers average total average total cost per car by 30 percent. Average total cost per car continues to decline with further increases in density. At 70 CPM, the mean cost per car was 35.2 percent of the 20 CPM baseline density. The elasticity of cost with respect to carloads was between 0.16 to 0.18.

Economies of size are less significant for short lines. Increasing the size of the network from 56 miles to 129 miles decreased average total cost per car by 7 percent. Further increases in size were accompanied by only minimal cost savings. Size cost savings are largely realized at a size of 350 miles. The elasticity of cost with respect to miles of road was between 0.60 to 0.80.

The findings suggest that potential cost savings from economies of size are limited for short lines. This is consistent with the findings for Class I carriers. Economies of size opportunities for short lines are also constrained by definition. When a carrier reaches a certain size, the Interstate Commerce Commission reclassifies it to be a Class I carrier.

The most important finding is the importance of economies of density relative to economies of size. In part, this arises because short lines have a cost structure characterized by large fixed costs.

This finding suggests that short line management should focus upon expanding traffic, not expanding the size of their operation. Short lines should work closely with shippers to show them the importance of increasing traffic density. In turn, an increase in volume may help short lines stabilize their operations, their costs, and ultimately, their rates.

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APPENDIX A

PAIRED T-TEST

The SAS t test employed tests the hypothesis that the true means for two groups of observations are the same.[1] The test computes the t statistic based on the assumption that the variances of the two groups are equal and also computes an approximate t based on the assumption that the variances are unequal.

The t statistic for testing the equality of means x_1 and x_2 from two independent samples with n_1 and n_2 observations is

$$t = \frac{(\overline{x_1} - \overline{x_2})}{\sqrt{s^2(1/n_1 + 1/n_2)}} \tag{A.1}$$

where s^2 is the pooled variance, or

$$s^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \tag{A.2}$$

where s_1^2 and s_2^2 are the sample variances of the two groups. The use of this t statistic depends on the assumption that population variances of the two groups are equal.

Under the assumption of unequal variances, the approximate t is computed as:

$$t = \frac{(\overline{x_1} - \overline{x_2})}{\sqrt{(s_1^2/n_1 + s_2^2/n_2)}} \tag{A.3}$$

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[1]See the *SAS/STAT User's Guide: Volume 2, GLM-VARCOMPV,* Version 6, 4th Ed., Cary, NC: SAS Institute, 1990, for details about the procedure.