TECHNICAL REPORT

THE TEXAS RAIL SYSTEM:
AN OPERATING AND FACILITY DESCRIPTION

Texas Rail Evaluation

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July 1977

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PREFACE

This report describes the operations and facilities comprising the Texas rail system and identifies relationships among rail operations, financial trends and rail facilities.

Rather than an attempt to chronical each mile of rail line in Texas and categorize the physical characteristics of rail line with indices of relative "quality," this report develops relationships between rail traffic and physical plant. Within this context, rail system physical components, maintenance and investment can be perceived as variables dependent upon rail traffic levels and financial viability. Variations in rail traffic and financial position result in variations in the physical plant, maintenance and investment levels. Thus, relationships among these variables provide explanations for observable differences in the Texas rail system.

I. Texas Rail Operations and Facilities

Railroad Mileage in Texas

There are presently 22 on line haul rail carriers in Texas. The line haul carrier groups exclude switching and terminal companies. The estimated 22 on line haul carriers include the aggregation of Class I rail carriers and their affiliates into 9 major rail systems. A list of the line haul rail carriers operating in Texas appears in Table 1.

TABLE 1: LINE HAUL RAIL CARRIERS OPERATING IN TEXAS

CLASS I	
1. BURLINGTON SYSTEM	
Fort Worth & Denver	(FWD)
2. FRISCO SYSTEM	
St. Louis San Francisco	(SLSF)
Quanah, Acme & Pacific	(QAP)
3. KANSAS CITY SOUTHERN	
Kansas City Southern	(KCS)
Louisiana & Arkansas	(LA)
4. MISSOURI KANSAS TEXAS	
Missouri Kansas Texas	(MKT)
5. MISSOURI PACIFIC	
Missouri Pacific	(MP)
Abiline & Southern	
Texas - New Mexico	
Weatherford, Mineral Wells & Northwestern	

TABLE 1 (continued)

6.	ROCK ISLAND	
	Chicago, Rock Island & Pacific	(RI)
7.	SANTA FE	
	Atchison, Topeka & Santa Fe	(ATSF)
8.	SOUTHERN PACIFIC	
	Southern Pacific	(SP)
	St. Louis Southwestern	(SSW)
9.	TEXAS MEXICAN*	
	Texas Mexican	(TM)
	CLASS II	
10.	ANGELINA & NECHES RIVER	(ANR)
11.	GALVESTON, HOUSTON & HENDERSON	(GHH)
12.	GEORGETOWN RAILROAD	(GRR)
13.	MOSCOW CAMDEN & SAN AUGUSTINE	(MCSA)
14.	PECOS VALLEY SOUTHERN	(PVS)
15.	ROSCOW SNYDER & PACIFIC	(RSP)
16.	ROCKDALE SANDOW & SOUTHERN	(RSS)
17.	SABINE RIVER & NORTHERN	(SRN)
18.	TEXAS CENTRAL	(TEXC)
19.	TEXAS & NORTHERN	(TN)
20.	TEXAS SOUTH-EASTERN	(TSE)
21.	TEXAS STATE RAILROAD	(TSR)
22.	WESTERN RAILROAD CO.	(WRR)

Source: Annual Reports of the Railroad Commission of Texas, Texas Railroad Map, Jimmy V. Morris Map Co., 1973 ed., National Railroad Highway Crossing Inventory File, U.S. Department of Transportation and Association of American Railroads, 1976.

* The Texas Mexican was not reported as a Class I carrier until 1973.

Total 1973 rail mileage in Texas represented approximately 86% of Texas rail mileage in 1955. Rail mileage in the United States represented 91% of the rail mileage owned in 1955. While the absolute mileage of the rail physical plant in Texas has declined more rapidly than that of the United States, the financial position of Texas rail carriers has not eroded as quickly as the U.S. rail industry average. Tables 2 and 3 illustrate changes in rail mileage and financial position of U.S. and Texas carriers from 1955 to 1973. In 1973 Texas lead all other states in rail mileage with approximately 7% of U.S. rail mileage.

TABLE 2: RAIL MILEAGE OWNED - U.S. and TEXAS

Year	Texas Mileage	U.S. Mileage
1955	15,378	220,670
1960	14,678	217,552
1965	14,445	211,925
1970	13,545	206,265
1973	13,301	201,585

Source: <u>Texas</u> - Annual Reports of the Railroad Commission of Texas
<u>U.S.</u> - <u>Yearbook of Railroad Facts</u>; Association of American Railroads.

TABLE 3: CHANGE IN RAIL MILEAGE & FINANCIAL POSITIONS - U.S. and TEXAS RAILROADS

Year	Texas Miles	Rate of Return On Net Investment Texas Railroads	U.S. Miles	Rate of Return On Net Investment U.S. Railroads
1955	15,378	5.23%	220,670	5.17%
1973	13,301	3.54%	200,000	2.76%

Source: Rail Miles - Texas - Annual Reports of the Railroad Commission of Texas, 1955-1973. U.S. - Yearbook of Railroad Facts, Association of American Railroads, 1976 ed.
Rate of Return - Financial Overview of Rail Carriers Operating in Texas, Texas Rail Evaluation, Texas A&M University, 1976.

Within Texas three rail carrier systems have represented the largest percentage of rail mileage owned. The Santa Fe, Missouri Pacific and Southern Pacific systems represented approximately 75% of all rail line mileage owned in Texas since 1955. The distribution of rail mileage among Texas carriers is listed in Table 4.

TABLE 4: RAIL MILES OWNED BY CARRIER

Year	ATSF	FWD	KCS	MKT	MP	RI	SLSF	SP	Unaffil.	Total
1955	3667	1116	263	1209	3565	786	215	4144	413	15,378
1960	3554	1116	256	1144	3329	774	203	3951	351	14,678
1965	3540	1116	256	1135	3231	774	203	3848	343	14,445
1970	3555	955	256	735	2970	736	201	3662	455	13,545
1973	3496	997	256	736	2946	623	201	3588	460	13,301

Source: Annual Reports of the Railroad Commission of Texas,

Rail Equipment Fleet

While rail mileage is an indication of the relative size of the fixed physical plant, an examination of the number of rail cars and locomotives operated in Texas gives an indication of the size of the equipment fleet in Texas. In 1973 therewere an estimated 1,559 diesel locomotives and 63,584 freight cars operated in Texas. Between 1955 and 1973 the locomotive fleet increased by 45%. The total number of freight rail cars increased between 1955 to 1975 by an estimated 77%. Table 5 illustrates the size of the transportation equipment fleet operated by railroads within Texas.

TABLE 5: TRANSPORTATION EQUIPMENT USED BY RAILROADS WITHIN TEXAS

Year	Total Locomotives	Total Freight Cars*
1955	1077	35,981
1960	971	41,355
1965	1244	55,585
1970	1458	60,537
1973	1559	63,584

* Excludes cabooses

Source: Annual Reports of the Railroad Commission of Texas.

Rail System Activity

All major indices of rail system activity in Texas have increased between 1955 and 1973. Freight train miles have increased from 26,146,000 in 1955 to 32,093,000 in 1973. During that same period U.S. freight train miles declined slightly.

TABLE 6: FREIGHT TRAIN MILES - U.S. and TEXAS

Year	U.S.	Texas
	(thousands)	(thousands)
1955	476,444	26,196
1960	404,464	23,556
1965	420,962	24,161
1970	427,065	26,425
1973	469,122	32,093

Source: Texas - Annual Reports of the Railroad Commission of Texas.

U.S. - Yearbook of Railroad Facts, Association of American Railroads, 1968, 1976 editions.

U.S. and Texas freight train miles declined significantly between 1955 and 1960. However, Texas freight train miles rebounded at a much quicker rate than U.S. freight train miles.

Rail tonnage carried in Texas increased considerably between 1955 and 1973. The change in tonnage figures between successive years was positive except for 1955 to 1960. As freight train miles also reflected, rail tonnage in the U.S. and Texas declined significantly over this period (1955-1960).

TABLE 7: TONNAGE CARRIED IN TEXAS AND TONNAGE ORIGINATED IN U.S.

Year	Tons Originated - U.S.	Tons Carried - Texas
	(thousands)	(thousands)
1955	1,396,339	166,742
1960	1,240,654	149,360
1965	1,387,423	181,553
1970	1,484,919	211,069
1973	1,532,165	253,366

Source: Texas - Annual Reports of the Railroad Commission of Texas
U.S. - *Yearbook of Railroad Facts*, Association of American Railroads 1968, 1976 editions.

Net revenue ton miles increased by 104% from 1955 to 1973 in Texas. Comparable national figures increased by 37% over the same period. From 1955 to 1960 U.S. net revenue ton miles declined absolutely and net revenue ton miles in Texas increased only slightly.

Freight car miles also increased over the period 1955 to 1973 in Texas. In 1955 railroads in Texas generated 1,649,636,000 car miles, while in 1973 Texas railroads generated 2,161,101,000 car miles. U.S. freight car miles increased by a very small amount, from 31,198,000,000 in 1955 to 31,248,000,000 in 1973.

TABLE 8: NET REVENUE TON MILES - U.S. and TEXAS

Year	U.S.	Texas
	(millions)	
1955	623,615	29,388
1960	527,309	30,866
1965	697,878	38,312
1970	764,809	46,265
1973	851,809	60,056

Source: Texas - Annual Reports of the Railroad Commission of Texas,

U.S. - *Yearbook of Railroad Facts*, Association of American Railroads 1968, 1976 editions.

TABLE 9: FREIGHT CAR MILES - U.S. and TEXAS

Year	U.S.	Texas
	(millions)	
1955	31,198	1,650
1960	28,170	1,575
1965	29,336	1,662
1970	29,890	1,838
1973	31,248	2,161

Source: Texas - Annual Reports of the Railroad Commission of Texas.

U.S. - *Yearbook of Railroad Facts*, Association of American Railroads 1968, 1976 editions.

Texas loaded freight car miles increased from 1,034,279,000 in 1955 to 1,207,827,000 in 1973, an increase of 17%.

TABLE 10: LOADED FREIGHT CAR MILES - TEXAS

Year	Texas
	(thousands)
1955	1,034,279
1960	968,061
1965	1,029,029
1970	1,055,699
1973	1,207,827

Source: Annual Reports of the Railroad Commission of Texas

While previous figures indicated the relative changes in activity on the Texas rail system, several averages calculated from these figures give an indication of the changes in rail operations in Texas.

From 1955 to 1970, the average freight train grew in length from 63 to 70 cars per train. The Texas trend toward increasing train length paralleled U.S. patterns over the same period. However, between 1970 and 1973 the trend toward increasing train length was arrested. The average freight train length dropped to 67 cars per train in 1973 both in Texas and the U.S.

While the average Texas freight train increased in absolute length between 1955 and 1973, the average load per freight car also increased. In 1955 the average freight car in Texas carried 28 net revenue tons.

TABLE 11: AVERAGE FREIGHT TRAIN LENGTH - RAILCARS - U.S. and TEXAS

Year	U.S.	Texas
1955	66	63
1960	70	67
1965	70	69
1970	70	70
1973	67	67

Source: Texas - Annual Reports of the Railroad Commission of Texas,

U.S. - Yearbook of Railroad Facts, Association of American Railroads, 1968, 1976 editions.

By 1973 the average Texas freight car load had increased to 50 net revenue tons. U.S. average freight car load increased from 42 tons per car in 1955 to 57 tons per car in 1973.

TABLE 12: AVERAGE FREIGHT CARLOAD - NET TONS - U.S. and TEXAS

Year	U.S.	Texas
1955	42	28
1960	44	32
1965	49	37
1970	55	44
1973	57	50

Source: Texas - Annual Reports of the Railroad Commission of Texas,

U.S. - Yearbook of Railroad Facts, Association of American Railroads, 1968, 1976 editions.

The combination increasing freight train lengths and freight car loads resulted in increasing freight train loads between 1955 and 1973. The average Texas freight train carried 1,122 net revenue tons in 1955 and in 1973 the average freight train load was 1,871 net revenue tons. Similar increases in freight train loads occurred in the U.S. Thus, the average freight train in Texas became longer and heavier. These trends increased at a greater rate between 1955 and 1973 in Texas than in the U.S.

TABLE 13: AVERAGE FREIGHT TRAIN LOAD - NET TONS - U.S. and TEXAS

Year	U.S.	Texas
1955	1,359	1,122
1960	1,453	1,302
1965	1,685	1,586
1970	1,820	1,751
1973	1,844	1,871

Source: Texas - Annual Reports of the Railroad Commission of Texas.
U.S. - Yearbook of Railroad Facts, Association of American Railroads,

Longer and heavier trains were initiated because of a desire to cut direct operating costs by consolidating rail cars into longer and heavier trains. The data suggests that in addition to operating longer and heavier trains between 1955 and 1973, Texas railroads operated fewer trains in 1973 than in 1955.

TABLE 14: AVERAGE NUMBER OF TRAINS OPERATED* - TEXAS

Year	Texas
1955	148,611
1960	114,716
1965	114,472
1970	120,542
1973	135,417

* Average number of trains operated is calculated by dividing total tons carried by the average freight train load.

Source: Annual Reports of the Railroad Commission of Texas.

The greatest absolute decline in the average number of freight trains operated occurred between 1955 and 1960. This decline was caused by the decline in overall economic and rail industry activity in the late 1950's.

It appears that factors affecting rail car utilization caused the percentage of loaded freight car per average train to decline between 1955 and 1973. In 1955 the ratio between loaded freight car miles to freight car miles was .63. In 1973 the same ratio was only .56. In 1973 Texas railroads were hauling longer and heavier freight trains with a greater percentage of empty rail cars per train.

While it appears that rail car utilization may have decreased between 1955, rail system utilization seems to have increased. Rail line density, an indication of the level of rail activity over rail system mileage, has increased both in terms of train miles per mile and ton miles per mile in Texas. Average line density in Texas increased by 136% when measured in net ton miles per mile and by 42% when measured by train miles per mile.

TABLE 15: PERCENT OF LOADED RAIL CARS PER FREIGHT TRAIN - TEXAS

Year	Texas
1955	.63
1960	.61
1965	.62
1970	.57
1973	.56

Source: Annual Reports of the Railroad Commission of Texas.

TABLE 16: AVERAGE ANNUAL RAIL LINE DENSITY - NET TON MILES PER MILE OF LINE OWNED - U.S. and TEXAS

Year	U.S.	Texas
1955	2,826,007	1,911,042
1960	2,423,830	2,102,875
1965	3,293,042	2,652,267
1970	3,707,895	3,415,651
1973	4,225,557	4,515,149

Source: Texas - Annual Reports of the Railroad Commission of Texas.

U.S. - Yearbook of Railroad Facts, Association of American Railroads, 1968, 1976 editions.

TABLE 17: AVERAGE ANNUAL RAIL LINE DENSITY - TRAIN MILES PER MILE OF LINE OWNED - U.S. and TEXAS

Year	U.S.	Texas
1955	2,159	1,703
1960	1,859	1,605
1965	1,986	1,673
1970	2,070	1,951
1973	2,327	2,413

Source: Texas - Annual Reports of the Railroad Commission of Texas.

U.S. - Yearbook of Railroad Facts, Association of American Railroads, 1968, 1976 editions.

While rail mileage in Texas is shrinking, utilization of mileage has been increasing. Without a greater understanding of the relative cost structures of rail operation, it appears from a rail service quality standpoint that the trends toward fewer, longer and heavier frieght trains are somewhat discouraging. However, given certain rail market conditions and relative labor and capital input costs, the trends in this direction may be rational in the short run because they lower average operating costs. The long run ramifications of these operating trends upon service quality are considered in another chapter of this report.

Rail System Description[*]

In 1976 there were an estimated 13,218 miles of rail line in Texas -- excluding switching and terminal rail carriers. They varied greatly in terms of traffic density, signal systems, feet of passing siding, maximum allowable operating speeds, and weight clearance restrictions.

Signal system types were broken into three categories. The simplest category was train order or timetable operation (TO), the next category was automatic block signal (ABS) and the most sophisticated category was automatic block signal with centralized traffic control (CTC). ABS provides greater operating safety for a given line of track than TO systems, thus allowing more frequent train operation. CTC provides greater control and capacity than ABS signal systems. Approximately 20% of Texas rail mileage is under CTC traffic control. An additional 22% of rail mileage is ABS signalled. The remaining 58% of rail mileage in Texas is not signaled.

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[*] While the previous portions of this chapter relied primarily upon data reported by the Railroad Commission of Texas, this section is based upon original data gathered from railroad operating timetables, the National Railroad Grade Crossing Inventory File and data verified by railroad companies operating in Texas. This section is not an attempt to compare the operations of one carrier with another. That approach was not chosen for a variety of reasons. Foremost among all was the desire to present a description of rail lines in Texas as a complete and unique "system". Rail company names were erased from the process in order that variables such as management style, financial position, etc. would not enter into the analysis. This section describes the rail system on the basis of operating and facility variables common to all lines in the state. The system approach enables one to describe the relationships among these variables with a greater clarity than would be available on a carrier by carrier basis.

TABLE 18: RAIL MILEAGE BY SIGNAL SYSTEM TYPE - TEXAS

	CTC	ABS	TO	Total Miles
Miles	2671	2895	7652	13,218
% of Total Miles	20.2%	21.9%	57.9%	

Source: Texas Rail Evaluation Data File, Texas Transportation Institute, 1977.

The amount of parallel passing track is another indication of the capability of a rail system to handle train movements. In Texas there were an estimated 4,947,053 feet of parallel passing track. This amounts to 936.9 miles of parallel or, loosely speaking, additional double track in Texas. Individual passing sidings range from several hundred feet to several miles in length. The average amount of passing siding per mile in Texas is 374.3 feet. The average density of passing siding length can be categorized and a distribution of miles of track under each category developed. Table 19 illustrates the distribution of passing siding density in Texas. The majority of rail mileage in Texas appears in the lowest passing siding density category, 0-399 feet per mile.

The maximum timetable speed for freight operation is the maximum allowable speed over a line of track. The maximum timetable speed gathered for this analysis was the maximum operating speed for ordinary freight operation. There are operations such as piggyback, high speed merchandise and unit coal trains that have maximum allowable speed either above or below the maximum allowed for ordinary freight operation The maximum allowable timetable speed for regular freight operations in

TABLE 19: RAIL MILEAGE BY PASSING SIDING DENSITY - TEXAS*

	Feet of Passing Track Per Mile							
	0-399	400-799	800-1199	1200-1599	1600-1999	2000-2399	2400-2799	2800-3199
Miles	7787	3873	1336	20	186	4	8	4
% of Total Miles	58.9%	29.3%	10.1%	0.15%	1.4%	-	-	-

* On a segment basis passing siding lengths appearing at end points were divided in half and allocated between the two segments with common end points.

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

Texas is 60 mph, while the maximum timetable speed for passenger operations is 79 mph. The average maximum timetable speed for freight operations in Texas is 40.7 mph. Distribution of line in Texas under each speed category follows in Table 20. The majority of rail mileage (68.2%) is within the range of maximum timetable speed for freight operations of 30-59 mph. An additional 10.7% of rail mileage in Texas has a maximum freight timetable speed of 60 mph. Nearly 80% of all rail mileage in Texas may be classified as a moderate to high speed track.

TABLE 20: RAIL MILEAGE BY MAXIMUM FREIGHT TIMETABLE SPEED - TEXAS

	Maximum Timetable Speed - mph					
	0-19	20-29	30-39	40-49	50-59	60-69
Miles	453	2339	2379	3846	2866	1336
% of Total Miles	3.3%	17.7%	18.0%	29.1%	21.0%	10.1%

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

There are approximately 172 miles of double main track in Texas. Of this amount, 62.2% is located on rail lines with freight speeds of 60 mph or greater.

TABLE 21: RAIL MILEAGE BY NUMBER OF TRACKS - TEXAS

	Number of Main Tracks	
	1	2
Miles	13,046	172
% of Total Miles	98.7%	1.3%

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

Permanent speed restrictions resulting from operating, design or legal (local ordinance) constraints were calculated for Texas rail lines. Speed restrictions greater than 10 miles below the maximum freight timetable speed for Texas are listed in Table 22.

TABLE 22: RAIL MILEAGE BY PERMANENT SPEED RESTRICTIONS - TEXAS

	10 to 20 mph below max.	Greater than 20 mph below max.
Miles	1402	331
% of Total Miles	10.6%	2.5%

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

Miles of permanent speed restrictions in Texas may be overstated since each was rounded up to the nearest mile. However, actual miles of speed restrictions caused by street crossings and local ordinances greater than 10 mph below the maximum timetable speed were calculated at 284 miles in Texas. Thus, at least 16% of all permanent speed restrictions in Texas are due to local speed ordinances. This category of restrictions has nothing to do with maintenance or track design policies.

The total number of at-grade street crossings in Texas amounted to 11,302 on main tracks. Of the 14,586 public at-grade crossings in Texas, 77.5% of these were on a line of track between rail stations. The remaining 3,284 public at-grade crossings were on spurs, industrial sidings, port trackage, etc.

There were 376 miles of rail line in Texas with a maximum weight restriction less than 221,000 pounds. Most of the lines in this category are unable to support the weight of a fully loaded 100-ton, four-axle rail car.

TABLE 23: RAIL MILEAGE BY WEIGHT RESTRICTION - TEXAS

	Maximum Weight Restriction					
	0-150	151-180	201-220	221-240	241-260	261-360
Miles*	2	81	295	122	668	12,050
% of Total Miles	.02%	.61%	2.23%	.92%	5.05%	91.17%

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

The majority of rail lines in Texas (91.17%) are classified to handle normal rail loadings on four-axle cars. All rail segments in Texas have a maximum vertical clearance in excess of 18 feet from the top of the rail while most have a maximum vertical clearance of 20-21 feet.

TABLE 24: RAIL MILEAGE BY VERTICAL CLEARANCE - TEXAS

	Maximum Vertical Clearance in Feet		
	18-19	20-21	22-23
Miles*	3,754	9,411	53
% of Total Miles	28.4%	71.2%	.4%

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

Rail operations in Texas are as varied as rail facilities. The majority of rail mileage in Texas has less than 10 trains per day, and only 1.3% of rail mileage in Texas has 30 or more freight trains per day.

The majority of rail mileage in Texas may be classed relatively light to moderate density as only 29.2% of Texas rail mileage has more than 10 trains per day.

TABLE 25: RAIL MILEAGE BY FREIGHT TRAIN FREQUENCY - TEXAS

	Average Daily Freight Train Frequency				
	0-9	10-19	20-29	30-39	40-49
Miles	9,320	2,755	954	185	4
% of Total Miles	70.8%	20.5%	7.4%	1.2%	---

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

One factor which has added to rail system utilization is joint railroad operation of a line. There are 1,275.2 miles of line in Texas where one or more carriers rent operating rights over another carrier's line. Joint operations, where feasible, increase system output without the requirement for parallel rail miles. Nearly 10% of all Texas rail miles are presently under joint operation arrangements and possibilities may exist in Texas where similar arrangements could be extended to other lines.

Of the 13,218 miles of rail line in Texas, there are 772.3 miles which are either under petition for abandonment or abandonment petitions have been granted since February 5, 1976. Of the 706.7 miles, 72% have one or less than one train per day. The maximum timetable speed for these lines ranges from 10-35 mph and many lines have maximum rail car weight limitations of less than 220,000 pounds. The average feet of passing track per mile for this entire group of lines is 16.7 feet and none have automatic signals.

If average freight train frequency is utilized as the primary characteristic describing the lines in the categories of petitioned for abandonment or petition for abandonment granted, there are a total of 1,934 miles in Texas with less than two freight trains per day. This figure represents 14% of total rail miles in the state.

While the primary concern of this report is with freight service, passenger operations also take place over the freight rail system. In Texas there are 1,831 miles of track in both freight and passenger operation. Passenger operations need to be mentioned because of their effect on freight operations. It was estimated by the Department of Transportation (Final Standards, Classification and Designation of Lines of Class I Railroads in the United States. Volume I, p. A3-6. U.S. Department of Transportation, January, 1977) that one passenger train consumes the track time capacity equal to four freight trains in mixed operations. Thus, the extent of rail passenger operations (13.9% of the entire freight system) on freight operations is significant in Texas.

While distributions of facility and operating characteristics for all rail miles in Texas are quite useful, a characterization of Texas rail lines by density and facility elements will demonstrate the significant differences among rail lines in the state. Density or train frequency was chosen as the element for comparison because there is a strong relationship between traffic density and facility characteristics.

Three "typical" very light density Texas rail lines and the characteristics of these lines are listed in Table 26.

TABLE 26: CHARACTERISTICS OF A VERY LIGHT DENSITY LINE IN TEXAS

	Avg. Daily Train Frequency	Max. TT Speed	Signal System	Feet of Passing Trk. Per Mile
ATSF - Bay City to Matagorda	<1	20	TO	62
FWD - Childress to Wellington	<1	25	TO	0
MKT - Witchita to OK. State Line	<1	10	TO	194

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

While the three lines listed in Table 26 are by no means the only light density lines in Texas, they illustrate the relative characteristics of light density lines.

The "average" rail line in Texas is quite different from the very light density line. The characteristics of an "average" line of track in Texas appear in Table 27.

TABLE 27: CHARACTERISTICS OF THE AVERAGE RAIL LINE IN TEXAS

Avg. Daily Train Frequency	Avg. Max. TT Speed	Avg. Signal System	Avg. Feet of Passing Track Per Mile
7.4	40.7	TO	374

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

In Texas the line of single track with the highest average daily train frequency is the Santa Fe line between Shattuck and Pampa. The characteristics of this line are listed in Table 28.

TABLE 28: CHARACTERISTICS OF THE HIGHEST TRAIN FREQUENCY, SINGLE TRACK LINE IN TEXAS

	Avg. Daily Train Frequency	Max. TT Speed	Signal System	Feet of Passing Trk. Per Mile
ATSF - Shattuck to Pampa	30	60	CTC	1,829

Source: Texas Rail Evaluation Data File - Texas Transportation Institution, 1977.

There appears to be a positive relationship among train operation and system facility variables. As train frequency increases, maximum timetable speeds, signal system type and passing siding lengths appear to increase. Explanations behind these relationships are relatively simple. Railroads build capacity-providing elements into a line of track according to the traffic demand. Therefore, where there is little traffic, one would not expect to see a sophisticated centralized traffic control system with high speed track and many miles of passing siding. Most facilities observed on the rail system would be expected under this reasoning.

To support the hypothesis that as traffic density increases, rail facility standards also increase, several distributions were calculated. Results of the distributions illustrate changes in rail facilities with traffic density.

Table 29 illustrates the distribution of maximum timetable speeds for categories of rail traffic frequency in Texas. The distributions are weighted by mileage.

TABLE 29: PERCENTAGE DISTRIBUTION OF MAXIMUM TIMETABLE SPEED MILEAGE BY TRAIN FREQUENCY CLASS - TEXAS

Maximum Timetable Speed	Daily Train Frequency 0-9	 10-19	 20-29	 30-39	 40-49	 Total
0-9	-	-	-	-	-	-
10-19	4.78	0.00	0.20	2.44	0.00	3.43
20-29	24.39	1.66	0.72	0.00	0.00	17.66
30-39	25.03	1.14	0.00	3.05	100.00	18.02
40-49	34.05	20.49	10.14	0.00	0.00	29.07
50-59	5.49	62.19	67.93	0.00	0.00	21.68
60-69	6.26	14.53	21.00	94.51	0.00	10.14
% of Total Miles	70.8	20.5	7.4	1.2	.1	

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

Distribution of maximum timetable speed mileage increases as one moves to the right in train frequency categories. The shift in the distribution of timetable speed miles indicates a strong positive relationship between train frequency and maximum timetable speed. This relationship suggests that as rail traffic increases, railroads upgrade and maintain lines for higher speed movements. One would expect heavier density track to have a higher maximum timetable speed than a lighter density rail line.

About 88% of all rail miles with a train frequency less than 10 trains per day have a maximum timetable speed of 49 miles per hour or less, 85% of all rail miles with a train frequency between 10 and 19 trains per day have a maximum timetable speed of 59 miles per hour or less, and 89% of all rail miles with a train frequency of 20-29 trains per day have a maximum timetable speed equal to or greater than 50 miles per hour. Finally, 95% of all rail miles with a train frequency of 30-39 trains per day have a maximum timetable speed equal to or greater than 60 miles per hour.

Distributions in Table 29 indicate that a positive relationship does exist between speed and train frequency variables. A linear least squares regression model was tested to determine how much of the variation in timetable speed was explained by variations in train frequency. The model was set up in the form:

$Y = a + bx$ where:

Y = maximum timetable speed (weighted by distance)

a = some constant

b = a coefficient of x

x = train frequency (weighted by distance)

The model was tested for all rail segments in Texas. The maximum timetable speed and train frequency for each segment were weighted by segment length. The results of the model indicated that train frequency explained a portion of the variation in maximum timetable speed. The b value was positive indicating a positive relationship between train frequency and timetable speed. The R^2 resulting from the model was .59. This meant that train frequency variation explained

59% of the variation in maximum timetable speeds. While this result was less than spectacular, there are several explanations for the lower than expected R^2 resulting from the model.

First, the relationship between train frequency in timetable speed may not be linear. There is evidence for this in the nature of the distribution in Table 29. It appears that initially timetable speeds increase greatly as train frequency categories increase, but then the increase in speed categories slows relatively. Factors such as safety regulations, operating policies and financial conditions may influence the maximum timetable speed limit to the extent that ordinary freight train speeds seldom are allowed to exceed 60 miles per hour regardless of increasing train frequencies. The relative time value of railroad freight probably does not warrant the increased maintenance costs that high freight train speeds may cause. A second less illuminating explanation for the lower R^2 may be that the sample size (7% of U.S. rail miles) did not provide a sufficiently wide range of observations to support the initial hypothesis. Of the two explanations, the first is probably the most realistic and it is responsible for nonlinearity in the relationship between speed and train frequency.

Table 30 illustrates the distribution of miles of main tracks by train frequency category. A serious problem with this distribution exists in the lack of observations in the double (2) track category. Only 1.30% of all rail mileage in Texas is double track. However, Table 30 signifies that a relationship does exist between number of tracks and train frequency. As train frequency increases, the percentage of miles of rail line in each category with two main tracks increases. On rail lines with less than 10 trains per day there are no miles of double track. On rail lines with 30-39 trains per day, 46% of this rail mileage is double track.

TABLE 30: PERCENTAGE DISTRIBUTION OF NUMBER OF MAIN TRACKS (MILEAGE) BY TRAIN FREQUENCY CATEGORY - TEXAS

# of Main Tracks	Train Frequency 0-9	 10-19	 20-29	 30-39	 40-49	Total
1	100.00	97.79	96.62	53.66	0.00	98.70
2	0.00	2.21	3.38	46.34	100.00	1.30
% of Total Miles	70.8	20.5	7.4	1.2	.1	

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

To test the strength of the relationship between the number of tracks and train frequency, a linear least squares regression model of the general form $Y = a + bx$ was utilized where:

Y = number of main tracks (weighted by miles)

a = some constant

b = a coefficient of x

x = train frequency (weighted by miles).

While the b value of this model was positive, R^2 results of this test were even less satisfactory than those achieved by the previous simple model. This model indicated that train frequency variability explained only 40.7% of the variability in the number of main tracks. However, it is encouraging that the model explained even 40.7% of the variance in the number of tracks in light of the following circumstances. Later in this report it will be shown that the practical operating capacity of a single line track is approximately 30-40 trains per day. In Texas, only .02% of the rail mileage has a line frequency greater than 40 trains per day. Also, only 1.30% of the Texas rail mileage is double track. Thus, the number of observations in Texas within the range where double or triple tracks are likely to occur are extremely limited. The equation had very little data in the range where Y > 1.

A third variable describing rail facilities is signal system type. A distribution of miles of signal system types by train frequency categories is illustrated in Table 31.

TABLE 31: PERCENTAGE DISTRIBUTION OF MILES OF SIGNAL TYPE BY TRAIN FREQUENCY CATEGORY - TEXAS

	Train Frequency					
Signal Type	0-9	10-19	20-29	30-39	40-49	Total
TO	79.35	6.60	5.33	0.00	0.00	58.00
ABS	14.13	48.73	18.55	36.59	100.00	21.85
CTC	6.51	44.61	76.13	63.41	0.00	20.16
% of Total Miles	70.8	20.5	7.4	1.2	.1	

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

The distribution of miles of signal type also tends to shift downward with increasing train frequency categories in Table 31. The shift in the distribution of miles of signal type indicates that as traffic on rail lines becomes more frequent, railroads improve the level of signalization. At a certain level of rail traffic, it becomes more efficient to upgrade signals from TO to ABS. If traffic increases further, CTC is added, thereby increasing the capability of the line to accommodate rail traffic increases.

A linear least squares regression was utilized to test the relationship between traffic frequency and signal systems. The model tested was based upon data from the Texas Rail Evaluation data file. Both signal and train frequency data were weighted by track segment length. The simple model was set up in the form:

Y = a + bx where:
Y = signal system type (weighted by length)
a = some constant
b = a coefficient of x
x = train frequency (weighted by length).

Results of the model indicated that the variability in train frequency explained 77.8% of the variability in signal system type. This R^2 result is considerably better than the R^2 obtained from the two previous models. However, 22.2% of the variability in signal system type is still not explained by this model. The primary explanation for the relative explanatory ability of this model is that while there is a range of approximately 40 values for train frequency, there are only 3 values for signal system type. Thus, it would be nearly impossible to obtain a perfectly fitting least squares curve through a cluster of data points based upon these two variables. Considering this severe constraint (which also affected the results of the model testing train frequency and number of tracks), an R^2 of .778 is extremely encouraging. Along with a positive b value, the results indicate that as traffic density increases railroads increase sophistication of signal systems. Additionally, the explanatory ability of the model may have been hampered by the relative value assigned to the signal types (TO-.333, ABS-.5, CTC-1). It is very probable that another set of relative values would more accurately reflect the capacity level provided by each of the signal system types.

The final variable which was examined in relation to train frequency was feet of passing track per mile. The distribution of feet of passing track per mile by train frequency category is listed in Table 32.

TABLE 32: PERCENTAGE DISTRIBUTION OF FEET OF PASSING TRACK PER MILE BY TRAIN FREQUENCY CATEGORY - TEXAS

Feet of Passing Siding Per Mile	Train Frequency					
	0-9	10-19	20-29	30-39	40-49	Total
0-399	76.74	22.18	4.20	32.32	100.00	58.91
400-799	22.07	59.10	19.26	0.00	0.00	29.32
800-1199	1.67	17.84	66.39	16.46	0.00	10.10
1200-1599	0.09	0.44	0.00	0.00	0.00	0.15
1600-1999	0.00	0.00	9.94	51.22	0.00	1.39
2000-2399	0.02	0.07	0.00	0.00	0.00	0.03
2400-2799	0.00	0.22	0.20	0.00	0.00	0.06
2800-3199	0.00	0.15	0.00	0.00	0.00	0.03
% of Total Miles	70.8	20.5	7.4	1.2	.1	

Source: Texas Rail Evaluation Data File - Texas Transportation Institute, 1977.

Table 32 demonstrates that the distribution of feet of passing siding shifts downward as train frequency increases. For train frequencies between 0-9 trains per day, 98.2% of the passing siding density is less than 800 feet per mile. For train frequencies between 10-19 trains, 99.4% of passing siding density is less than 1,200 feet per mile. For train frequencies between 20-29 trains per day, 99.8% of passing siding density is less than 2,000 feet per mile. Table 32 indicates that as train frequencies increase railroads add passing sidings or increase the length of existing passing sidings to accommodate additional rail traffic over a line. Railroads can adjust passing siding lengths fairly well to relative traffic levels.

To determine the relationship between train frequency and passing siding length, a fourth model was tested by a linear least squares regression procedure. The model was set up in the general form:

$Y = a + bx$ where:

Y = feet of passing track

a = some constant

b = a coefficient of x

x = train frequency (weighted by length).

The data used in the model was extracted from the Texas Rail Evaluation data file and train frequencies for each segment were weighted by segment length. The results of the model produced an R^2 value of .848. In this model, the variation in train frequency explained 85% of the variation in feet of passing track. The fairly high R^2 value and the positive sign of the b coefficient indicate that railroads increase passing siding length with rail traffic. As rail traffic grows, passing sidings are simply extended, sometimes, into a second main line track.

From the distributions and simple models, three inferences can be drawn. First, there is a positive relationship between operating (train frequency) and rail facility (signal system, maximum timetable speed, number of track, feet of passing siding) variables. Second, despite any limitations of the data source, the relationships between the operating and facility variables are fairly significant.

Finally, the inference may be drawn that the level of rail traffic determines the "quality" of rail systems. Railroads do not or will not invest in high-speed, signalized, multiple track systems unless rail traffic demands require such systems. To meet these demands there are a variety of methods available to adjust the rail plant incrementally. A great deal of the observable variations in system facilities can be explained by variations in rail traffic.

System Utilization and Rail Facilities

Previous portions of this report referred to the level of system utilization in Texas. While average line density or average line frequency are an indication of the level of utilization or level of activity on the rail system, they do not reveal what percentage of the system is being heavily utilized and what portion is utilized to a lesser extent. In the U.S., the Department of Transportation estimated the level of utilization on the rail plant (Final Standards, Classification, and Designation of Lines of Class I Railroads in the United States, Volume I, p. A2-1, U.S. Department of Transportation, January 1977). The U.S. D.O.T. estimated that 67% of the total rail traffic is carried by about 20% of the rail mileage. The remaining 80% of the U.S. rail system carries only 33% of rail traffic. This indicates that large segments of the rail system carry only very small percentages of total rail traffic.

A similar analysis of the Texas rail system was performed. The data was extracted from the Texas Rail Evaluation data file. Cumulative train miles and cumulative miles were calculated for the entire rail system in Texas. While the distribution of system utilization in Texas is not nearly so skewed as the U.S. distribution, it was found that

73% of Texas rail traffic is carried on 34% of system miles. While Texas system utilization is not nearly as imbalanced as that in the United States, there remain many rail lines which carry very low levels of traffic. The 34% of the rail system which carries 73% of the rail traffic is and will continue to be the track with the highest timetable speeds, most sophisticated signal systems, and greatest passing siding density. The relationships between these variables and traffic frequency support this conclusion.

Thus, where traffic creates heavy density, railroads will invest, upgrade and maintain rail plant in a condition commensurate with traffic levels. Lines in Texas with low traffic densities will necessarily be of lower "quality" than the heavy density freight mains in the state. Railroads have acted rationally in the past by upgrading or downgrading the relative physical characteristics of rail lines in Texas according to traffic levels. As railroad financial conditions decline, however, less capital becomes available to upgrade and maintain lines. Available capital will first be invested in heavy density lines, with remaining amounts distributed over the rest of the rail system.

II. Rail System Capacity

Factors Affecting Capacity

Rail system capacity can be described as a function of rail system design, maintenance standard, the intensity and variability of the queues in the system, operating requirements, equipment availability, and random incident variables.

For any rail line, system capacity can be increased by improving or upgrading the design standards of the line. Design standard improvements would involve curvature and gradient reductions, passing siding increases, signal system improvements, parallel main track additions, etc. Any other changes which improve the physical features of the line could be included in this category. Such changes allow more trains over the line within a given time period.

Maintenance standards will affect line capacity by determining average speed over a line. When maintenance expenditures are reduced, slow orders will result, or maximum timetable speeds must be lowered. Otherwise the probability of derailments and other track related accidents will increase, thus reducing average line speed. The reduction in average line speed will reduce the number of trains that can be moved through the system within a given time period.

The intensity and variability of queues in rail operations are perhaps the least understood elements affecting rail system capacity. As trains are added to a given system, the probability of delay or reduced average speed increases until the system eventually fails to operate. As this is true with a rail line, it is also true of rail yards. The variability of the queues may be measured two ways, first as the average speed variance. If the variation in average traveling speeds over a line is great, fewer trains can be handled within a time period than on line where there is very slight variance in average traveling speeds. Also, if train movements of different priorities (i,e, passenger trains and freight trains) are introduced into the system, capacity will be reduced. Second, variability in queues may result from scheduling demands. Operations which are more evenly spaced over a time period can be accommodated more easily than severe peak and off-peak operating demands. Gross daily traffic demand is responsible for the intensity of the queues. Railroads demand available capacity to account for the randomness in the intensity and variability of the queues in their operation. Local trains, on-track maintenance requirements, trains of differing priorities, terminal operations, and seasonal traffic are partially responsible for the randomness associated with the queues in rail movements.

Terminal throughput is an intergral part of determining system capacity. Train operations which require fewer terminal functions (such as unit trains) can be moved through the system with a less noticeable effect on system capacity. The greater percentage of traffic flow in a system that is composed of movements which require fewer terminal functions the greater relative system capacity. A considerable number of unit trains could be accommodated by a rail system relative to a lesser number of mixed-traffic freight trains.

Rail equipment must necessarily be available to move the amount of traffic demanded. Lack of equipment or utilization of equipment with a higher probability for enroute delay will decrease system capacity.

The probability of unplanned incidents occurring on a rail line will affect capacity. While the level of maintenance will affect the probability of accidents, train length may increase the probability of derailments or equipment failures. A greater number of short, fast trains may be handled over a rail line than an equal number of longer, slower trains.

Variability of Capacity

When considering periods of several years, rail capacity is a highly variable element. Real rail assets must continuously be replaced. A portion of the rail system continuously falls in a replacement cycle. Actual maintenance and upgrading expenditures can be finely tuned to determine capacity over any given several year period. A rail manager has a wide range of choices before him to control the level of real investment in the rail system. If profit expectations increase (due to higher traffic levels, for instance) he can increase investment with a wide assortment of engineering methods. Similarly, rail managers may decrease real investment and capacity by failing to replace assets and reducing facility life through maintenance deferral. Very few discontinuities in this investment function exist as the financial and engineering options to increase or decrease capacity are diverse.

Capacity change options are also incremental. Increases in capacity can be made on an incremental basis at modest expense. As traffic increases slowly, incremental capacity changes can be made to match traffic. Similarly, as traffic levels decline, or the demand for capacity declines, capacity can be decreased incrementally by maintenance deferral and by failing to replace or renew facilities. The relationship between capacity and cost may be represented by a continuous function. Figure 1 is an example of such a relationship.

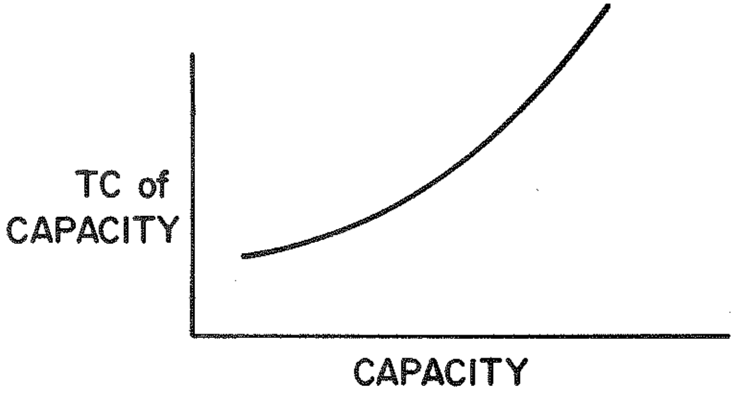


Figure 1

It is doubtful that significant amounts of excess capacity exist in the United States in terms of operating practicality. Rail lines can be altered incrementally by adding and extending passing siding, adding CTC signaling to ABS, increasing maximum timetable speeds, and increasing maintenance expenditures. Combinations of this process will adjust rail capacity to operating demands.

A computer model was tested using maximum timetable speed, number of main tracks, feet of passing siding, and signal system as independent variables and daily through freight trains as the dependent variable. The calculations were performed utilizing the Texas rail evaluation data file. This model produced an R^2 of .874 indicating that the facility variables explained 87% of the variation from the mean in daily freight train movements.

As train frequency changes, investment in rail property (feet of passing track, signal systems, and other facilities) can be altered incrementally so that rail managers maximize their return on investment by adjusting real investment according to expected traffic demands.

Estimates of Capacity

While all of the factors above affect the capacity of each line quite differently, general estimates of rail line capacity have been attempted. Table 33 illustrates the capacity of four types of rail line estimated by the Department of Transportation.

The FRA estimates represent the engineering capacity of the respective types of rail lines. Practical operating capacity will be limited on its upper bounds by factors such as those mentioned in the beginning of this chapter - curvature, gradient, line speeds, passing siding lengths, operating procedures, etc. A more practical estimate of rail line capacity can be developed by analyzing the relationships between actual train operations and facility requirements. Actual operating variables should reflect the practical capacity levels of various combinations of rail facilities.

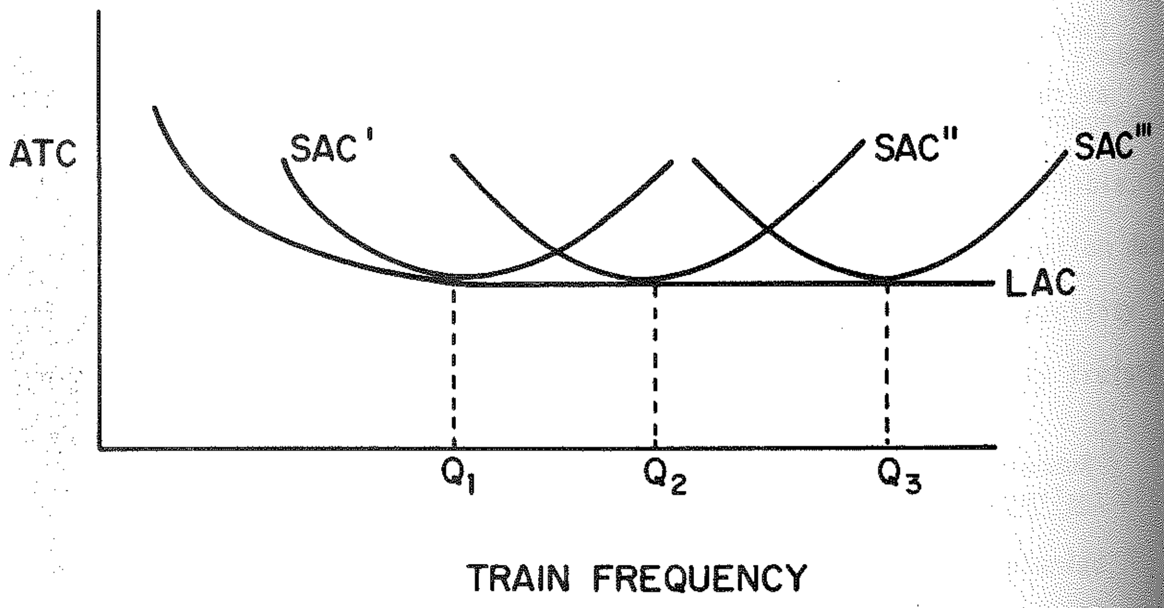
If rail managers are sensitive to variations in operating cost over time, they will change from one type of facility to another to minimize average total cost. For example, as the demand for rail output increases, a

TABLE 33: Estimates of Rail System Capacity - U.S.

	Signal System			
	Automatic Block System		Centralized Traffic Control	
Number of Tracks	Trains Per Day	Gross Tons Per Year (millions)	Trains Per Day	Gross Tons Per Year (millions)
Single	40	62	60	93
Double	120	186	160	250

Source: Rail Service in the Midwest and Northwest Region, Vol. I, U.S. Department of Transportation, 1974 rail manager faces a series of short run average cost curves from which to choose. The average total cost curves may be seen to represent the operating cost functions (operating cost, facility cost, plus delay cost) for single, double and triple track rail systems. When the short run average cost of operating a single track system exceeds the expected short run average cost of operating a double track system for a comparable traffic load, the rail manager would expand his facility to the double track system (Expansion directly from a single to a double track system seldom occurs before passing sidings, signal systems, etc. are upgraded incrementally. However, to simplify the analysis, these factors are ignored.) Refering to Figure 2, train frequency Q_2 can be accommodated along SAC' (single track), however, ATC is greater than if Q_2 is produced along SAC" (double track). Depending upon the mean train frequency demanded, the SAC curve chosen will be that which minimizes expected ATC.

FIGURE 2



If the hypothesis concerning train frequency demands and distinct cost functions for single and multiple track systems is correct, then empirical data should reflect the traffic density within the range of each function. For instance, all rail movements under single track systems should have a distinct distribution and range apart from the distribution and range of movements under double and triple track systems. Not only should the data support the hypothesis concerning the average cost of operation for various size systems, but it should also define the ranges and operating limitations or practical operating capacity of single, double and triple track rail systems.

In order to produce a distribution of rail movements by the number of main tracks, a data file consisting of 186,940 observations was utilized. This data file contains the number of main tracks, number of through trains per day, maximum timetable speed and the presence or absence of train signalization for every line of main track in the United States. Two sets of distributions were produced. The first distribution contains the train frequency of main tracks for non-signaled lines. The second distribution contained train frequencies of main tracks for signaled lines.

For all train movement observations on non-signaled track, 98% are over single line track and approximately 2% of the observations appear on double track. Signaled track exhibits a distribution of rail movements over a wider range of number of tracks than non-signaled tracks as 77% of all train movement observations on signaled track were on single track, 22% of all train movement observations on signaled track were on double

TABLE 34 : PERCENTAGE DISTRIBUTION OF TRAIN FREQUENCIES BY NUMBER OF MAIN TRACKS - NONSIGNALED TRACK, U.S.

	Percentage of Observations by # of Main Tracks						
Train Frequencies	1	2	3	4	5	6	Total
<1	37.76	19.44	30.00	15.79	16.67	0.00	37.38
1-10	60.01	31.55	23.33	39.47	33.33	50.00	59.41
11-20	1.84	25.32	8.89	15.79	25.00	50.00	2.32
21-30	0.34	15.99	18.89	15.79	8.33	0.00	0.66
31-40	0.04	4.60	3.33	2.63	0.00	0.00	0.13
41-50	0.01	2.30	1.11	2.63	16.67	0.00	0.06
51-60	0.00	0.16	10.00	0.00	0.00	0.00	0.01
61-70	0.00	0.20	0.00	2.63	0.00	0.00	0.01
71-80	0.00	0.00	3.33	2.63	0.00	0.00	0.00
81-90	0.00	0.08	0.00	2.63	0.00	0.00	0.00
Total # of Observations	124,665	2,520	90	38	12	2	127,327

Source: National Railroad-Highway Crossing Inventory File, U.S. Department of Transportation and Association of American Railroads, January 1977.

track, and 1% of train movement observations distributed primarily between 3 and 4 main tracks.

An examination of the distributions of train movements under signaled main tracks reveals that 99.65% of all train movements on single tracks are less than 41 trains per day. On double tracks, 98.27% of all train movements are less than 71 trains per day. 99.77% of all train movements on triple tracks are less than 111 trains per day. 99.07% of all train movement observations on 4 track main line are less than 111 trains per day, however, there is one observation on 4 track main line with 121-131 trains per day.

From the range of these distributions, it may be assumed that the practical operating limit for mixed traffic signalized rail systems in the United States is 31-40 trains per day for single track, 61-70 trains per day for double track, 101-110 trains per day for triple track, and possibly 121-131 trains per day for 4 track main lines.

The distributions and capacity limits define the maximum practical operating capacity which United States railroads have encountered for various main track and frequency combinations. They enable one to identify the points at which, given present technology, railroads would shift to a multiple track railroad system. The distributions are based, not on engineering possibilities, but rather upon actual observations. Their validity is based upon revealed relationships between rail operating costs and rail facility requirements in the United States.

The results of Table 36 indicate that with sufficient signal, passing track, rail terminal, and line investment, signalized, single track main lines in Texas could possibly carry between 31 and 40 trains per day.

TABLE 35 : PERCENTAGE DISTRIBUTION OF TRAIN FREQUENCIES BY NUMBER OF MAIN TRACKS - SIGNALED TRACK, U.S.

Train Frequencies	Percentage of Observations by # of Main Tracks						
	1	2	3	4	5	7	8
<1	3.49	1.03	2.58	5.61	0.00	0.00	0.00
1-10	58.10	14.30	9.60	6.54	0.00	0.00	0.00
11-20	28.07	34.54	10.54	8.41	16.67	100.00	100.00
21-30	8.25	24.48	14.05	7.48	0.00	0.00	0.00
31-40	1.74	13.11	9.37	8.41	50.00	0.00	0.00
41-50	0.12	7.06	9.60	8.41	0.00	0.00	0.00
51-60	0.02	2.70	12.18	18.69	16.67	0.00	0.00
61-70	0.14	1.05	4.92	13.08	0.00	0.00	0.00
71-80	0.06	0.85	9.37	12.15	16.67	0.00	0.00
81-90	0.00	0.03	1.17	3.74	0.00	0.00	0.00
91-100	0.00	0.63	6.32	4.67	0.00	0.00	0.00
101-110	0.00	0.02	10.07	1.87	0.00	0.00	0.00
111-120	0.00	0.03	0.23	0.00	0.00	0.00	0.00
121-130	0.00	0.02	0.00	0.93	0.00	0.00	0.00
131-140	0.00	0.05	0.00	0.00	0.00	0.00	0.00
# of total observations*	45,689	13,012	427	107	6	1	1

* Because of the nature of this data file, the probability of encountering an observation decreases as train frequency increases. There are proportionately fewer public at grade crossings on very heavy density freight lines.

Source: National Railroad-Highway Grade Crossing Inventory File: U.S. Departme of Transportation and Association of American Railroads, January 1977.

TABLE 36: Observed Rail System Operating Limits

# Main Tracks	Trains Per Day Non-Signaled Track U.S.	Trains Per Day Non-Signaled Track Texas	Trains Per Day Signaled Track U.S.	Trains Per Day Signaled Track Texas
1	11-20	20	31-40	30
2	41-50	n.a.	61-70	n.a.
3	n.a.	n.a.	101-110	n.a.

n.a. - Not applicable because of insufficient number of observations in the following cell.

Source: U.S. - National Railroad Highway Crossing Inventory Data File, U.S. Department of Transportation, and Association of American Railroads.
Texas - Texas Rail Evaluation Data File.

Presently, the average train frequency in Texas today is slightly more than 7 trains per day. This table does not indicate the amount of investment necessary to upgrade tracks to accommodate heavier traffic volumes.

A study done in 1974 utilizing a Train Dispatching Simulation model (TDC) tends to support the previous conclusion that actual capacity may be considerably below engineering capacity estimates. The model analyzed the capacity requirements of a single and double track railroad. The results of the study indicated that "Many railroads may be nearer to capacity than is generally believed. . ." The results of the modeling also indicated that "line congestion problems inherently grow as traffic increases, especially on single track. While there are many alternatives available which reduce rail line congestion. . .current trends point in the opposite direction. Unless these trends are reversed, major investment in improved signaling and double tracking will be required to achieve operating leverage required."[4]

One note concerning the effect of economic regulation upon the level of captial stock in the railroad industry is in order. The ICC may influence the level of capital stock by its policies, but it cannot regulate levels of capital stock. That economic regulation has created "excess capacity" in the railroad industry may be far from the actual fact. While regulation can certainly limit exit through changes in mileage, the ICC is unable to limit exit in the form of internally generated funds. Economic regulation, in fact, has probably encouraged the exit of capital investment from the railroad industry by reducing expected profit levels.

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[4] "Volume Spells Profit Or Does It?" Modern Railroads and Rail Transit, March 1974.

III. Railroad Electrification

There are primarily four advantages attributed to pure electric rail operations compared to conventional diesel-electric. Advantages of electrified rail operations are superior locomotive performance, greater flexibility of energy sources, the lower energy cost of electricity versus petroleum fuels, and improved environmental quality. (Reduced total U.S. energy consumption from railroad electrification would be minimal).

Proponents of electric locomotives view them as superior to diesel-electric locomotives because of longer service lives (30 years compared to 15 years for diesel-electric), requirements for less maintenance, simpler mechanisms, higher reliability, greater short-time overload power capacity, greater speed flexibility, and greater adhesion because of non-slip capabilities. It is assumed also that two electric locomotives could replace three diesel-electric locomotives. The second advantage of electrified rail operations is utilization of a stationary power source that can utilize up to five fuel sources

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For a more complete discussion of the advantages and disadvantages of electrified rail operations refer to the following sources:

- American Railway Engineering Association - Bulletin #656, January 1976, pp. 404-413.
- A United States Rail Trust Fund - Prescription for Modern Rail Transportation, Commonwealth of Pennsylvania, Milton Shapp, Governor, 1974, pp. 30-31.
- Air Pollution Impact of Railroad Electrification, Journal of the Environmental Engineering Division, August 1976.
- Energy Aspects of Rail Electrification. A presentation by Blair A. Ross to the national conference on "The Role of the U.S. Railroads in meeting the Nation's Energy Requirements," Madison, Wisconsin, 1974.
- "Railroad Electrification - An Idea Whose Time has Come?" Remarks by L. Stanley Crane, President, Southern Railway System, before the American Bar Association, December 1975.

including coal, natural gas, oil, hydro, and nuclear power. The difference in the cost of electrical versus petroleum-based energy is thought to provide a primary advantage of electrified rail operations. Railroad energy savings of 5%-10% may be realized by conversion from diesel-electric operations. The final advantage of electrified rail operations is improved environmental quality. Controls on air emissions are more efficient for single source electrical energy production than they are for diesel-electric operations.* Noise levels of electric locomotives are generally lower than for comparable diesel locomotives.

Electrification Costs

Despite all possible benefits, the costs of rail electrification combined with the rate of return on U.S. railroads have limited implementation of electrified rail operations in the United States. Foreign countries have electrified rail operations on nationalized railroads and have paid for them with general revenue funds. In the United States, private rail carriers have not been able to justify the initial capital expense of electrification when far more pressing capital requirements for rolling stock and other fixed facility improvements must be met. Initial costs of electrification include substations, catenary, signal and communication conversions, all-electric locomotives, and other costs. Three estimates of electrification costs follow in Table 37.

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* This is correct if petroleum products or natural gas is utilized as the boiler fuel in electric utility plants. This is not necessarily correct if coal is utilized as the boiler fuel in electric utility plants and diesel fuel is utilized by railroad locomotives.

TABLE 37: UNIT COST OF ELECTRIFICATION

	Cost Per Mile	
Estimate 1	$102,548	(1974 dollars, electric locomotive costs not included)
Estimate 2	$105,000-$143,000	(1975 dollars, excludes cost of elect. locomotives)
	$153,125-$191,125	(1975 dollars, includes cost of elect. locomotives)
Estimate 3	$286,000	(1975 dollars, includes locomotives)

Source: Estimate 1 - A United States Rail Trust Fund - Prescription for Modern Rail Transportation. Commonwealth of Pennsylvania, Milton Shapp, Governor, 1974, p. 53.

Estimate 2 - American Railway Engineering Association - Bulletin #656, January 1976, pp. 404-413.

Estimate 3 - "Railroad Electrification - An Idea Whose Time has Come?" Remarks by L. Stanley Crane, President, Southern Railway System, before the American Bar Association, Dec. 1975.

Initial capital costs of railroad electrification based upon these estimates range from $143,000 to $286,000 per mile including the cost of electric locomotives. Assuming a mean cost per mile from the two estimates, cost for electrification would be $214,500 per mile. If all 13,218 miles of track in Texas were to be electrified based upon this estimate, the total initial cost of electrification would be $2,835,261,000. On total 1973 operating revenues of approximately $1 billion it is extremely unlikely Texas railroads will undertake such an expensive project.

In order to estimate a more realistic cost of electrification for Texas railroads, the level of traffic density required to justify an electrification project must be determined. From a private or public standpoint, electrification for all Texas lines should not be considered. For instance, light density rail lines would not warrant such large capital expenditures.

The Southern Railroad is one of about 10 U.S. railroads seriously studying the costs and benefits of electrification. To justify an electrification project the Southern has determined that a minimum traffic density of 39 million annual gross ton miles per mile is requried.[5] Thus, only heavily used lines can be considered seriously for electrification projects.

The Federal Railroad Administration has developed density estimates for all lines in the United States. Based upon these estimates, there were approximately 15,000 miles of mainline in the United States with traffic densities equal to or greater than 39 million annual gross ton miles per mile. Additionally, the Federal Railroad Administration has published density estimates for all lines in the United States. Unfortunately, the published line densities are categorized by 6 codes. The highest code represents lines with equal to or greater than 30 million annual gross ton miles per mile. It is not possible to determine which lines in Texas have greater than 39 million annual gross ton miles per mile. To circumvent this problem, the Texas Rail Evaluation data file and an estimate of average gross tons per train were utilized to determine the total mileage in Texas with 39 million annual gross ton miles per mile.

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[5] "Railroad Electrification - An Idea Whose Time Has Come?" Remarks by L. Stanley Crane, President, Southern Railway System, before the American Bar Association, December 1975.

Interstate Commerce Commission data for 1974 was used to determine the average gross tons per train to be 4,370 tons. One average train operating 365 days per year would generate an average annual density of 1,595,050 gross tons annually. To determine the minimum number of daily trains required to justify an electrification project in Texas 39,000,000 gross tons was divided by 1,595,050 to arrive at 24.45 trains per day. To allow for variance in the estimate two ranges were calculated. Total rail mileage in Texas equal to or greater than 24 trains per day first was calculated. Secondly, total mileage in Texas with 20 or greater trains per day was calculated.

There are 457 miles of track with 24 or more trains per day and there are 1,143 miles of line with 20 or more trains per day in Texas. By using estimates for initial electrification costs of $143,000 to $286,000 per mile, ranges of total capital requirements for Texas railroad electrification projects can be estimated. The minimum amount of capital cost required would be $65,351,000 if 457 miles of track were considered. The maximum amount of capital cost for electrification would be $326,898,000 if 1,143 miles of track at $286,000 per mile were electrified. Table 38 contains estimates of the capital costs of Texas railroad electrification.

TABLE 38: ESTIMATED CAPITAL COST OF TEXAS RAILROAD ELECTRIFICATION

Unit Electrification Costs	Miles of Track Justified for Electrification	
	457 miles	1,143 miles
$143,000 per mile (1974 dollars)	$ 65,351,000	$163,449,000
$286,000 per mile (1975 dollars)	$130,702,000	$326,898,000

Source:
- Texas Rail Evaluation Data File, Texas Transportation Institute, January 1977.
- American Railway Engineering Association - Bulletin #656, January 1976.
- "Railroad Electrification - An Idea Whose Time Has Come?" Remarks by L. Stanley Crane, President, Southern Railway System, before the American Bar Association, Dec. 1975.

Financial Problems of Railroad Electrification

While the total initial costs of railroad electrification are easily determined, the process of justifying large capital expenditures by railroads is more complex. Even though a project may appear to be financially feasible on a cost-benefit or internal rate of return basis, an industry with a limited amount of externally available and internally-generated capital is cautious when approaching alternate investment decisions. The firm will set a minimum rate of return for investment projects which is sufficiently above the weighted incremental cost of capital. As capital becomes available for investment, the firm will rank the rate of return for all improvement projects. Those above the minimum return required will be chosen in order of relative profitability according to the amount of capital available. Because of the limited amount of available capital in the railroad industry, there are numerous improvement projects, other than electrification, with considerable cost-reducing and service advantages. Many of these projects have estimated rates of return in excess of the rate of return anticipated from railroad electrification. New classification yards, centralized traffic control extensions, welded rail installations, double tracking projects, and new locomotives compete for the limited capital dollars available. Other railroad improvement projects may return a higher rate than railroad electrification, even if an additional $165,400,000 or $326,900,000 were available to invest in Texas railroads.

Other Problems of Electrification

Other problems exist. Foremost is the relative cost of electricity versus petroleum fuels. It was assumed that there would be no appreciable change in the relative prices of the two energy sources. However, recent evidence indicates that electrical power rates may be escalating more rapidly than petroleum costs. Public utility commissions have shifted emphasis so industrial users must share a larger burden of the cost of producing electricity. This shift clouds confidence in the ability to accurately predict future electricity costs relative to petroleum costs. If electric power costs escalate more rapidly than diesel fuel costs, the advantages of electrification are limited.

Electrification cost estimates are based upon a 30 year service life expectancy for pure electric locomotives based on the Pennsylvania Railroad GG-1 locomotive. However, according to the Southern Railway, today's electric locomotives do not approximate the durability or design of the GG-1. Another problem of pure electrical operations is that the operating flexibility associated with the diesel electric locomotive would be lost.

While locomotive maintenance may be reduced because of fewer operating parts on an electric locomotive, right of way maintenance will certainly increase. Catenary maintenance costs may exceed the reduction in locomotive maintenance costs.

Additionally, high voltage power lines may adversely affect signal and communication systems on the railroad. Electrical fields set up around the power distribution systems may require additional modifications to signal and communication systems.

A final problem of electrification is the requirement for a minimum vertical clearance of 22-25 feet. Only .4% of rail segment mileage in Texas has a vertical clearance in excess of 21 feet

IV. Rail Maintenance Expense

Factors Affecting Railroad Maintenance Expense

There are many factors which affect the level of expense required to maintain railroad roadway and associated structures. While it is difficult to isolate specific factors which influence the maintenance cost of any particular line of railroad, a list of typical factors which affect maintenance costs could be divided roughly into twelve areas.[6]

- Right of way location - subgrade soil characteristics, drainage, grade, alignment, terrain, vegetation, accessability to work forces, and equipment.
- Track structure characteristics - sub-ballast, ballast, ties, rail, welded rail, fasteners, special track including switches, crossover, and rail crossing frogs.
- Fixed structures - bridges, tunnels, culverts, grade crossings, yards, sidetracks, scales, mechanical service facilities, and miscellaneous structures.
- Traffic characteristics - gross tonnage, train frequency, train length or tonnage, speed, motive power, axle loadings, dynamic vehicle characteristics, car condition, traffic pattern (including unit train and mixed load), direction of traffic, seasonability, and industrial development.
- Environmental characteristics - temperature range, rainfall, snow and ice conditions, and blowing dust or sand.
- Human factors - quality of supervision and labor, and labor contracts.
- Quality and availability of maintenance equipment.
- Use of mechanized equipment.
- Quality of maintenance accepted - managerial policy.
- Current maintenance based upon past maintenance experience, ie. time lag phase as it changes quality levels.

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[6] The list of factors affecting maintenance costs was contained in Bulletin No. 646, American Railway Engineering Association, Jan.-Feb., 1974, pp. 567-568.

- Financial position of the company - available cash, tax situation, expected earnings, etc.
- Other factors - signals, communications, electrification, surrounding development, etc.

In the United States total maintenance expenditures have increased from $1,387,000,000 in 1955 to $2,034,000,000 in 1973. In terms of constant 1973 dollars,* however, maintenance expenditures for way and structures have actually declined from $3,856,000,000 in 1955 to $2,034,000,000 in 1973. Average maintenance expenditures per mile for the United States also dropped from $17,474 per mile in 1955 to $10,909 per mile in 1973. Table 39 lists U.S. maintenance expenditures over the period 1955-1973 on page 61.

In Texas total maintenance expenditures for way and structures increased from $78,944,000 in 1955 to $118,119,000 in 1973 for Class I rail lines. The Southern Pacific in Texas spent the largest amount for total maintenance in 1973. Maintenance expenditures for Class I rail lines in Texas are illustrated in Table 40 on page 62 .

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* Constant dollars calculated from the Railroad Index of Material Prices and Wage Rates, Yearbook of Railroad Facts, 1972 and 1975 editions, Association of American Railroads.

TABLE 39: Maintenance Expenditures in the U.S. - Class I Carriers

Year	Total Expenditure Current Dollars (millions)	Total Expenditure 1973 Dollars (millions)	Expense/Mile 1973 Dollars
1955	1,387	3,856	17,474
1956	1,405	3,597	16,334
1957	1,431	3,406	15,547
1958	1,224	2,778	12,719
1959	1,236	2,682	12,327
1960	1,192	2,539	11,671
1961	1,118	2,281	10,538
1962	1,155	2,310	10,740
1963	1,183	2,319	10,817
1964	1,226	2,354	11,073
1965	1,236	2,250	10,617
1966	1,304	2,282	10,810
1967	1,288	2,112	10,065
1968	1,405	2,164	10,372
1969	1,503	2,179	10,500
1970	1,612	2,144	10,394
1971	1,813	2,212	10,779
1972	1,920	2,150	10,576
1973	2,034	2,034	10,090

Source: Yearbook of Railroad Facts, Association of American Railroads, 1968,1972 editions.

TABLE 40: Total Maintenance Expenditures for Way and Structures Class I Lines in Texas - Current Dollars (thousands)

Year	FWD	MKT	KCS	MP	RI	SLSF	ATSF	SP	TEXAS
1955	4,643	5,683	903	21,764	2,506	1,136	16,598	26,711	78,94
1960	3,870	3,187	823	15,109	2,920	669	14,983	20,304	61,8
1965	2,717	3,964	1,188	19,999	2,186	703	18,266	19,329	68,3
1970	2,924	4,788	1,961	21,746	3,587	844	22,360	28,901	87,1
1973	5,482	4,648	3,048	29,065	4,077	1,238	30,865	39,692	118,11

Source: Annual Reports of the Railroad Commission of Texas, selected years.

In terms of constant dollar expenditure, total maintenance expense in Tex followed the United States trend. Between 1955 and 1973, constant dollar (1973 dollar) maintenance expenditure fell from $219,465,000 to $118,115,000. The period of the greatest decrease in constant dollar maintenance expenditure was approximately from 1955 to 1960. Constant dollar expenditure for maintenance of way and structure in Texas for selected years follows in Table 41.

TABLE 41: Total Maintenance Expenditures for Way and Structures Class I Lines in Texas - 1973 Dollars (thousands)

Year	FWD	MKT	KCS	MP	RI	SLSF	ATSF	SP	TEXAS
1955	12,908	15,799	2,510	60,504	6,967	3,158	46,142	71,477	219,46
1960	8,243	6,788	1,753	32,182	6,220	1,425	31,914	43,248	131,77
1965	4,945	7,214	2,162	36,398	3,979	1,279	33,244	35,179	124,40
1970	3,889	6,368	2,608	28,922	4,771	1,123	29,739	38,438	115,85
1973	5,482	4,648	3,048	29,065	4,077	1,238	30,865	39,692	118,11

Source: Annual Reports of the Railroad Commission of Texas, selected years.

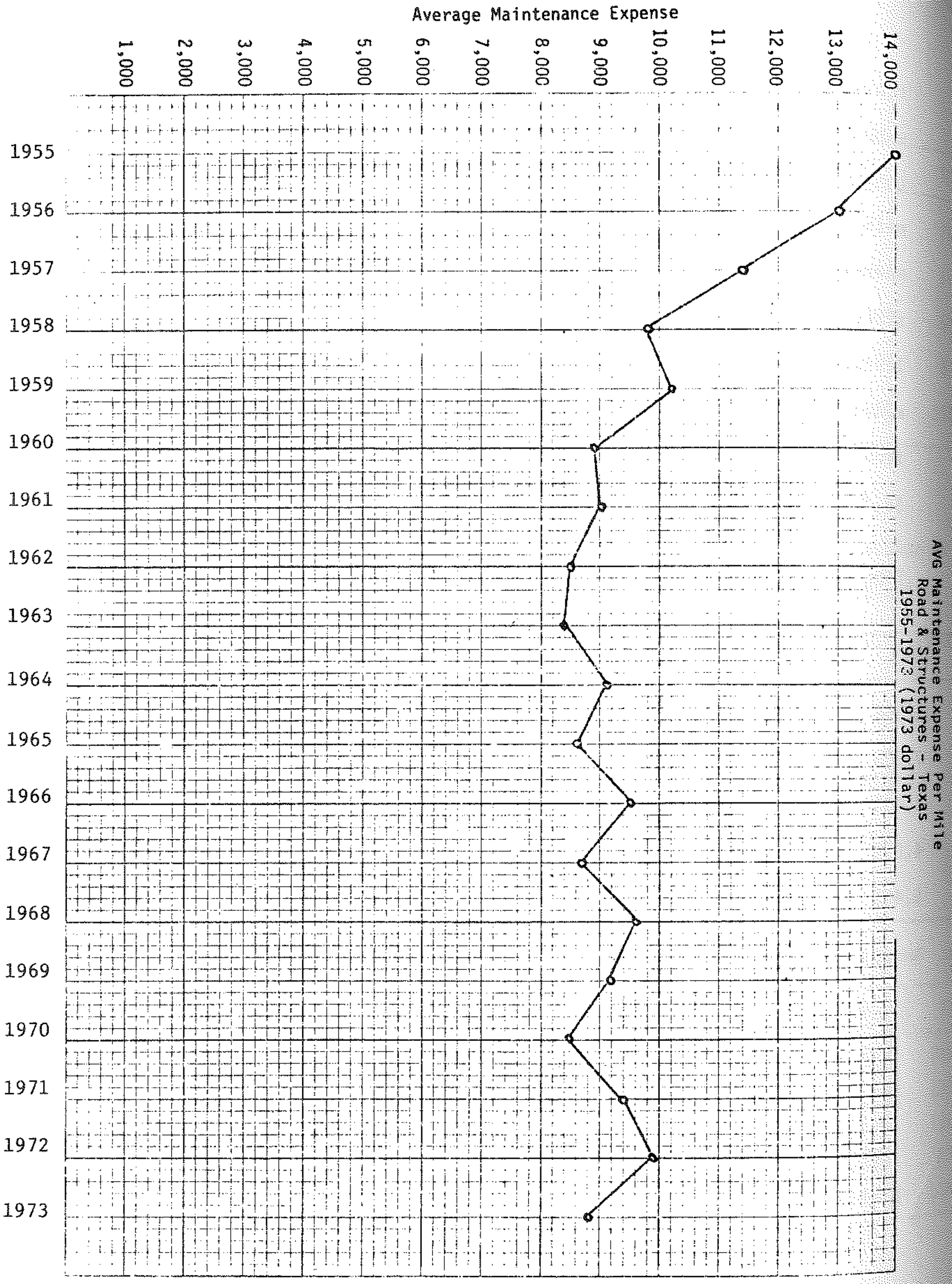
While 1973 total maintenance expenditures for road and structures represented only 54% of 1955 expenditures (1973 dollars), maintenance expenditures per mile decreased by a smaller amount because of the concurrent reduction in total rail miles over the same period. 1973 maintenance of way expenditures per mile represented 62% of 1955 maintenance of way expenditures per mile (1973 dollars). Roadway and structures maintenance expenditures per mile of line owned in Texas are listed in Table 42. These figures are plotted in Figure 3. While maintenance expenditures per mile (1973 dollars) declined most dramatically from 1955 to 1960, they remained fairly constant, varying between $8,400-$10,000 per mile, from 1960 to 1973.

TABLE 42: Total Maintenance Expenditures for Way and Structures Per Mile of Line Owned - Class I Lines in Texas (1973 dollars)

Year	FWD	MKT	KCS	MP	RI	SLSF	ATSF	SP	TEXAS
1955	11,556	13,067	9,544	16,972	8,864	14,688	12,583	17,248	14,271
1960	7,386	5,934	6,848	9,667	8,036	7,019	8,980	10,946	8,978
1965	4,431	6,356	8,445	11,265	5,140	6,300	9,391	9,142	8,612
1970	4,072	8,664	10,188	9,738	6,482	5,587	8,365	10,496	8,553
1973	5,498	6,315	11,906	9,866	6,544	6,159	8,828	11,062	8,880

Source: Annual Reports of the Railroad Commission of Texas selected years.

While many factors which affect rail maintenance costs have been discussed, rail system use is thought to have the greatest single impact upon the level of maintenance costs. Maintenance costs for a highly utilized rail line would be expected to be greater than those for



AVG Maintenance Expense Per Mile
Road & Structures - Texas
1955-1973 (1973 dollar)

Figure 3

a line with less traffic density. The Federal Railroad Administration estimated annual maintenance costs for two types of rail lines.

TABLE 43: Estimated Annual Cost to Maintain Modernized Track and Railway

Type of Track	Estimated Cost Per Mile
Signalled track - primarily heavy density	$12,000
Unsignalled track - primarily light density	$ 5,000

Source: Rail Service in the Midwest & Northeast Region, Volume I, U.S. Department of Transportation, 1974.

The relationship between maintenance costs and density was pointed out by the Department of Transportation in the "Preliminary Standards, Classification and Designation of Lines of Class I Railroads in the United States," report submitted in 1976.

> "Density has a close relationship to maintenance costs. From a practical standpoint, the cost of maintaining track can be roughly divided between a fixed and variable cost based on the level of traffic."[7]

Cross-sectional data among Texas carriers does tend to support the claim of a relationship between maintenance expenditures and traffic density.

Before examining the cross-sectional relationship further, a look at several other factors which may have influenced maintenance expenditures over time would be helpful. Initially, three factors may have influenced maintenance expenditures in Texas between 1955 and 1973

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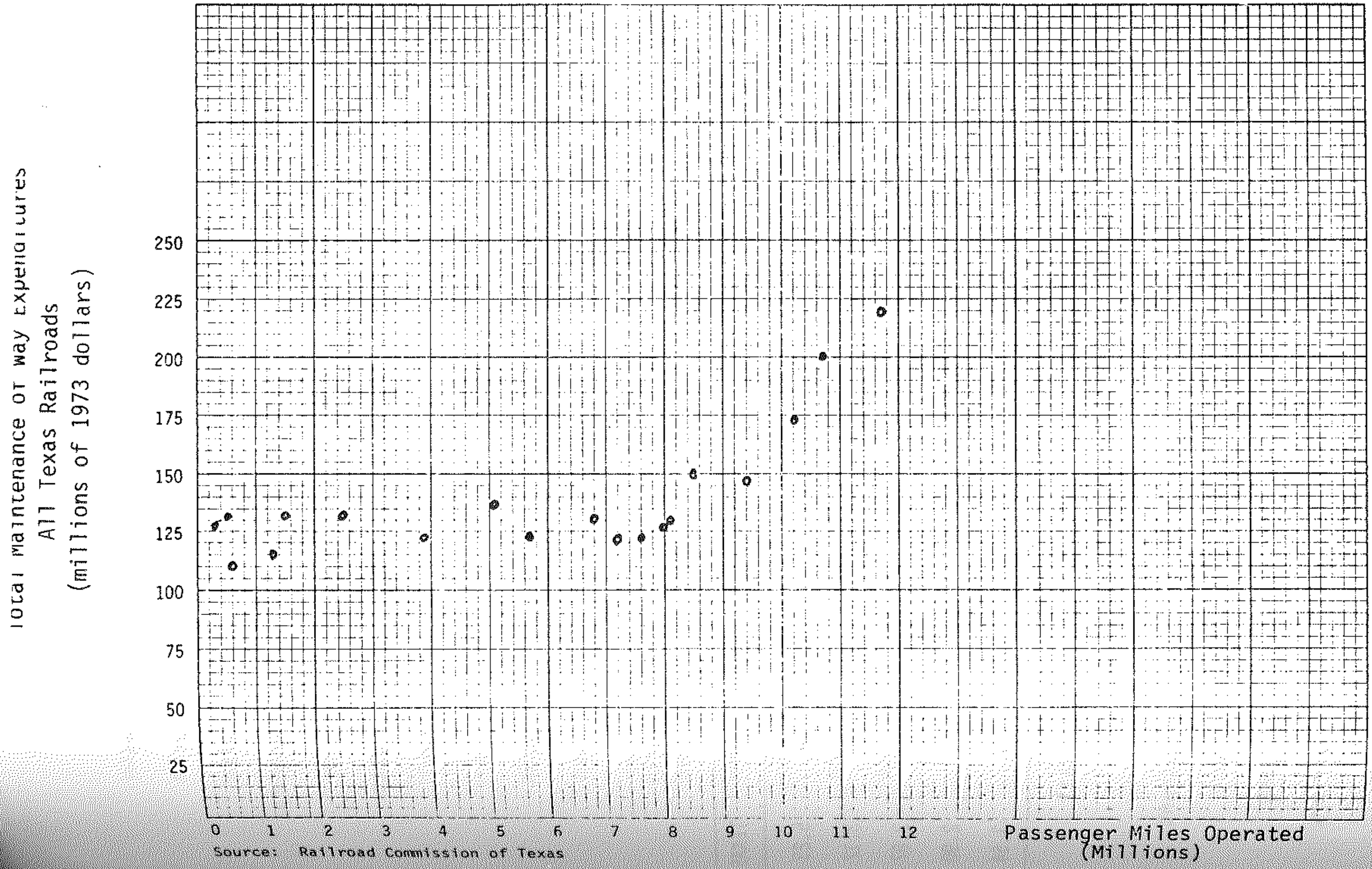
[7] Preliminary Standards, Classification and Designation of Lines of Class I Railroads in the United States. A report by the Secretary of Transportation, Vol. 1, 1976.

to a greater extent than density. They are passenger traffic carried, financial position of the carriers and the introduction of mechanized maintenance of way equipment.

During the period from 1955 to 1960, Texas passenger train miles operated dropped from 11,701,000 to 8,151,000. Passenger train miles in 1960 represented 69.7% of passenger train miles operated in 1955. Maintenance expenditures (1973 dollars) in 1960 represented 60% of the total expenditure for maintenance in 1955 in Texas. Figure 4 illustrates the relationship between passenger train miles operated and maintenance expenditures in Texas. Up to approximately 8 million passenger train miles operated, there appears to be little relationship between passenger traffic and maintenance costs. However, from about 8 to 12 million passenger miles, maintenance expenses appear to increase steadily. While this increase may not be attributed solely to increased passenger train traffic, there appears to be some logic behind the possibility that increased passenger train traffic would be expected to increase maintenance expenditures for road and structures. When most rail lines operated significant amounts of passenger service, maximum system speeds were maintained for passenger operations, not for lower speed freight trains. Total maintenance expenses were required to account for freight train tonnages plus higher level passenger train speeds. Tolerances in gauge, curvature, superelevation, and roadbed smoothness required additional expenditures to provide safe and comfortable passenger service at higher speeds not required by freight trains.

Passenger Train Miles Operated
All Texas Railroads 1955-1973
(millions)



Source: Railroad Commission of Texas

FIGURE 4

Thus, as passenger service was reduced on rail lines in Texas, railroads reduced maintenance expenditures to the levels necessary to accommodate slower freight train schedules. They simply permanently deferred the additional amounts necessary to maintain higher passenger train speeds on rail lines which carried only freight traffic.

Another factor which may have influenced the level of maintenance expenditures in Texas from 1955 to 1973 is the financial position of the carriers involved. The rates of return on net investment in transportation property for carriers operating in Texas are listed in Table 44.

TABLE 44: Rate of Return on Net Investment on Transportation Property for Railroads serving Texas

Year	FWD	MKT	KCS	MP	RI	SLSF	ATSF	SP	TEXAS
1955	3.69	2.39	4.91	6.00	5.07	4.59	6.00	5.09	5.23
1960	1.49	1.48	4.92	3.66	2.03	5.46	3.22	3.05	3.12
1965	1.45	2.37	5.50	4.72	0.60	4.90	5.00	3.79	3.87
1970	(0.21)	(0.36)	5.39	3.94	(3.79)	4.62	3.33	3.14	2.90
1973	(0.51)	(1.14)	2.37	4.70	(5.17)	4.10	4.89	3.79	3.54

Source: Financial Overview of Railroad Companies Operating in Texas, Texas Rail Evaluation, Texas Transportation Institute, 1976.

Between 1955 and 1960, the average rate of return on net investment for rail carriers operating in Texas fell rather significantly from 5.23 to 3.12 and did not rise above 3.95 (1968) for any year from 1960 to 1973. It would seem that as the financial position of Texas carriers declined during this 5 year period, maintenance levels on many secondary main and branch lines may have been reduced in order to permit distribution of maintenance funds to primary main lines. Thus, total maintenance expended would have decreased during this period.

The last factor which may have influenced the reduction in maintenance expenditure in Texas from 1955 to 1960 is the introduction of mechanized equipment into the maintenance process. One of the largest groups of railroad employees affected by reduction in the railroad work force were the Maintenance of Way and Structures employees. They have been affected by mechanized operations which have replaced, to a large extent, the smaller section gangs. The mechanized extra gangs function in a large-scale manner across the entire rail system. The reduction in the number of maintenance of way employees between 1955 and 1973 coincides with both the decline in carrier financial position and the mechanization of the maintenance work force. Table 45 lists the number of rail maintenance of way employees in Texas from 1955-1973.

TABLE 45: Maintenance of Way Employees in Texas

Year	Number of Employees
1955	11,342
1960	8,061
1965	8,000
1970	6,500
1973	6,300

Source: Railroad Employment Analysis, Texas Rail Evaluation, Texas Transportation Institute, 1976

Maintenance of Way employment in 1960 represented 71% of this group's employment in 1955. The decline in rail Maintenance of Way employment from 1955-1960 was the greatest absolute decline between any five year period since 1955. Much of this employment reduction may be attributed to increased mechanization of maintenance activities which, in turn, reduced total maintenance expenses for rail carriers.

In 1973, Texas rail carriers spent $118,115,000 on maintenance. The average maintenance expenditure per mile ranged from $5,498 to 11,906 per mile, while average density (net ton miles per mile) ranged from 1,900,000 to 5,400,000. Figure 5 illustrates the relationship between average maintenance expenditures and average traffic density for Texas rail carriers in 1973. There seems to be a fairly positive relationship between rail line density and average maintenance based upon the results plotted in Figure 5. The upward sloping cluster of points would seem to reinforce the thesis that a relationship exists between the two variables. However, because of the limited number of observations in the Texas data, it is very difficult to develop any kind of statistical relationship between maintenance costs and traffic density.

It is even more difficult to gather maintenance cost data for particular pieces of rail lines. Railroads do not report expenditures by track segment; thus, it is difficult to prove whether maintenance policies based upon density are actually the rule in the railroad industry. It would seem that lines with greater densities would receive a greater amount of total maintenance expenditure relative to comparable miles of light density lines. One major carrier has recently begun

AVG Maintenance Expense - Per Mile
Road and Structures

NTM/M Traffic Density - Texas, 1973

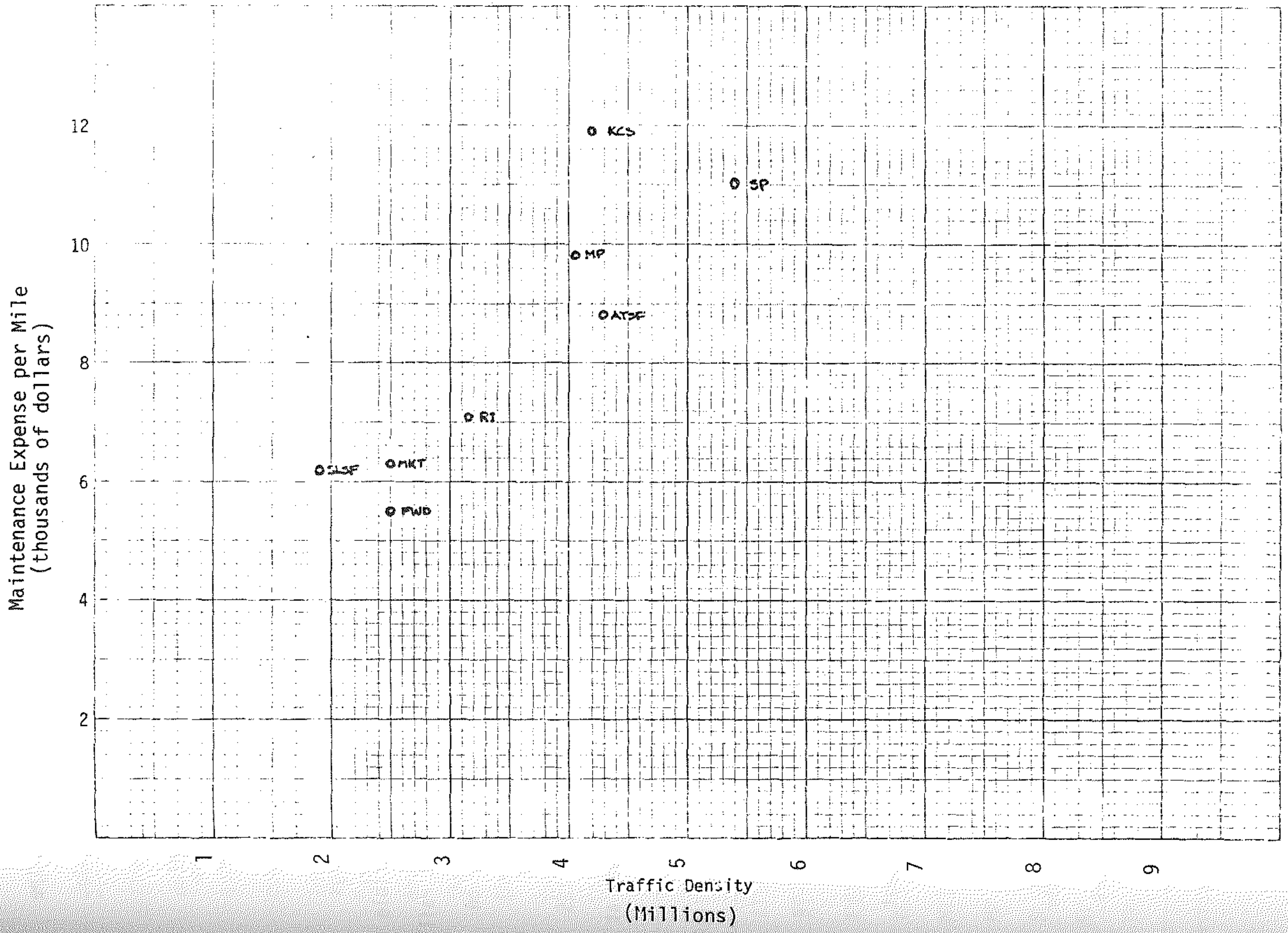


Figure 5

a maintenance of way priority program which would tend to support the thesis concerning maintenance expenditures according to line density.

> "Present priorities call for devoting 70% of ConRail's M/W funds to lines which carry piggyback traffic and/or 20 million gross tons of freight a year. Lines carrying between 5 and 20 million gross tons per year will receive 25%, while the balance of the program will be devoted to lines carrying less than 5 million gross tons."[8]

While rail line density may be supposed to have a positive relationship with maintenance expense levels, rail car axle loadings are frequently becoming the concern of many rail officials responsible for system roadway maintenance. There is increasing evidence that rail cars of 100-125 ton capacity are producing a cost in terms of wear on the roadway in excess of the revenue which they are earning. Many roadway engineering officers feel that loads in excess of 100 and 125 tons per 4-axle rail car are accellerating wear on the rail roadway at an increasing rate. However, many of the 100-125 ton cars are in unit train service where equipment utilization is very high and productivity is much greater than that of the rail car fleet in general service. It has been difficult for railroads to identify the specific costs associated with various kinds of heavier rail car movements and measure these in terms of increased revenue/investment ratios produced from superior rail car utilization.

Deferred Maintenance

The Interstate Commerce Commission has become interested in the level of maintenance expenditures on railroads in the United States.

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[8] "ConRail Pushes Its 10 Year Track Upgrading Program," Railway Track and Structures, June 1976, p. 54.

Pursuant to Ex Parte No. 305, Nationwide Increase of Ten Percent in Freight Rates and Charges, 1974, the Interstate Commerce Commission required railroads to report the estimated level of deferred maintenance, delayed capital improvements, and miles of slow orders issued on a quarterly basis. While it is difficult to determine what exactly constitutes "deferred maintenance," the term has probably been interpreted to mean the difference between the total "desired" or "adequate" level of maintenance expenditures for given traffic levels and the actual maintenance expenditure for a particular railroad. The estimated levels of deferred maintenance reported to the ICC for the entire system of rail carriers operating in Texas are listed in Table 46.

TABLE 46: Deferred Maintenance of Roadway - for Quarter ended 6/30/75

Railroad	Total Deferred Maintenance (thousands)	Miles Owned	Avg. Deferred Maintenance per mile
ATSF	0	12,086	0
RI	$213,736	6,417	$33,308
FWD	$ 7,207	995	$ 7,243
KCS	$ 10,669	1,537	$ 6,941
MKT	$ 59,761	1,910	$31,288
MP	$ 48,079	9,930	$ 4,842
SLSF	$ 23,960	4,536	$ 5,282
SP	$ 29,119	12,304	$ 2,367
TM	0	157	0

Source: Interstate Commerce Commission: Application of Additional Revenues from Ex Parte 305 for quarter ended 6/30/75, January 28, 1976, No. 112-76.

A comparison of total deferred maintenance reported in 1975 and the level originally reported as of 6/30/74 indicates that of all carriers, the level of deferred maintenance declined or remained the same except for the MKT. A comparison of carriers operating in Texas indicates that on a per mile basis the Rock Island (RI) and the Katy (MKT) have reported the highest levels of deferred maintenance. The Santa Fe (ATSF), Southern Pacific (SP) and Missouri Pacific System (MP) have reported the three lowest levels of deferred maintenance on a per mile basis. The relative grouping of these carriers according to reported deferred maintenance coincides with the relative financial positions of the carriers concerned.

Since 6/30/75, both the MKT and RI have initiated rehabilitation programs on their mainlines in Texas and the level of deferred maintenance on both of these carriers should be reduced significantly. The Fort Worth and Denver, with the third highest reported level of deferred maintenance per mile on 6/30/75, has also begun a rehabilitation of its mainline in preparation for increasing coal movements into Texas.

In future years, relative financial positions of rail carriers in Texas plus the level of rail traffic density will be the determining factors of maintenance expenditure. Recent federal government loans and/or prospects of increased western coal traffic bound for Texas utility markets have both enabled and prompted several financially weak rail carriers to undertake significant rehabilitation programs in Texas.

As financial position of carriers along with traffic levels vary, rail system maintenance expenditure will most likely also vary accordingly. Without adequate traffic levels or financial capability, railroads will not maintain lines in excess of traffic requirements or financial ability.

V. Railroad Investment

Rail Line Upgrading Costs

Under the Interstate Commerce Commission's accounting rules, only a portion of total expense involved with line rehabilitation or upgrading can be included as a capital expenditure, the remainder being accounted for as maintenance expense. For instance, if a line is relayed with new rail, only the portion of rail that is greater in weight per yard than the previous rail in place may be capitalized. Thus, while upgrading costs are composed to a large extent under ICC accounting rules as expense, they are in reality, an investment in the rail system to increase line service levels.

Upgrading costs for rail lines depend upon a number of factors including the existing and planned service level of track, signalization, alignment changes, traffic volume mix, and whether or not electrified territory is involved. The Federal Railroad Administration estimated upgrading costs for two types of track rebuilding. These costs are listed in Table 47.

Recently within Texas, the MKT railroad upgraded its line from Temple to Taylor at an approximate cost per mile of $49,000. This cost included roadbed rehabilitation and extensive tie replacement, but no new rail. Similar costs were encountered by the MKT on the rehabilitation of their mainline from Smithville into Houston. However, with the addition of continuously welded rail to this segment of track, upgrading costs were increased by another $100,000 per mile. Speeds on both of these MKT segments prior to rehabilitation were 20 mph or less, while after rehabilitation they were raised to 70 mph for passenger trains, 50 mph for freight trains on the Temple-Taylor

TABLE 47: Estimated Cost To Modernize Track and Roadway

Type of Modernization	Estimated Cost Per Mile
Major Rebuild of Signallized Track*	$225,000
Minor Rebuild of Signalled and Unsignalled Track**	$ 20,000

* Includes rebuilding subgrade and ballast, new ties and rails, and rehabilitating signal systems.

** Includes necessary tie and rail replacement, resurfacing and alignment.

Source: <u>Rail Service in the Midwest and Northeast Region</u>, Volume I, U.S. Department of Transportation, 1974.

segment and to 49 mph for freight trains on the Smithville to Houston segment.

Conversations with the Fort Worth and Denver Railway staff in 1974 indicated that tie and rail upgrading from Amarillo, Texas to Sixela, Texas was expected to exceed $100,000 per mile. This upgrading was carried out primarily in anticipation of unit coal train traffic.

The Florida East Coast Railway has estimated that their track rebuilding program involving granite ballast, concrete ties, and 132 pound continuous welded rail has cost about $157,000 per mile.[9]

It is difficult to uncover recorded data on track upgrading costs because these costs are not kept as a separate account, but are interdispersed between the income statement and balance sheet. However,

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[9] "Finish Looms for 13 Year Concrete Tie Program." Railway Track and Structures, March 1977, p. 31.

estimates in the range of $5,000 per mile for minor tie replacement to $250,000 per mile for major upgrading are realistic (depending upon the type of upgrading or rehabilitation to be performed, the actual condition of the track before upgrading, and the standard to which it is to be raised).

While the majority of rail line upgrading is considered a maintenance expense under the Interstate Commerce Commission's rule of accounting, it is as much an investment decision as the decision to purchase additional freight cars or locomotives. The decision to upgrade a particular line of track to a higher service level depends upon (1) the availability of internally generated or external funds and (2) the expected rate of return on the upgrading project in relation to the opportunity cost of internally generated capital and the cost of capital attracted from external sources. Because of these two constraints and the long repayment horizon for line improvements, it has been difficult for many railroads to be able to justify investment decisions in many roadway upgrading projects.

Railroad Investment

Between 1955 and 1973, railroad net investment in transportation property increased by a very small amount. From 1955 to 1973, net investment in transportation property increased from $26,851,343,000 to $27,979,177,000, an increase of 4% over 18 years. However, average net investment in transportation property per mile increased by 14% over the same period, from $12,168,000 per mile to $13,880,000 per mile, in 1973.[10]

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[10] Yearbook of Railroad Facts, Association of American Railroads, 1976 ed.

An explanation for the sluggish growth in total net investment in rail transportation property may be that the rate of return on net investment in transportation property declined from 4.22% in 1955 to 2.33% in 1973. (All of the net investment figures are in current dollar amounts.) Since there was a rise in the general price level during this period, it may be inferred that the 1973 net investment in transportation property represents actually less of an increase in real net investment in transportation property over 1955 figures. In 1975, the total net investment in transportation property was estimated at $29,500,000 and the average rate of return for Class I railroads in the United States was estimated at 1.20 percent.

TABLE 48: Government Bond Yields, Railroad Rate of Return on Net Investment and Railroad Net Investment

	U.S. Government Bond Yield	U.S. - RR Rate of Return on Net Investment	U.S. - RR Net Investment (thousands of dollars)
1950	2.32		
1951		3.76	25,518,512
1955	2.84	4.22	26,851,343
1960	4.01	2.13	27,474,089
1965	4.21	3.69	26,318,532
1970	6.59	1.73	28,186,077
1973	6.30	2.33	27,979,177
1975 (est.)	na	1.20	29,500,000

Source: U.S. Bond Yields - Statistical Abstract of the United States, U.S. Department of Commerce, 1975 ed., p. 479.

U.S. Railroad Data - Yearbook of RR Facts, Association of American Railroads, 1968, 1976 editions.

Net investment in transportation is not available on a reliable statewide basis for the period 1955 to 1973. This figure is not recorded on a statewide basis simply because it is extremely difficult to determine the proportions of net investment for an entire railroad which should be allocated within state boundaries. Investments in one state usually may generate income streams from operations in another state. A computer facility or an automated classification yard located in one state may result in lower operating costs on parts of the railroad which happen to be located in other states. Because of the credibility limitation of statewide net investment data, figures offered here are system-wide numbers for rail carriers operating in Texas.

TABLE 49: Net Investment in Transportation Property
(thousands of dollars)

Year	FWD	MKT	KCS	MP	RI	SLSF	ATSF	SP
1955	54,885	266,204	141,678	910,970	388,795	275,102	1,229,111	971,081
1960	52,860	251,268	146,396	970,477	409,966	304,359	1,360,027	1,486,368
1965	47,929	226,719	145,687	945,890	415,019	332,953	1,463,723	1,810,904
1970	44,466	187,853	138,071	1,052,743	378,366	397,776	1,610,462	1,958,875
1973	44,886	176,937	204,221	1,093,961	351,996	434,878	1,665,247	2,048,733

Source: <u>Financial Overview of Railroad Companies Operating in Texas</u>, Texas Rail System Evaluation, Texas Transportation Institute, 1976.

Net investment in transportation property for carriers operating in Texas declined for three carriers over the period 1955 to 1973. These three carriers also experienced the greatest decline in their rate of return on net investment. During this period, probably because of very low expected return on investment, no additional dollars were added to the transportation property bases of these carriers. In fact, a portion of whatever capital was generated before 1963-1967 probably fled to areas where the expected return on investment would be greater. After 1963-1967, there was little or no net railway operating income available to reinvest in the transportation property bases of these railroads.

Total net investment in transportation property includes cash, materials and supplies (after deducting depreciation and amortization accrued under ICC accounting rules). Roughly, net investment in transportation property can be augmented by an addition of internally generated funds as capital expenditures and by the addition of capital investments (mainly locomotives and cars) in which (1) a small portion is paid by internally generated funds and (2) a larger portion is accounted for by medium to long term obligations. Conversely, net investment in transportation property can be decreased when the amount of accrued depreciation and amortization exceeds the amount of capital expenditures in any given year.

Capital Expenditures

Over the period 1955-1973, capital expenditures for Class I carriers in the United States increased from $909,521,000 to $1,342,138,000, a rise of 48%. (Capital expenditure data is not available for Texas.)

In nearly every year during this period, the level of capital expenditures on equipment has exceeded the level of capital expenditures on roadway and structures by 200%-400%. Part of the reason behind the ratio of equipment to roadway and structures capital expenditures is the greater ease with which railroads can obtain external financing for equipment compared to roadway and structures financing. One of the keys to the difference in the availability of external financing for equipment and roadway and structures financing is the relative liquidity of the assets in case of default. Rail cars and locomotives can easily be resold to another carrier, but grading, ties in place, or bridges have little transferable value. Another reason behind the lower relative capital expenditures for roadway is that under ICC accounting rules, a significant portion of maintenance of way expenses perform a function that would be included as capital investment under standard business accounting procedures.

Capital expenditures for Class I carriers are listed in Table 50. While equipment expenditures have increased by 57% from 1955 to 1973, roadway and structures capital expenditures increased by only 32% during the same period.

In conjunction with Ex Parte No. 305, the Interstate Commerce Commission required railroads participating in the rate increase to report the amount of delayed capital improvements in equipment and roadway. A list of the reported delayed capital improvements reported by railroads operating in Texas is shown in Table 51.

TABLE 50: Capital Expenditures for Class I Railroads
(thousands of dollars)

	Total	Equipment	Roadway and Structures
1955	909,521	568,202	341,319
1960	919,154	633,490	285,664
1965	1,630,687	1,303,602	327,084
1970	1,351,439	993,095	358,344
1973	1,342,138	892,690	449,448
1975	1,789,756	1,303,312	486,445

Source: Yearbook of Railroad Facts, Association of American Railroads, 1976 ed.

TABLE 51: Delayed Capital Improvements - Roadway and Equipment
Quarter ended 6/30/75 (thousands of dollars)

	Delayed Roadway Improvements	Delayed Equipment Improvements
ATSF	58,000	280,000
RI	82,748	77,854
FWD	21,949	1,286
KCS	12,356	55,394
MKT	19,819	24,040
MP	61,906	148,603
SLSF	35,909	9,309
SP	74,879	28,820
TM	0	0

Source: Interstate Commerce Commission: Application of Additional Revenues from Ex Parte 305 for quarter ended 6/30/75, January 28, 1976, No. 112-76.

The interpretation of what constitutes "delayed" capital improvements may take several guises. It is as difficult to define what capital improvements are "delayed" in the same sense that it is difficult to determine the actual level of maintenance that is "deferred." It would seem that capital improvements in this context could only be considered delayed if one or both of the following conditions exist: (1) internal or external funds are not available to make the investment and (2) the expected return from such investment projects is not equal to or greater than the opportunity cost of internally generated funds or the capital cost of externally available funds. Otherwise, a definition of "delayed improvements" implies normative judgments concerning the timing of capital expenditures. However, many of the forces which determine the availability of funds are exogenous (economic regulations, freight traffic levels affected by economic activity, etc.) and do effect the possible level of capital expenditure by limiting the availability of funds to invest during the time period.

While the relative difficulty in obtaining external financing for equipment versus roadway investments was discussed previously, the nature of the problem requires some additional explanation. One obstacle, in addition to the virtual lack of liquidity associated with investments in grading, ballast costs, fills, signals, and other things that are fixed in place, is the "hereafter" clause in many railroad mortgages.

> (The hereafter clause) means that not only was the property mortgaged as it stood on the day the indentures were signed, but the railroads agreed that anything acquired thereafter would also be covered by the original mortgage and serve as collateral. Therefore, even though a railroad upgraded its plant or acquired additional

> property increasing the value of its holdings tremendously, there is no way to place a mortgage only on the property that has been improved. With railroads being what they are, very few railroads find it possible to attract money on the basis of a second mortgage or debentures. And equity - common stock - is unsaleable at any price.
>
> On the other hand, it is generally possible for a railroad, even the weaker ones, to finance equipment purchases because these items do not come under the "hereafter acquired" clause until they have been paid for or "acquired." Since you can move equipment around, the lenders are always in a position to seize the equipment in the event of a default, so the bankruptcy courts have always reaffirmed these contracts. . . .
>
> But even if you were in a position to grant a mortgage lien on a particular piece of track, the majority of the cost is tied up in grading, ballast, cuts, fills, tunnels, signals, and other things that cannot be moved. This means that only a small part of the cost can be considered as repossessable collateral having a tangible asset value. This forces the lender to look at the financial earning power of a railroad corporation rather than the collateral. Since this power is determined by the system as a whole, the cases where a track repair loan would have significant impact on system earnings would be relatively few, and in any case, lenders are reluctant to take long term risks when the industry faces so many practices and political problems.[11]

In general, the after-acquired clause, the lack of collateral liquidity, the difficulty in determining the return on the investment project, the relatively long pay-off period, and the low rate of earnings by the industry in general have made it relatively difficult to attract external capital for investment in roadway and structures.

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[11] "Capital Needs for the Future," Address by R. N. Whitman, President, Missouri-Kansas-Texas Railroad Co. before the Transportation Requirements of the Ozarks Region, December 1975.

Cost of Capital

The cost capital for the railroad industry is fairly high relative to their rate of earnings measured by the rate of return on net investment. In 1950, the average rate railroads paid on bonds was 3.10% and their rate of return was approximately 3.70%. In 1974, however, railroads were paying an average of 8.98% on bonds while their rate of return on net investment was only 2.70%. Thus, the average cost of purchasing additional long term debt or refinancing older debts has begun to far exceed the industry average rate of return and also the rate of return for any Class I railroad in Texas.

TABLE 52: Railroad Average Bond Yields and Railroad Rate of Return on Net Investment

Year	Railroad Bond Yields	Railroad Rate of Return	U.S. Government Bond Yields
1950	3.10	3.76*	2.32
1955	3.34	4.22	2.84
1960	4.92	2.13	4.01
1965	4.72	3.69	4.21
1970	8.77	1.73	6.59
1971	8.38	2.12	5.74
1972	7.99	2.34	5.63
1973	8.12	2.33	6.30
1974	8.98	2.70	6.99

Source: Railroad Bond Yields and U.S. Goverment Bond Yields - Statistical Abstract of the United States, United States Department of Commerce, 1975 ed., p. 479.
Railroad Rate of Return - Yearbook of Railroad Facts, Association of American Railroads, 1976 ed.

* Actual 1951 railroad rate of return; 1950 data not available.

While all industry groups in the economy have certainly experienced increases in direct capital costs similar to those felt by the railroad industry, earnings in those sections have generally kept pace or exceeded direct capital costs over the past 20 years. Table 53 illustrates the comparative profitability of major industry sectors from 1955 to 1976. All major sectors (with the exception of the airline industry in certain years) have far out performed the railroad industry in terms of financial measures. As railroad industry earnings have declined and capital costs have increased, the railroad industry's incentive and ability to compete for captial funds have diminished. Refinancing at higher rates requires greater relative earning capacity, a factor noticeably absent from railroad industry financial statements in recent years.

TABLE 53: Profitability of Eight Industry Groups

(Net income after taxes as percent of net worth)

Year	Class I Railroads	Common Carrier Trucking	Air transportation	Electric & Gas Utilities	Telephone & Telegraph	Commercial Banking	Total Manufacturing	Total All In- dustr
1955	5.7	n.a.	13.9	9.9	9.5	7.9	15.0	12.
1960	2.6	6.3	4.1	10.0	9.9	10.1	10.6	9.
1965	4.6	19.7	29.5	11.3	9.9	8.7	13.9	11.
1970	1.3	9.6	def	11.3	9.5	10.4	10.1	9.
1975	0.7	12.7	def	11.6	10.0	11.8	12.6	11.
1976	1.8	14.8	13.1	11.8	11.6	11.8	15.0	13.

Source: Lemont K. Richardson, Railway Age, June 27, 1977, pp. 32-38.

There are four rail carriers operating in Texas with railroad bonds maturing between 1977 and 1980. In all cases, the carriers paid between 2 7/8% and 4 1/2% on this debt (which totals $50,393,000).[12] Using the listed interest rates as the average interest paid annually, the four carriers have paid a total of $1,652,594 annually in interest. At the average railroad bond yields in 1974 of 8.98%,the same carriers, if they refinanced the debt at this rate, would pay a total of $4,525,291 per year in interest charges; an increase of $2,872,697 annually in interest charges alone. As it stands, only $1,798,000 of the $50,393,000 in debt does not have a sinking fund and must be refinanced, but the difference in current interest rates over past rates is quite significant considering the industry's earning record. Hypothetically, if the total $50,393,000 had to be refinanced by the carriers, and an additional $2,872,697 were required for annual fixed charges, the dilemma necessarily arises as to where those carriers would find the additional money to pay increase in interest charges alone on the same level of debt.

Another consideration of the debt which railroads are financing is that investors are not selling as much long term debt to railroads. Railroads are not only having to pay more for bonds, but they're having to turn them over more frequently. The Penn Central crisis also affected the rate of interest which railroads will be paying on long term debt.

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[12] "What Price Money?", <u>Modern Railroads and Rail Transit</u>, February 1975.

> "Institutional investors . . . have been through other railroad bankruptcies, but PC is different, because it appears that they won't be able to foreclose and get their money back. And if you can't foreclose, you don't have a true mortgage."[13]

Thus, the increased risk involved with selling railroad debt has forced interest rates associated with what used to be considered a fairly safe investment, upward in order to compensate for the decline in real or perceived stability.

As for stock, the only reason one would want to buy railroad stock is for an expectation of future earnings along with expected future dividends and appreciation. However, railroad earnings just don't support these expectations, and stockholders are the last in line to collect at a bankruptcy proceeding.

While railroad bond yields give an idea of the approximate direct cost of external capital, reinvesting internally generated capital into the railroad industry also has a cost. For the railroad industry, this cost is the difference between the expected return from investing internally generated funds into the industry versus the expected return from investing those funds elsewhere. In 1973 the implicit cost on internally generated funds of that year was at least equal to the difference in the 1974 average railroad industry return of 2.70% and the 1974 yield in U.S. Government bonds of 6.99%. (Since 1957 the rate of return on net investment in the railroad industry has been consistently below the average yield paid on U.S. Government bonds and yield on railroad bonds.)

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[13] "What Price Money?", Modern Railroads and Rail Transit, February 1975.

While this example serves only as an approximation of the implicit cost in funds reinvested in the railroad industry, it clearly illustrates the significant differences in returns earned in the railroad industry relative to those earned elsewhere in the economy. Thus the incentive for railroad funds reinvestment has diminished as the differential in relative returns has widened over the past 20 years.

The railroad industry faces not only a direct capital cost in excess of its earnings, but it also faces a significant cost on internally generated funds reinvested in the railroad industry. In terms of capital investment, railroads have been paying more in capital costs than they have been earning on net investment.

In the future, the relative direct cost and availability of external capital for roadway and equipment expenditures will continue to make it relatively difficult for railroads to invest in roadway and structures versus equipment. As the implicit cost of capital rises relative to railroad earnings, incentives will increase for railroads to direct internally generated funds to areas where the rate of return is higher. Rational rail managers will follow this course of action in order to maximize the value of investment to stockholders.

VI. Effects of Declining Railroad Earnings

The decline in the return on U.S. and Texas railroads has had obvious effects. Service levels have declined and rail accidents have increased. Both reduced service levels and increased accident rates directly affect future demand for rail transportation, thereby further reducing expected rates of return. Prospects for lower rates of return in the railroad industry should prompt rail managers to seek alternate investments for internally generated capital.

Rail Service Levels

The relatively low rate of return on net investment in the railroad industry has affected its ability to provide a higher level of service than that presently offered. Investment projects which may enhance the level of service offered are often delayed due to the relative lack of available capital funds. Additionally, investments in improved service by one carrier may not be matched by interchanging carriers and the effect of the overall service improvement would be minimal. With a limited amount of external and internal capital available, the investment decisions of railroads are first directed to those areas necessary to maintain basic system operations. Often times there is little capital remaining to invest in areas which may significantly improve the quality of rail service.

Increased relative rail labor cost have prompted rail management to substitute rail capital inputs for rail labor in operations. In order to reduce total operating costs, the ratio of crew members per rail car hauled is minimized. The result has been longer, heavier and fewer trains operated. While there is no inherent advantage to operating longer and heavier trains, many direct, short run operating costs are minimized.

While fewer and longer trains, per se, do not have a deleterious effect on rail service, the probability distributions underlying the quality of rail service are certainly affected. Approximately one-half of all rail shipments are interlined[14] and 62% of a typical rail car cycle is spent in intermediate and terminal rail yards.[15] The magnitude of these statistics indicates that a large number of train connections must be made by a rail car as it travels from origin to destination. There is a probability that a rail car will make each of its train connections on-time and that the rail car will arrive at the destination within the time period desired by the shipper. If the number of trains are reduced, the total number of possible connections at each yard are reduced. When the total number of possible connections at each yard are reduced, the probability that a rail car will make each of its connections on-time and arrive at the destination within the original time period is necessarily reduced.

Because this probability is reduced, the expected mean shipping time increases. The variance in shipping time shifts to the right about the increased mean shipping time.

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[14] Improving Railroad Productivity. Task Force on Railroad Productivity, 1973, p. 232.

[15] Rail Service in the Midwest and Northeast Regions, Secretary of Transportation, Vol. I, 1974, p. 9.

Value of Service to Shippers

While another report in the Texas Rail Evaluation is devoted entirely to an analysis of shipper service demands and the value of improved rail service, this section is an abbreviated look at what service quality means to a shipper. Shippers perceive the full price of transportation service to be composed of two elements, rate or tariff amount plus a time element. Whenever the time element of transport service increases, shippers pay a higher "full price" for transport services. When railroads increase the mean or variance in transit time for shipments, shippers pay a higher "real" transport price.

The time component of transport cost affects shippers through their inventory policy. First, rail shippers will attempt to minimize the level of inventory that they must carry in order to reduce inventory costs (warehouse space, interest on money borrowed to pay for inventory, insurance, etc.). However, they must balance inventory cost minimization against the cost of not being able to deliver a product to a customer due to inadequate inventory. The cost of not being able to deliver a product to a customer is (1) the opportunity cost or the cost of the sale foregone and (2) the effect that the inability to deliver a product will have on the future arrival rate of customers at the shipper's firm. (If customers know that a business has a higher probability of being out of an item, they will not continue to return to that business.) Shippers will demand more reliable transportation service in order that they may reduce overall inventory and yet not increase the probability of ever having zero inventory levels. Unfortunately, rail transportation has not enabled shippers and receivers to more efficiently manage inventory levels and many shippers have shifted to alternate modes for transport services in order to reduce "full" transport costs.

In the report, A Survey of Transportation Users' Attitudes and Perceptions of Rail Service in Texas,[16] the majority of respondents chose the area of improved reliability in rail movements more often than any other desired improvement. Shippers in Texas indicated that improvements in transit time and improved consistency of transit time are most significant to them in terms of rail system utilization.

Loss and Damage

Another result of longer and heavier trains is an increased incidence in loss and damage. Increased loss and damage has the same effect upon shipper costs as inventory levels. An increased probability in loss and damage means that the receiver has to maintain higher inventory levels or the opportunity cost and costs in terms of reduction in demand for his products will increase due to more frequent stock-outs.

Longer and heavier trains increase loss and damage expenses because slack action in longer trains increases and the probability of derailments increases with train length.[17] A digression into the technology of rail freight trains will assist one in understanding the cause of increased slack action in longer and heavier trains. The modern Janney coupler replaced the old link and pen coupler by the 1880's.

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[16] A Survey of Transportation Users' Attitudes and Perceptions of Rail Service in Texas. Texas Rail Evaluation, Texas Transportation Institute, 1976, p. 61.

[17] Refer to "Slack - The End Result of Most of What is Wrong With Railroading," George A. Hilton, Trains, February 1976, pp. 22-28.

The advantage of the Janney coupler was that two couplers could be closed without the assistance of human hands. While numerous human appendages were no doubt saved by this invention, it did introduce several drawbacks. The Janney coupler had to have a knuckle strong enough to hold the weight of a good long train behind it, and something that substantial required a real bash to close it. Today's optimal coupling speed is recommended at 4 mph. The impact created by coupling increases with coupling speed. An impact at 8 mph is 16 times as great as the impact between two cars created at 2 mph. Because of the tremendous impacts created by coupling, it is very difficult to protect a shipment against damage from switching impact alone. Not only is impact created when switching rail cars. Rail car couplers and draft gears are allowed a certain amount of longitudinal play in order to absorb longitudinal forces. When a train is in motion all of the slack is pulled out. Slack will run out car by car as the train begins. When a train comes to a stop, slack will run in because air pressure to brake systems requires time to traverse the length of an entire train.

When a train runs upgrade and downgrade, train length expands and contracts irregularly but quickly and the cars bang into one another. The longer the train length, longer time is required for air pressure to reach cars at the end of the train. Train expansion and contraction irregularity increases with train length, which increases slack action and impact forces upon rail cars. The increase in impact forces with train length will increase the amount of loss and damages since cargo will also be subjected to greater impacts.

There is another effect of increases in train length upon loss and damage. The probability of a train derailing from equipment-related causes increases faster than train length. A study entitled A Study of the Economics of Short Trains, Peat, Marwich & Mitchell Co., 1974, found that the probability of a train's derailing from equipment-related causes was .001 when train length was under 100 cars. The probability at 200 cars was .005. At 250 cars it was 0.12, and over 250 cars was .024. While railroads seldom run trains in excess of 200 cars, the trend toward increasing train length in combination with the increased probability of a derailment indicates that a portion of loss and damage expense increases in past years may be attributed to these causes. In the event of a derailment, cargo is subjected to severe impacts, theft and other potential losses.

Train Accidents

Another result of the low rate of return on U.S. and Texas railroads is an increase in railroad derailments. As the rate of return for railroads has declined, maintenance expenditures have also declined (refer to Chapter 4). Reduced maintenance on many lines has increased the probability and incidence of railroad derailments. In 1970 there were 273 railroad derailments in Texas. By 1974 this total had risen to 525, an increase of 92%. U.S. derailments over the same period rose by 52% from 5,602 to 8,513 in 1974.

TABLE 54: RAILROAD DERAILMENTS - U.S. and TEXAS

	Total Number of Derailments Reported	
Year	U.S.	Texas
1970	5,602	273
1974	8,513	525

Source: Summary and Analysis of Accidents on Railroads in the U.S. Federal Railroad Administration,
Bulletin #139 - Table 106, 1970
Bulletin #143 - Table 122, 1974.

Derailment data was not reported on a statewide basis by the FRA before 1970; therefore, a more meaningful interpretation of the change in Texas derailments over time is not possible. In the United States in 1974 track defects were the leading cause of train derailments. Of the 8,513 derailments in 1974, 49% were related to track.

TABLE 55: TRAIN ACCIDENTS BY TYPE AND CAUSE - U.S.

	Cause of Derailments				
	Human Factors	Equipment	Track	Other	Total
	877	1,973	4,193	1,470	8,513
% Distribution by Cause	10.3%	23.2%	49.2%	17.3%	100.0%

Source: Summary and Analysis of Accidents on Railroads in the U.S. Federal Railroad Administration, Bulletin #143, Table 201, 1974

The relatively high percentage of total derailments related to track would tend to support the hypothesis previously raised. The reduction in profitability has caused a reduction in maintenance.

A closer look at railroad accidents over time is afforded by data reported by the Texas Railroad Commission. Total train accidents (excluding railroad highway crossing accidents) declined from 1955 to 1973 from 928 to 671. Train accidents per thousand train miles operated also declined from .025 in 1955 to .021 in 1973.

TABLE 56: TRAIN ACCIDENTS IN TEXAS

	Total Train Accidents	Total Train Accidents per 1,000 train miles
1955	928	.025
1960	792	.025
1965	940	.031
1970	972	.035
1973	671	.021

Source: Annual Reports of the Railroad Commission of Texas, selected years.

On a time series comparison, train accidents have actually declined in Texas. Because of the differences in reporting formats, it is difficult to draw distinct interpretations from the Texas Railroad Commission and the Federal Railroad Administration data for comparable years. One may only say that while total train accidents appear to be decreasing in Texas, derailments resulting from levels of industry profitability appear to be increasing.

A final note concerning derailments is in order. If the hypotheses that derailments are a function of maintenance expenditure, and maintenance expenditure is a function of train density are correct, it may be inferred that derailments have a higher probability of occuring on lightly used rail lines. The well maintained heavy density rail lines have a lower probability per thousand train miles of experiencing a derailment.

VII. Projected Rail System Activity in Texas

Projected Railroad Activity

Forecasting the level of railroad activity through the following decade is a highly speculative task. Because of the dramatic changes which have occurred in the northeastern United States concerning industry structure, and a constantly changing demand for rail transportation, estimates of future levels of industry activity may vary widely.

However, there are estimates of the rate of growth of the Texas economy from 1970 to 1985. Projects SD 1 & 2, a report the Governor's Energy Advisory Council prepared in January 1975, estimated real growth for all Texas economic sectors. The result of this work indicated that the real growth in the Texas economy between 1970 and 1985 would result in an increase of 89%, or an average annual growth of 5.93%. Railroad output was estimated to increase by 84% or 5.6% on an average annual basis, while transportation in general was projected to increase by 79% over the 15 year period.

TABLE 57: PROJECTED REAL OUTPUT 1970-1985, TEXAS
(millions of 1967 dollars)

	1970	1985	% increase 1970-1985
Texas - all sectors	80,509.23	152,221.86	89%
Transportation sector	2,790.80	4,982.03	79%
Railroads	572.60	1,052.67	84%

Source: Report to the Governor's Energy Advisory Council, Projects SD 1 & 2, Austin, Texas, January 1975.

In accordance with past U.S. trends, transportation growth is expected to increase more slowly than total economic output. While railroads are projected to increase more rapidly than transportation in general, railroad output is still expected to increase at a rate less than total economic output.

This estimate of future rail activity may be slightly high. However, an examination of estimated activity of selected economic sectors will provide additional insight into the future demand for rail service in Texas. In 1974 ten commodity groups accounted for 89% of originated tonnage in Texas. They are listed in Table 58

TABLE 58: TOP TEN COMMODITY GROUPS BASED UPON
ORIGINATED TONNAGE IN TEXAS, 1974

Commodity	% of Total Tons	Related Economic Sector(s)
Non-metallic Minerals	26	Other Mining & Construction secto
Chemicals & Allied Products	25	Chemicals sector
Farm Products	10	Agriculture sector
Petroleum & Coal Products	9	Petroleum Refining & Product sector
Food & Kindred Products	7	Food Processing
Lumber & Wood Products	5	Logging, Wood & Paper
Stone, Clay & Glass Products	4	Glass, Clay, Stone, & Cement
Waste & Scrap	4	All manufacturing sectors
Primary Metal Products	3	Primary Metal Process
Pulp, Paper & Allied Products	3	Logging, Wood & Paper
Misc. Mixed Shipments	2	Wholesale trade

Source: Commodity Data - R-1 Annual Reports to the Railroad Commission of Texas,
Economic Sector Data - <u>Report to the Governor's Energy Advisory Council,</u>
<u>Projects SD 1 & 2</u>, Austin, Texas, January 1975.

With the exception of the petroleum refining and chemical products, all economic sectors which generated the greatest amount of rail tonnage in 1974 are expected to grow at a rate between 10%-20% below the average rate of the Texas economy. The petroleum refining, chemical product and electric services sectors are among the sectors expected to experience the highest rate of growth through 1985. The electric service sector was introduced because its rate of growth will greatly influence the demand for coal transport into Texas. A list of the expected rates of growth for the petroleum refining, chemical product and electric services sectors appears in Table 59. (Even under a more restricted energy availability scenario, the projected 1985 output for these three sectors still exceeds 1970 output by 100%.)

TABLE 59: PROJECTED RATE OF GROWTH OF IMPORTANT RAIL RELATED ECONOMIC SECTORS IN TEXAS - 1970 TO 1985

Economic Sector	Projected Rate of Growth
Petroleum Refining & Products	190%
Electric Services	156%
Chemical Products	124%
Texas Economy Avg.	89%

Source: Report to the Governor's Energy Advisory Council, Projects SD 1 & 2, Austin, Texas, January 1975.

The implications of the 1985 growth projections are fairly obvious. Railroad output is expected to expand slightly more slowly than total output in Texas (84% vs. 89%) and with two exceptions, demand generated for principal commodity groups originated by railroads in Texas is expected to grow at a rate between 10-20% more slowly than the economy in general. Railroads hauling proportionally more chemical products, petroleum products, or coal will experience greater demands for transportation services relative to other rail carriers in Texas. If it can be assumed that higher relative growth in transportation demands will be translated into greater financial stability, the future appears brighter for carriers with chemical, petroleum product or coal traffic mixes.

While growth in output was projected at an average annual increase of 5.6% between 1970 and 1985, least square trend analysis based upon historical data indicates that Texas railroad ton miles would increase by 2.3% on an average annual basis. This estimate may be accepted as a possible low estimate of rail ton mile increases.

While rail output is forecast to increase at an average annual rate of 2.3%-5.6%, the industry will still face substantial problems. It has been estimated that between 1975 and 1985 an additional $5 billion will be required to rehabilitate rail lines to a "normal" engineering standard in the U.S. (excludes ConRail).[18] This amount of cash shortfall is defined as the amount that is required to "catch-up" on "deferred" maintenance activity for which cash has not been and will not be available. The $5 billion equals $500 million on an annual basis in the U.S.

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[18] A Review of National Railroad Issues, United States Congress, Office of Technology Assessment, Washington, D. C., December 1975.

In 1973, Texas generated 7% of U.S. ton miles and in 1975 Texas represented 7% of U.S. rail miles. If it can be assumed then that 7% of this problem is applicable to Texas, Texas railroads will experience an average annual "cash shortfall" of $35,000,000. However, Texas railroads have been in a superior financial position relative to the nation's railroads. Thus, if $35,000,000 is multiplied by the ratio of the 1973 Texas rate of return on net investment to the 1973 U.S. rate of return on net investment, Texas railroads' annual cash shortfall could amount to $27,300,000. Under this scenario, while railroad output is expected to grow, track conditions (which are probably optimal under present financial constraints) will not improve. There are several options within the sphere of public control which could ease this cash shortage. A list of options and an estimate of their annual magnitude follows.

- State and local advalorem taxes - In 1975 railroads paid $20,679,000 in state and local taxes in Texas.
- Local speed ordinances - There are an estimated 406.8 miles of speed restrictions in Texas imposed by local authorities. The average number of daily through trains were identified for each speed restriction. Based upon the speed reduction from the maximum caused by the local ordinance and upon cost data calculated by the Stanford Research Institute, it was estimated that local ordinance speed restrictions cost Texas railroads between $2,801,374 and $6,761,625 annually through additional operating expense.[19]

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[19] General Overview of Railroad Safety in Texas, Texas Transportation Institute, College Station, Texas, August 1977, p. 42.

- Texas Railroad Commission rate delays following ICC approval - The ratio of intrastate to total revenue for Class I carriers in Texas was calculated for the period 1963-1973. Over the period, an average of 20% of total revenues for Class I carriers in Texas was obtained from intrastate traffic. In 1973, total rail revenues amounted to $928,419,976. If it can be assumed that railroad revenue in Texas in 1976 was at least equal to 1973 revenue, that railroads will request a minimum of 5% general rate increase annually, and the Railroad Commission of Texas will delay each request for a general rate increase on intrastate traffic by an average of 2 months per year, the cost of the delays in terms of revenues lost can be calculated.

  Of $928,419,976 in total revenue, 20% would be $185,693,995 from intrastate rail traffic. A 5% increase in intrastate rail traffic would amount to an additional $8,274,200 in revenue in that year. A delay of 2 months before granting the general increase results in $1,576,614 being lost in that year. (See Table 60 for a review of the delay in rate increases on intrastate rail traffic in Texas.) This figure would be even larger if revenues of Class II rail carriers were added into the calculation. Thus, future Railroad Commission policy concerning rate delays has a significant impact upon additional net revenue available to railroads.

TABLE 60

APPLICATION OF GENERAL RAIL EX PARTE INCREASES ON INTERSTATE AND TEXAS INTRASTATE TRAFFIC

Ex Parte Increase Tariff No.	-Interstate-		-Texas Intrastate-		Time Difference Between Interstate Increase and Texas Intrastate Increase
	Effective Date	Percentage Increase	Effective Date	Percentage Increase	
X-259-A	6/24/68	3%	6/30/69	6%	12 months 6 days
X-259-B	11/26/68	6% Absorbed 3%			
X-262	11/18/69	6%	4/28/70	6%	5 months 10 days
X-265-A	6/9/70	5%	2/5/71	6%	7 months 27 days
X-265-B	11/20/70	6% Absorbed 5%			
X-267-A	11/21/70	8%	6/2/71	12%	6 months 12 days
X-267-B	4/12/71	12% Absorbed 8%			
X-281	2/5/72	2½%	3/24/73	5%	13 months 19 days
X-281-B	10/23/72	5% Absorbed 2½%			
X-295-A X-295-B	8/19/73	3%	11/3/73	3%	2 months 15 days
X-299	10/1/73	1.9%	11/15/73	1.9%	1 month 14 days
	1/1/74	2.6% Absorbed 1.9%	1/1/74	2.6%	None
X-299-A X-299-B	3/16/74	2.8% Absorbed 2.6%	6/29/74	2.8%	3 months 13 days
X-301	1/31/74	2.1%	2/13/74	2%	0 months 13 days
			4/16/74	2.1%	1 month 7 days
X-301-A	3/9/74	2.5% Absorbed 2.1%	6/29/74	2.8%	2 months 28 days
X-301-B	4/1/74	2.8% Absorbed 2.5%			
X-301-C	5/1/74	3.0% Absorbed 2.8%	7/12/74	3%	2 months 11 days
X-301-D	6/1/74	3.3% Absorbed 3.0% (Transferred to X-305-A 6/20/74)	(See X-305-A below)		
X-303-A X-303-B	3/9/74	4%	4/16/74	4%	1 month 7 days
X-305-A	6/20/74	3.3% then 10%	11/28/74	10%	5 months 8 days
		(Cancels X-301-D)	5/14/75	3.3%	11 months 14 days
X-305-RE	10/11/75	10% Recyclables	5/26/76	10%	7 months 15 days
X-310-A	4/27/75	7%	7/1/75	7%	2 months 3 days
X-313					
Phase I	6/20/75	5%	8/27/75	5%	2 months 7 days
Phase II	10/11/75	2.5%	11/7/75	2.5%	0 months 27 days

Source: Correspondence with Mr. L.O. [illegible], Missouri-Kansas-Texas Railroad Company, June 5, 1976

Appendix A

TEXAS TRACK SEGMENT DATA

1.	Card Number	1 1
2.	Segment Number	☐☐☐☐☐☐☐ 2 8
3.	Segment Points	☐☐☐☐☐☐ ☐☐☐☐☐☐ 9 14 15 20
4.	Mileposts	☐☐☐☐☐●☐ ☐☐☐☐☐●☐ 21 26 27 32
5.	Length	☐☐☐☐●☐ 33 37
6.	Joint Operation	☐☐☐☐ ☐☐☐☐ ☐☐☐☐ 38 41 42 45 46 49
7.	Maximum timetable speed	Pass. ☐☐ Frt. ☐☐ 50 51 52 53
8.	Signal System	☐ 54
9.	Number of Tracks	☐ 55
	Avg. Daily Through Trains	Pass. ☐ Frt. ☐☐ 56 57 58
	Feet of Passing Track	☐☐☐☐☐☐ 59 64
	Operating Status	☐ 65
	Number of Street Crossings	☐☐☐ 66 68
	Maximum Weight Limit (000)	☐☐☐ 69 71
	Maximum Vertical Clearance	☐☐ 72 73
	Miles of Speed Restriction 10-20 m.p.h. Below Maximum Speed	☐☐ 74 75
	Miles of Speed Restriction Greater Than 20 m.p.h. Below Maximum Speed	☐☐ 76 77

TEXAS TRACK SEGMENT DATA

1. Card Number 2
1

2. Segment Number
2 8

3. Division
9 23

4. Sub-Division
24 38

Appendix B

Effect of Terminals on Rail Reliability*

It is generally agreed that transit time unreliability is one of the most important problems of rail service today. Poor reliability results in higher shipper and consignee costs. Transit time unreliability may be the largest determinant of shipper modal choice; and it may be most explanatory of the railroads' declining market share. Delays to cars in yards are much more important factors in system reliability than delays to road trains.

It is the nature of railroad operations that a car encounters numerous opportunities for delay as it moves from its origin to its final destination. At each yard, cars moving to common intermediate or final destinations are consolidated into "blocks," placed in a train consisting of one or more blocks, and handled together to another yard which may be twenty or more than a thousand miles distant. Whenever a car is set off from a train or the train reaches its destination, the car is reswitched and consolidated with other traffic into a new block and a new train. This procedure is repeated until the car reaches its final destination.

This process of switching and consolidation necessarily results in longer transit times than would be required for direct movement (such as by unit train). Equally as important, this process is unreliable. That is, each time a car is switched, the potential for a missed connection at that yard exists.

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* This chapter has been extracted directly from Studies in Railroad Operations and Economics, Vol. 4, "The Impact of Classification Yard Performance on Rail Trip Time Reliability." Robert M Reid, et. al. MIT, June 1972.

Missed connections are critical in that they lead to car delays on the order of 12-24 hours (the time until the next appropriate outbound train), large variations in transit time and hence unreliable performance.

A car may miss its outbound connection for a variety of reasons:

a. Outbound train cancellations - the outbound train or block did not run due to a lack of power, crew, traffic or other causes.

b. Train Length/Weight Constraints - If the appropriate outbound train has already exceeded its length or weight restrictions, the car in question will not be accommodated.

c. Other causes including car misclassification, car repairs, "no-bill", etc.

d. Late arrival of car - the inbound train carrying the car in question may arrive behind schedule and the connection with the outbound train is missed. Of course, the outbound train could be held for the car allowing the connection to be made despite the lateness of the arrival. However, this may well lead to further problems because the primary cause of late arrivals at a yard is late departure from a preceeding yard. Hence, holding trains to allow particular connections to be made may well lead to inbound lateness at succeeding yards and the possibilities of other missed connections.

The problem of yard performance and missed train connections is a complex one with the various components and operating policies of the rail network heavily interacting to effect performance. Because a rail car moves through a series of yards from origin to destination, even small probabilities of missing each connection will produce high levels of overall movement unreliability when repeated serially.

In general, there are two ways to improve movement reliability through yards: reduce the level of unreliability at each yard or accept the present level of unreliability at each yard and reduce the number of yards through which a car must pass. Railroads have traditionally chosen the second alternative wherever traffic volume has been sufficient.

Apparently, there have been few generalized attempts to identify the causes of unreliability in sufficient detail to improve performance at the individual yards through which a car must pass.

Since a missed connection at a terminal will typically lead to a 12-24 hour delay, one study focused upon the causes of missed connections. An analysis of car movement records for one large hump yard and two small flat yards demonstrated:

a. that a substantial number of cars missed normal connections at the yards studied. In the yards studied, the percentage of loaded cars which did so ranged from 25-31%. Comparable figures for empties ranged from 34-68%.

b. that many of these missed connections result from the cancellation of outbound trains. On the order of 20-30% of cars fell into this category.

c. that even if outbound cancellations were discounted, on the order of 5-15% of all cars are delayed and these delays are due predominately to late inbound arrival. Considering only those cars whose outbound is not cancelled, on the order of 7-30% of cars are delayed.

d. that there is a causal relation between time available to make a connection and the probability of that connection being made successfully.

e. that substantial movement unreliability exists through terminals.

The study demonstrated that there is substantial room for improvement in terminal performance. Policies exist that would allow shippers to experience more reliable performance with respect to freight transit times. However, the costs inherent in implementing such policies are difficult to determine.

In Texas the two largest rail freight terminal complexes are centered in the Dallas-Ft. Worth, and Houston areas. Either of these terminal complexes handle the large volume of north-south freight movement through Texas. The Houston terminal complex is served by six of the major rail systems serving Texas. Only the SLSF and KCS systems do not serve Houston. The Dallas-Ft. Worth complex is served by every major rail system in the state.

While there are numerous other rail yards throughout Texas, the terminal areas in Dallas-Ft. Worth and Houston are most complex and handle the greatest traffic loads. Any actions which reduce the probability of delay in these areas will have the greatest effect upon improving rail system reliability in Texas.

Appendix C

Military Utilization of the Rail System in Texas

In addition to providing transportation service to many significant sectors of the economy, the railroads play a vital role in the flow of military traffic for the Department of Defense. While there are many large corporate rail shippers, the Department of Defense is perhaps the single largest rail shipper and receiver in the United States.

Just as many economic sectors are vital to the Texas economy, defense installations are significant to the Texas economy in terms of their employment and purchasing impacts. Not withstanding their critical defense roles during mobilization periods, defense installations in Texas have significant peacetime economic importance. Therefore, railroads' role in providing transportation support to the many defense installations in the state warrants further examination.

Military Rail Traffic Description

During a period from April, 1974, to March, 1975, the Department of Defense originated 3,268,806 tons of traffic. This would have amounted to approximately .002 or two tenths of one percent of total United States originated rail tonnage in 1974.

TABLE C-1: Department of Defense Rail Traffic - Originated U.S. & Texas

	DOD Tonnage	DOD Carloadings
U.S.	3,268,806	83,628
Texas	302,581	8,742
Texas Percent of U.S.	9.3	10.4

Source: Analysis of Rail Routing for Defense Commodities. Military Traffic Management Command. Department of Defense. April, 1974 - March, 1975.

Within Texas, the Department of Defense originated 302,581 tons of military traffic. 302,581 tons represents .0042 of total originated Texas rail tonnage in 1974. Because military traffic is two times greater as a percentage of total originated rail traffic in Texas relative to the United States, it may be inferred that military traffic is of greater significance to railroads in Texas. Such an inference is not entirely unfounded since 9.3% of all originated military rail tonnage and 10.4% of all military rail carloadings originated in Texas.

During the period from April, 1974, to March, 1975, 224,986 tons of military traffic was terminated in Texas. This amount would have represented .0025 of all terminated rail traffic in Texas in 1974. The 224,986 tons of military traffic terminated in Texas represented 6.9% of all military rail traffic terminated in the United States during the same period. This tonnage was terminated by 7,144 carloads of traffic or 8.5% of all U.S. terminated rail military carloads in the United States during that period.

Four single commodity groups account for approximately 84% of military rail tonnage in Texas. The four groups are, in order of tonnage: petroleum products, ammunition and explosives, military vehicles, and tractors and tanks.

While petroleum products move primarily in bulk in tank cars or trucks, military vehicles and tanks and tractors often have weight and dimensional characteristics which restrict movements to rail. It is sometimes more hazardous to ship ammunition and explosives in large quantities by a transport mode other than rail. Because of the unique characteristics of many of the military traffic requirements, rail service is essential to the Department of Defense in its military traffic management plans.

TABLE C-2: Military Commodity Groups in Texas

Commodity	Tonnage Originated or Terminated
Petroleum Products	307,106
Other Commodities*	58,723
Ammunition and Explosives	55,946
Military Vehicles	39,713
Tractors and Tanks	39,579
Motor Vehicles	12,014
Iron and Steel	6,017
Machinery Parts	3,995
Provisions	3,395
Electrical Equipment and Parts	1,079
Total	522,567

* Other commodities include all commodities not represented in one of the nine commodity groups.

Source: Analysis of Rail Routing for Defense Commodities. Military Traffic Management Command. Department of Defense. April, 1974 - March, 1975.

Military Rail Facilities in Texas

There are approximately 26 defense activities in Texas with available rail freight service. A documentation of the defense activity name and location, the connecting rail carrier, and a description of the rail facility at these 26 defense activities follows.

Dyess Air Force Base Abilene, Texas

Government trackage connects with the Texas and Pacific Railway Co. at Tye, Texas. The TP performs internal switching. Trackage is available for troop trains and storage space is available for 25 freight cars. Side and end ramps are available. Installation can receive aviation gasoline and JP-4 fuel by tank car. Facilities are available to receive containers by rail and crane capacity is 20 tons.

Bergstrom Air Force Base southeast of Austin, Texas

This installation is served by the team tracks of the Missouri-Kansas-Texas Railroad, the Missouri Pacific Railroad and the Southern Pacific Railroad at Austin, Texas, 8 miles away. Activity is also served by the facilities of the MoPac for unloading a maximum of 10 tank cars of JP-4 jet fuel at Vinson, Texas, ½ mile away from installation.

Naval Air Station, Chase Field east of Beeville, Texas

The Southern Pacific Transp. Co. operates a receiving depot with a side ramp approximately 6 miles from this installation.

Webb Air Force Base west of Big Spring, Texas

Government trackage has been placed in condition 4-Sterile. Activity is served by the team tracks of the Texas and Pacific Railway Co., 5 miles away. Side and end ramps are available for use with TP team tracks.

Naval Air Station Corpus Christi, Texas

Government trackage connects with the Texas Mexican Railway at Flour Bluff, Texas. Trackage terminates inside boundary of the Naval Air Station. The Government has no internal switching capability. There is storage space for 3 freight cars; however, there are no off-loading facilities. Facilities are available to receive containers by rail and the crange capacity is 18 tons.

Naval Auxiliary Air Station, Cabaniss Field (Inactive) south of Corpus Christi, Texas

Government trackage connects with the Texas-Mexican Railway Co. between Flour Bluff and Flour Bluff Jct., Texas. Trackage is available for troop trains and storage space for 10 freight cars. Side ramps are available. Facilities are available to receive bulk petroleum products by tank car.

Naval Air Station Dallas, Texas

Government trackage connects with the Texas and Pacific Railway Co. at Mountain Creek, Texas. Internal switching is by the T&P. Trackage is available for troop trains and storage space is available for 50 freight cars. Side ramps are available. Facilities are available to receive aviation gas and JP-4 fuel by tank car. Facilities are available to receive containers by rail.

Laughlin Air Force Base east of Del Rio, Texas

Activity is served by the team tracks of the Southern Pacific Co. at Del Rio, Texas, 7.5 miles away.

Fort Bliss north of El Paso, Texas

Government trackage connects with the Southern Pacific Co., at Fort Bliss. Government performs internal switching. Trackage is available for troop trains. Storage space is available for 75 freight car.

Fort Hood west of Killeen, Texas

Government trackage connects with the Santa Fe Railway Co. within the reservation boundary. Government performs internal switching. Trackage is available for troop trains. Storage space is available for 75 freight cars. Side and end ramps are available. Facilities are available to receive shipments in bilevel and trilevel cars. Facilities are available to receive containers by rail. The crane capacity is

18 tons, but lift capacity of 100 tons can be effected by the Santa Fe at the installation on 24 hours advance notice.

Naval Air Station southeast of Kingsville, Texas

This installation is served by team tracks of the Missouri Pacific Railroad Co. at Kingsville, Texas, 5 miles away.

Reese Air Force Base west of Lubbock, Texas

This installation is served by the team tracks of the Santa Fe and Fort Worth & Denver Railway Companies.

Fort Wolters (Inactive) east of Mineral Wells, Texas

Government trackage connects with the Weatherford, Mineral Wells and Northwestern Railway Co. at Deacon, Texas. The WMWN performs internal switching. Trackage is available for troop trains and there is storage space for 100 freight cars. Side and end ramps are available. Facilities are available for loading or undloading bilevel cars. Facilities are available to receive containers by rail. The installation crane capacity is 20 tons.

Naval (Inactive) Ship Maintenance Facility Orange, Texas

Government trackage connects with the Southern Pacific Co., at the entrance to the facility. The Missouri Pacific Railroad Co. serves the activity through reciprocal switching. SP drops off and picks up cars. Facilities are available to receive bulk petroleum by tank cars and to receive containerized cargo by rail. The crane capacity is 25 tons.

Carswell Air Force Base northwest of Fort Worth, Texas

Government trackage connects with the Texas and Pacific Railroad at Beubrock, Texas. Government performs internal switching. Trackage is available for troop trains and storage space is available for 48 freight cars. Facilities are available to receive aviation gasoline and JP-4 fuel by tank car. Facilities are available to receive containers and crane capacity is 10 tons.

Ellington Air Force Base Houston, Texas

Government trackage connects with the Missouri Pacific and Missouri-Kansas-Texas Railroads at Olcott, Texas. Initial placement and internal switching is performed by the carrier. End ramp, capacity 100 tons, is available for loading and unloading all types of vehicles. Facilities are available to receive bulk petroleum products by tank car. Facilities are available to receive containers and crane capacity is 20 tons.

Longhorn Army Ammunition Plant Karnack, Texas

Government trackage connects with the Louisiana and Arkansas Railway Co. at Karnack, Texas. Government performs internal switching. Trackage is available for troop trains and storage space is available for 100 freight cars. Side ramps only are available. Facilities are available to receive diesel fuel by tank car. Facilities are available to receive containers and the crane capacity is 10 tons.

Goodfellow Air Force Base San Angelo, Texas

Activity is served by team tracks of the Santa Fe Railway at San Angelo, 3 miles away. Facilities are available to load or unload bilevel or trilevel cars at Santa Fe team tracks upon 48 hours advance notice.

Brooks Air Force Base San Antonio, Texas

Government trackage connects with the Southern Pacific Railroad at Bergs, Texas. The SP performs internal switching. Trackage is available for troop trains. Storage space is available for 4 freight cars. Side and end ramps are available. Facilities are available to receive containers and the crane capacity is 10 tons.

Fort Sam Houston San Antonio, Texas

Government trackage connects with the Missouri-Kansas-Texas Railroad and the Southern Pacific Railroad at San Antonio. The Missouri Pacific serves the installation through reciprocal switching arrangements. Trackage is available for troop trains and there is storage space for 45 freight cars. Side and end ramps are available for loading and unloading bilevel and trilevel cars at the team tracks of all carriers serving San Antonio, 3 miles away. Facilities are available to receive containers by rail. The crane capacity is 10 tons, but lift capacity of 120 tons can be provided by SP at its San Antonio team track facility with a 2 hour advance notice.

Kelly Air Force Base San Antonio, Texas

This installation has two areas for receiving rail freight, each depending upon the class of material being shipped.

Lackland Air Force Base San Antonio, Texas

Government trackage connects with the Southern Pacific Railroad at Cadet, Texas. Government performs internal switching. Trackage is available for troop trains. Side and end ramps are available. Facilities are available to receive containers by rail and crane capacity is 15 tons.

Randolph Air Force Base east of San Antonio, Texas

Activity is served by team tracks of the Southern Pacific Company, Missouri Pacific Railroad, and the Missouri-Kansas-Texas Railroad Co. in San Antonio, Texas, and the Missouri Pacific Railroad Co. at North Loop, Texas.

Lone Star Ammunition Plant   Texarkana, Texas

Government trackage connects with the St. Louis Southwestern Railway Co. and the Texas and Pacific Railway Co. at Defense, Texas. Government performs internal switching. Trackage is not available for troop trains. Ramps for loading and unloading bilevel and trilevel cars are available at Red River Army Depot, adjacent to this activity. Facilities are available to receive containers and the crane capacity is 20 tons.

Red River Army Depot   Texarkana, Texas

Government trackage connects with the St. Louis Southwestern Railway Co. and the Texas & Pacific Railway Co. at Defense, Texas. Government performs internal switching. Trackage is available for troop trains. Storage space is available for 332 freight cars. Side and end ramps are available. Portable ramps are available for loading and unloading bilevel or trilevel cars. Facilities are available to receive bulk petroleum products by tank car. Facilities are available to receive containers and the installation crane capacity is 60 tons.

Sheppard Air Force Base   Wichita Falls, Texas

Government trackage connects with the Missouri-Kansas-Texas Railroad Co. at Oldom, Texas. Carrier performs internal switching. Trackage is available for troop trains. Storage space is available for 46 freight cars. Side and end ramps are available. Facilities are available for loading and unloading bilevel or trilevel cars at downtown team tracks of MKT, 5 miles away. Facilities are available to receive aviation gasoline and JP-4 fuel by tank car. Facilities are available to receive containers and crane capacity is 20 tons.

A review of military installation locations within Texas indicates that of all 26 locations, only 2 appear to be located on lines with less than one train per day. Sheppard Air Force Base, located north of Wichita Falls, and Fort Wolters seem to be the only military installations in Texas on light density rural rail lines.

Fort Wilters is located on the Weatherford, Mineral Wells and Northwestern Railway, while Sheppard Air Foce Base is located on the Missouri-Kansas-Texas Rail line from Wichita Falls, Texas to Altus, Oklahoma. Rail service on the Weatherford, Mineral Wells and Northwestern is less than one train per day. The maximum weight limitation for a 4 axle rail car is 220,000 lbs. with vertical clearance of 20 feet. Since it appears that between April 1974, and March 1975, 322 carloads of military traffic were shipped and received at this installation, rail service might seem to be significant to the peacetime operations of this facility.

A review of the shipments originated and terminated at this facility by origin, destination and commodity class follows.

The predominant flow of rail traffic at Fort Wolter is outbound, composed of ordinance and "other" commodities. Because of Ft. Wolter's present inactive status, stored material were shipped out from the base for use at other military installations in the United States. It may be assumed that the 1974-1975 shipments represent an unusual volume that may not be expected in the future. If, however, the WMWNW were abandoned, there is a TP freight station at Bennet, Texas approximately 10 miles to the south.

BLE C-3: Originating and Terminating Military Rail Shipments - Ft. Wolters

Origin Station	Destination Station	Commodity Class	Carloads
Mineral Wells, TX	Parsons, KS	Ordinance	41
Mineral Wells, TX	Parsons, KS	Other	145
Mineral Wells, TX	Milan, TN	Ordinance	16
Mineral Wells, TX	Milan, TN	Other	66
Mineral Wells, TX	Defense, TX	Ordinance	6
Mineral Wells, TX	Defense, TX	Other	18
Mineral Wells, TX	Independence, MO	Other	2
Boise, ID	Deacon, TX	Military vehicles	19
Baldwin, AK	Mineral Wells, TX	Iron & steel	2
Baldwin, AK	Mineral Wells, TX	Other	4
Pine Bluff, AK	Mineral Wells, TX	Other	1
Warner, UT	Mineral Wells, TX	Machinery parts	1
Waltho, GA	Mineral Wells, TX	Military vehicles	1
TOTAL CARLOADS			322

Source: Analysis of Rail Routing for Defense Commodities. Military Traffic Management Command. Department of Defense. April, 1974 - March, 1975.

Sheppard Air Force Base connects with the Missouri-Kansas-Texas Railroad, five miles north of Wichita Falls, Texas, at Oildom, Texas. Service frequency on the MKT line from Wichita Falls, Texas, to Altus, Oklahoma, is also less than one per day. The maximum weight limitation for a 4 axle rail car is 210,000 lbs. with vertical clearance of 20 feet.

A review of the commodities shipped and received at Sheppard Air Force Base follows.

TABLE C-4: Originating and Terminating Military Rail Shipments - Sheppard AFB

Origin Station	Destination Station	Commodity	Carloads
Oildom, TX	Kinros, MI	Iron & steel	3
Oildom, TX	Rome, NY	Motor vehicles	1
Oildom, TX	Oklahoma City, OK	Motor vehicles	2
Oildom, TX	Denver, Co.	Other	4
Oildom, TX	Benbrook, TX	Other	1
Oildom, TX	Fairchild, WA	Iron & steel	2
New Orleans, LA	Oildom, TX	Iron & steel	1
Memphis, TN	Oildom, TX	Provisions	2
Memphis, TN	Oildom, TX	Other	3
Beebl. VA	Oildom, TX	Other	1
Columbus, OH	Oildom, TX	Other	1
Ft. Worth, TX	Oildom, TX	Petroleum products	25
Ft. Worth, TX	Sheppard AFB, TX	Petroleum products	220
Ft. Worth, TX	Wichita Falls, TX	Petroleum products	15
TOTAL CARLOADS			281

Source: Analysis of Rail Routing for Defense Commodities. Military Traffic Management Command. Department of Defense. April 1974 - March 1975.

While it is not known what future plans are for this light density line, Sheppard AFB's close proximity to Wichita Falls and connections with the Fort Worth and Denver Railway's main line seem insure that rail service in some form should continue to be available to this base. Even if the entire MKT line were abandoned from Wichita Falls to Altus, Oklahoma, the Government could purchase the line from Oildom to Wichita Falls, approximately 5 miles in length, and allow either the Missouri-Kansas-Texas or the Fort Worth & Denver to provide facility rail service on a limited basis. Since approximately 85% of the Sheppard Air Force Base's traffic is petroleum traffic from Fort Worth, either the MKT or FWD could provide rail service on a 5 mile branch to Oildom in the event that the MKT, Wichita Falls to Altus, Oklahoma, line was ever abandoned.

Military installations in Texas form an integral role in U.S. defense planning and strategy. They also contribute to the economy of Texas through employment, purchasing impacts and rail freight shipments.

While it appears that none of the existing active military installations in Texas are presently in danger or will be in danger of losing significant rail service, any future changes in the rail system should recognize and incorporate defense requirements into planning efforts accompanying such changes. However, private rail carriers should not be financially penalized in order to accommodate such rail service requirements. From the perspective of national defense and local economic impact, the defense installation should be viewed according to its importance to these two public functions. Then, public investment or subsidy to continue rail service may be recognized as an alternative.